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Impact of COVID-19 on the sleep-wake patterns of preschool children

O.Y. Wong [a, b, 1], C.T. Au [a, c, d, 1], H.M. Yuen [a], K.N. Yu [a], Q.Y. Lan [a], N.Y. Chan [e, f], C.C. Tsang [e, f], A.M. Li [a, c, d], K.C. Chan [a, c, d, *]

[a] Department of Paediatrics, Prince of Wales Hospital, The Chinese University of Hong Kong, Hong Kong
[b] Department of Paediatrics and Adolescent Medicine, Tuen Mun Hospital, Hong Kong
[c] Hong Kong Hub of Paediatric Excellence, The Chinese University of Hong Kong, Hong Kong
[d] Laboratory for Paediatric Respiratory Research, Li Ka Shing Institute of Health Sciences, Faculty of Medicine, The Chinese University of Hong Kong, Hong Kong
[e] Li Chiu Kong Family Sleep Assessment Unit, Department of Psychiatry, Faculty of Medicine, The Chinese University of Hong Kong, Hong Kong
[f] Department of Psychiatry, Faculty of Medicine, The Chinese University of Hong Kong, Hong Kong

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ABSTRACT

Objective: To explore the impact of the COVID-19 pandemic on the sleep-wake patterns of preschool children.
Methods: A cohort of preschoolers established before the COVID-19 pandemic was invited to participate in this study. Data including children's demographics, their own and parental sleep-wake patterns, physical activities, and screen time were collected through an online questionnaire from August to September 2020. A comparison was made on the collected data from the same cohort of children before and during the pandemic.
Results: The cohort which was established before the pandemic consisted of 3720 preschoolers. For this current study, 642 (17%) participated, and 497 (13%) children who fulfilled the eligibility criteria were included in the final analysis. They showed a delay in their bedtime and wake time on both weekdays and weekends with a 15–30 min increase in nocturnal sleep duration. However, with a reduction in nap time, the average daily sleep duration was shortened by 16.3 ± 64.3 min ($p < 0.001$) and 27.5 ± 72.9 min ($p < 0.001$) during weekdays and weekends, respectively. Screen time was increased while outdoor activity duration was decreased. Parental sleep/wake times were also delayed with an increase in sleep duration. Children's sleep habits were associated with screen time and parental sleep/wake patterns.
Conclusion: Despite school suspension during the COVID-19 pandemic, preschoolers were not sleeping longer. Screen time and parental sleep/wake patterns were the major factors driving the preschoolers' sleep habits. Health education is required to control screen time in children and to promote sleep hygiene among all family members.

1. Introduction

The novel coronavirus disease-2019 (COVID-19) has quickly spread across the globe and turned into a worldwide pandemic since it was first diagnosed in December 2019. In Hong Kong, with the implementation of social distancing interventions since late January 2020, schools have been suspended and replaced with e-learning classes. Extracurricular and outdoor activities have been restricted with the closure of parks, sports centres, playgrounds, and private tutorial classes. Special work arrangement with working from home was encouraged. It is reported that these restrictions have a wide range of impact on children's activities and health [1].

Optimal sleep habit is essential for a child's health and development. The negative impact of the COVID-19 pandemic on sleep has been observed globally, albeit some would report improvement in their sleep, probably because of a more flexible schedule [2,3]. While school suspension may allow a more flexible sleep schedule and hence a greater chance of obtaining sufficient sleep [4,5], social distancing advice to stay at home may reduce both sunlight exposure and physical activities [4,6], and affect the sleep-wake schedule. Remote e-learning and online social networking

* Corresponding author. Department of Paediatrics, Prince of Wales Hospital, The Chinese University of Hong Kong, Shatin, Hong Kong.
E-mail address: katechan@cuhk.edu.hk (K.C. Chan).
[1] Joint first authors.

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increase screen time duration [4,6] and possibly increase the time spent on non-sleeping activities such as screen time in the bed including the pre-sleep period [7]. Parents' sleep routines may be affected by school suspension as well as working from home. All these factors can potentially affect children's bedtimes and wake times [5,7] [–] [9], bedtime routines [10], sleep quantity and quality [7–11], and regularity of sleep timing [5].

Studies investigating the effects of school suspension and social distancing on child sleep are limited. *Liu* et al. surveyed 1619 preschool children in Guizhou, China, and found that children during the lockdown period had later bedtimes and wake times and less sleep disturbance, compared to the data collected in 2018 [9]. *Dellagiulia* et al. conducted a longitudinal study on 37 pre-schoolers for 30 consecutive days from the pre-lockdown period to the full lockdown period in Italy and found that sleep duration and quality decreased initially and then stabilised, but sleep duration remained shorter with a poorer quality compared to initial days [10]. Another longitudinal study on 41 children and adolescents aged 6–18 years from Italy compared the lockdown period data to the baseline data collected in the middle of 2019 and showed that time spent in sporting activities decreased substantially by a mean of 2.3 h/week while sleep and screen time increased by 0.65 and 4.85 h/day, respectively [4]. An online survey of 1472 Canadian parents of children aged 5–17 years during the lockdowns revealed that parents who continued to support physical activity were associated with better adherence to the sleep recommendations for their children [6]. The few published longitudinal follow-up studies consisted of small sample size, the comparison was made between cohorts established at different time points and did not explore how parental sleep habits during the pandemic influence their children's sleep patterns.

Hence, we conducted a survey on a previously established cohort of preschool children to explore the changes in their sleep patterns, physical activity, screen time, and changes in their parents' sleep habits during the COVID-19 pandemic with school suspension in Hong Kong.

2. Methods

Subjects: This was a follow-up study on a cohort established before the COVID-19 pandemic. The cohort consisted of 3720 children who participated in a preschool sleep education project when they were 2–6 years of age [12]. The cohort was recruited from randomly selected local kindergartens, which were selected based on computer-generated random numbers. If the selected school declined to participate, the next randomly selected one would be invited. Teachers distributed the baseline questionnaire to students and parents were invited to complete the questionnaire. The baseline questionnaire included children's demographics, parents' education levels, parental employment status, children's past medical history including developmental and psychiatric history, children's and parents' sleep patterns, physical activities, and screen time [12].

The same cohort of pre-schoolers was approached and invited to join this study during the COVID-19 pandemic. All children who participated in the baseline study were invited. Data was collected through an online questionnaire from August to September 2020. Information on children's demographics, parents' education levels, parental employment status during the COVID-19 pandemic, children's past medical history including developmental and psychiatric history, children's and parents' sleep patterns in the past six months (i.e. during the implementation of social distancing interventions), physical activities, and television and electronic devices screen time were collected. Same questions were used in the baseline and follow-up surveys. Parents were asked to provide the duration of screen time and whether the child had television or electronic device screen time 1 h before bedtime [13]. Information about the study and informed consent was also included in the online questionnaire. Children without physician-diagnosed psychiatric or developmental disorders and whose sleep data were completed were included in the analysis. The data were then compared with previously obtained information collected in the baseline questionnaire from the same child. Ethics approval was obtained from the Clinical Research Ethics Committee of the Joint Chinese University of Hong Kong – New Territories East Cluster (CREC Ref. No.: 2020.406).

Statistical analysis: Normally distributed data were presented as mean ± standard deviation (SD) and skewed data as median (interquartile range). Categorical variables were presented as percentages. Comparisons between respondents and non-respondents of the follow-up study were tested by *t*-test for normally distributed data and Mann-Whitney *U* test for skewed data in the baseline questionnaire. Subsequent analysis was carried out on respondents who completed the follow-up questionnaire. Sleep patterns, outdoor activities duration, and screen time before and after the start of the COVID-19 pandemic were compared by paired *t*-test for normally distributed data and Wilcoxon signed-rank test for skewed data. Further subgroup analysis by the baseline napping status was performed for the changes in the sleep patterns, outdoor activities duration, and screen time before and after the start of the pandemic. A child was defined as a napper if he/she had an average nap duration >0 min during weekdays or weekends at baseline. A linear mixed model was used to examine the effects of the COVID-19 pandemic on sleep pattern parameters while adjusted for age, gender, parental sleep pattern, parental education level, work pattern, child's outdoor activity duration, and screen time. Comparison between sleep parameters on age and sex-matched subjects before and during the COVID-19 pandemic was also carried out using independent t-tests or Mann-Whitney U tests for normally distributed data and skewed data, respectively. Spearman rank correlation test was used to examine factors that contributed to the change in sleep patterns. Statistical analyses were performed using SPSS statistical software package (version 23.0 for Windows; SPSS Inc.). A p-value <0.05 was considered statistically significant.

3. Results

Of the initial cohort of 3720 children, 642 (17%) participated in the current study. A total of 497 (13%) children who fulfilled the eligibility criteria were included in the final analysis. They were 4.3 ± 0.9 years old at baseline pre-COVID-19 pandemic and 5.8 ± 1.1 years old during the current study period. Supplementary Tables 1 and 2 demonstrate the demographic characteristics and sleep patterns of the subjects included and excluded (non-responders and non-eligible responders) in the current study. There were no significant differences in baseline sleep/wake patterns and sleep duration between the subjects included and not included in the analysis during weekdays. Although the children included in the analysis woke up slighter earlier (8:39 ± 1:03 vs 8:47 ± 1:03; p = 0.009) with shorter nocturnal time in bed (603 ± 53 min vs 611 ± 55 min; p = 0.003) and shorter average daily sleep duration (661 ± 65 min vs 668 ± 71 min; p = 0.027) during weekends than those not included, the differences were small. When compared with children not included, children included in the analysis had shorter television screen time (60 (40–120) mins vs 90 (47–150) mins; p = 0.029) and electronic devices screen time (30 (10–60) mins vs 30 (10–90) min; p = 0.029) during the pre-COVID-19 pandemic weekends. However, there was no difference in television or electronic screen time during the weekdays. In addition, parents of the children that were included had shorter average

daily sleep durations (father's average daily sleep durations were 449 ± 70 min vs 458 ± 77 min; p = 0.015; mother's average daily sleep durations were 467 ± 72 min vs 478 ± 75 min; p = 0.003) when compared with parents of children not included in the analysis during weekdays. Parents of children included in the analysis had higher education levels than parents of children not included, however, there was no difference in their employment status before the pandemic. The parental employment status did not change significantly during the pandemic (Supplementary Table 3).

3.1. Changes in sleep patterns

The changes in patterns of sleep, duration of outdoor activities, and screen time of the children and the parental sleep patterns are shown in Table 1. During the COVID-19 pandemic, children had delayed sleep/wake patterns with bedtime being setback by 29.8 ± 54 min (p < 0.001) during weekdays and 19.1 ± 54.1 min (p < 0.001) during the weekends. There was also a 57.2 ± 69.1 min (p < 0.001) delay in wake time during the weekdays and a 33.9 ± 58.8 min (p < 0.001) delay during the weekends. Nocturnal sleep duration was increased by 27.6 ± 61.8 min (p < 0.001) during the weekdays and 15 ± 60.8 min (p < 0.001) during the weekends. However, nap duration was shortened by 40 (−90 to 0) minutes (p < 0.001) on weekdays and decreased from 60 (0–120) minutes to no nap (p < 0.001) during the weekends. As a result, the average daily sleep duration was also shortened by 16.3 ± 64.3 min (p < 0.001) and 27.5 ± 72.9 min (p < 0.001) during weekdays and weekends, respectively.

Parental sleep/wake patterns were also delayed during the pandemic. Father's bedtime was delayed by 17.8 ± 61.5 min (p < 0.001) during the weekdays and 26.9 ± 71.4 min (p < 0.001) during the weekends. Wake time was delayed by 21.7 ± 64.3 min (p < 0.001) during the weekdays and 15.4 ± 95.6 min (p < 0.001) during the weekends. However, there was only a small change in the father's average daily sleep durations during the pandemic (+7.1 ± 65.3 min; p = 0.035). Similarly, the mother's sleep/wake patterns were also delayed. Bedtime was setback by 27.8 ± 66.6 min (p < 0.001) during the weekdays and 31.6 ± 72 min (p < 0.001) during the weekends. Wake time was markedly delayed by 50.3 ± 78.6 min (p < 0.001) during weekdays and 32.0 ± 74.3 min (p < 0.001) during weekends. Mothers, however, had more sleep during the pandemic on weekdays. Their average daily sleep duration was increased by 27.2 ± 84.9 min (p < 0.001). There were no significant changes in their average daily sleep duration during the weekends.

The changes in the sleep patterns, duration of outdoor activities, and screen time by the baseline napping status are shown in Supplementary Tables 4 and 5. At baseline, 317 and 277 children napped on weekdays and weekends, respectively. Those who napped at baseline were younger than those who did not. Both baseline nappers and non-nappers showed a delay in bedtime and wake time on both weekdays and weekends. However, only baseline nappers demonstrated a significant increase in nocturnal sleep duration and a significant decrease in the average daily sleep duration, on both weekdays and weekends. While there were similar changes in the paternal sleep pattern between the napper and non-napper groups, only mothers of the napper group showed a significant increase in the weekday nocturnal sleep duration.

3.2. Changes in outdoor activities and screen time

Television screen time was double compared to baseline on both weekdays and weekends (+60 (0 to +105) minutes; p < 0.001 and + 60 (0 to +90) minutes; p < 0.001, respectively). Total screen time with electronic devices was also double that from baseline (+30 (0 to +90) minutes; p < 0.001 on weekdays and +30 (0 to +75) minutes; p < 0.001 on weekends) during the pandemic. The duration of outdoor activities was significantly shortened by 30 (−60 to 0) minutes (p < 0.001) and 90 (−180 to −30) minutes (p < 0.001) during weekdays and weekends, respectively (Table 1).

3.3. Factors associated with child's sleep parameters and their changes during the COVID-19 pandemic

COVID-19 pandemic was found to be an independent factor associated with the preschoolers' sleep/wake patterns, nocturnal sleep duration, and their average daily sleep duration on weekdays, wake time, and nocturnal sleep duration on weekends after adjusting for age, gender, parental sleep pattern, parental education

Table 1
Sleep pattern, outdoor activity duration, and screen time before and after the start of the COVID-19 pandemic.

	Weekday				Weekend			
	Pre	Post	Change (min)	p	Pre	Post	Change (min)	p
Child bedtime, hh:mm	22:10 ± 0:51	22:40 ± 1:03	+29.8 ± 54.0	<0.001	22:35 ± 0:54	22:55 ± 1:00	+19.1 ± 54.1	<0.001
Child wake time, hh:mm	7:58 ± 1:00	8:55 ± 1:12	+57.2 ± 69.1	<0.001	8:39 ± 1:03	9:13 ± 1:11	+33.9 ± 58.8	<0.001
Child nap duration, min	60 (0–120)	0 (0–0)	−40 (−90 to 0)	<0.001[a]	60 (0–120)	0 (0–0)	0 (−90 to 0)	<0.001[a]
Child nocturnal sleep duration, min	588 ± 55	616 ± 55	+27.6 ± 61.8	<0.001	603 ± 53	619 ± 56	+15.0 ± 60.8	<0.001
Child average daily sleep duration, min	651 ± 53	635 ± 60	−16.3 ± 64.3	<0.001	661 ± 65	633 ± 59	−27.5 ± 72.9	<0.001
Father bedtime, hh:mm	23:57 ± 1:08	0:17 ± 1:25	+17.8 ± 61.5	<0.001	0:19 ± 1:13	0:53 ± 1:33	+26.9 ± 71.4	<0.001
Father wake time, hh:mm	7:20 ± 1:15	7:43 ± 1:35	+21.7 ± 64.3	<0.001	8:52 ± 1:32	9:06 ± 1:47	+15.4 ± 95.6	<0.001
Father nap duration, min	0 (0–0)	0 (0–0)	0 (0–0)	0.062[a]	0 (0–0)	0 (0–60)	0 (0–0)	<0.001[a]
Father nocturnal sleep duration, min	443 ± 70	447 ± 70	+4.0 ± 63.4	0.21	513 ± 88	510 ± 82	+0.4 ± 86.9	0.93
Father average daily sleep duration, min	449 ± 70	455 ± 71	+7.1 ± 65.3	0.035	533 ± 95	535 ± 95	+7.5 ± 94.8	0.15
Mother bedtime, hh:mm	23:35 ± 1:01	0:11 ± 1:25	+27.8 ± 66.6	<0.001	23:53 ± 1:03	0:32 ± 1:24	+31.6 ± 72.0	<0.001
Mother wake time, hh:mm	7:14 ± 1:00	8:04 ± 1:23	+50.3 ± 78.6	<0.001	8:27 ± 1:10	8:58 ± 1:25	+32.0 ± 74.3	<0.001
Mother nap duration, min	0 (0–0)	0 (0–0)	0 (0–0)	0.43[a]	0 (0–0)	0 (0–0)	0 (0–0)	0.62[a]
Mother nocturnal sleep duration, min	459 ± 70	482 ± 82	+28.1 ± 85.1	<0.001	513 ± 71	516 ± 80	+4.4 ± 80.3	0.32
Mother average daily sleep duration, min	467 ± 72	489 ± 85	+27.2 ± 84.9	<0.001	530 ± 77	532 ± 90	+3.7 ± 85.8	0.44
Outdoor activity duration, min	60 (30–90)	0 (0–30)	−30 (−60 to 0)	<0.001[a]	150 (120–240)	60 (0–120)	−90 (−180 to −30)	<0.001[a]
TV screen time duration, min	60 (30–120)	120 (60–180)	+60 (0 to +105)	<0.001[a]	60 (40–120)	120 (60–180)	+60 (0 to +90)	<0.001[a]
Electronic devices screen time, min	30 (0–60)	60 (30–120)	+30 (0 to +90)	<0.001[a]	30 (10–60)	60 (30–120)	+30 (0 to +75)	<0.001[a]
Online class time, min	/	60 (30–120)	/	/	/	0 (0–60)	/	/

Comparison of variables before and after the start of the COVID-19 pandemic was tested by paired *t*-test unless otherwise specified.
[a] Comparison of variables before and after the start of the COVID-19 pandemic was tested by Wilcoxon signed-rank test for skewed data.

Table 2
Factors associated with weekday sleep pattern and duration.

	Weekday bedtime (min)		Weekday waketime (min)		Weekday nocturnal sleep duration (min)		Weekday average daily sleep duration (min)	
	beta (SE)	p	beta (SE)	p	beta (SE)	p	beta (SE)	p
Post-COVID-19 visit (with reference to Pre-COVID-19 visit)	13.6 (4.9)	0.006	20.7 (5.1)	<0.001	18.5 (4.7)	<0.001	17.8 (4.8)	<0.001
Male gender	−3.02 (4.19)	0.471	−2.84 (4.32)	0.512	−1.59 (3.88)	0.682	−1.90 (3.89)	0.624
Age, y	1.25 (2.17)	0.563	−5.10 (2.24)	0.023	−6.59 (2.03)	0.001	−6.47 (2.04)	0.002
[a] Father's sleep data, min	0.10 (0.03)	<0.001	0.10 (0.02)	<0.001	0.08 (0.03)	0.005	0.07 (0.03)	0.010
Father education: tertiary or above (Yes/No)	−5.79 (4.99)	0.246	−3.90 (5.16)	0.451	1.02 (4.63)	0.826	1.22 (4.66)	0.793
Father full-time work (Yes/No)	−1.15 (5.36)	0.830	1.20 (5.67)	0.833	4.42 (5.17)	0.393	4.57 (5.26)	0.386
[a] Mother's sleep data, min	0.19 (0.03)	<0.001	0.34 (0.03)	<0.001	0.13 (0.02)	<0.001	0.13 (0.02)	<0.001
Mother education: tertiary or above (Yes/No)	0.47 (4.98)	0.925	1.33 (5.12)	0.796	−1.87 (4.61)	0.685	−2.15 (4.62)	0.641
Mother full-time work (Yes/No)	7.71 (4.07)	0.058	6.52 (4.30)	0.130	−7.54 (3.80)	0.048	−6.19 (3.86)	0.109
Weekday nap duration, min	0.07 (0.04)	0.054	−0.38 (0.04)	<0.001	−0.49 (0.04)	<0.001		
Weekday outdoor activities, min	0.03 (0.02)	0.237	0.02 (0.02)	0.347	−0.01 (0.02)	0.770	−0.01 (0.02)	0.630
Weekday TV time, min	0.04 (0.02)	0.070	−0.01 (0.02)	0.638	−0.04 (0.02)	0.065	−0.04 (0.02)	0.083
TV viewing 1 h before bedtime (Yes/No)	5.20 (3.69)	0.160	0.71 (3.84)	0.853	−2.98 (3.63)	0.413	−3.48 (3.67)	0.344
Weekday electronic devices screen time, min	0.12 (0.03)	<0.001	0.14 (0.03)	<0.001	0.00 (0.03)	0.867	0.00 (0.03)	0.971
Electronic devices screen time 1 h before bedtime (Yes/No)	8.61 (4.01)	0.032	7.76 (4.14)	0.061	−0.31 (3.92)	0.937	0.20 (3.97)	0.960
Any electronic device in bedroom (Yes/No)	7.83 (3.77)	0.038	0.65 (3.93)	0.868	−9.84 (3.68)	0.008	−9.86 (3.73)	0.008

[a] Corresponding father's and mother's sleep parameters were used for each outcome variable.

Table 3
Factors associated with weekend sleep pattern and duration.

	Weekend bedtime (min)		Weekend waketime (min)		Weekend nocturnal sleep duration (min)		Weekend average daily sleep duration (min)	
	beta (SE)	p	beta (SE)	p	beta (SE)	p	beta (SE)	p
Post-COVID-19 visit (with reference to Pre-COVID-19 visit)	7.4 (4.7)	0.116	13.1 (4.5)	0.004	10.7 (4.6)	0.021	9.1 (4.7)	0.055
Male gender	0.55 (4.19)	0.896	−2.56 (4.25)	0.548	−7.96 (3.84)	0.039	−8.72 (3.87)	0.025
Age, y	0.62 (2.22)	0.780	−2.44 (2.21)	0.270	−1.85 (2.06)	0.370	−2.40 (2.09)	0.250
[a] Father's sleep data, min	0.10 (0.03)	<0.001	0.03 (0.02)	0.178	0.09 (0.02)	<0.001	0.06 (0.02)	0.007
Father education: tertiary or above (Yes/No)	−10.18 (4.95)	0.040	−9.22 (5.04)	0.068	−0.94 (4.52)	0.835	−2.31 (4.58)	0.614
Father full-time work (Yes/No)	−1.68 (5.26)	0.750	−6.55 (5.24)	0.212	0.34 (5.16)	0.947	0.94 (5.23)	0.858
[a] Mother's sleep data, min	0.19 (0.03)	<0.001	0.39 (0.03)	<0.001	0.16 (0.03)	<0.001	0.15 (0.02)	<0.001
Mother education: tertiary or above (Yes/No)	−1.08 (4.96)	0.828	2.41 (5.02)	0.631	−1.92 (4.50)	0.669	−1.56 (4.53)	0.731
Mother full-time work (Yes/No)	10.74 (4.04)	0.008	−2.41 (4.04)	0.551	−11.74 (3.79)	0.002	−12.15 (3.86)	0.002
Weekend nap duration, min	−0.01 (0.04)	0.839	−0.27 (0.04)	<0.001	−0.29 (0.04)	<0.001		
Weekend outdoor activities, min	0.01 (0.02)	0.490	0.02 (0.02)	0.203	0.01 (0.02)	0.674	0.01 (0.02)	0.524
Weekend TV time, min	0.02 (0.02)	0.279	−0.03 (0.02)	0.164	−0.07 (0.02)	<0.001	−0.09 (0.02)	<0.001
TV viewing 1 h before bedtime (Yes/No)	7.48 (3.68)	0.042	2.79 (3.65)	0.446	1.79 (3.70)	0.628	2.60 (3.78)	0.493
Weekend other screen time, min	0.09 (0.03)	<0.001	0.08 (0.02)	<0.001	0.00 (0.03)	0.867	0.01 (0.03)	0.784
Electronic devices screen time 1 h before bedtime (Yes/No)	10.43 (4.00)	0.009	8.21 (3.96)	0.039	1.07 (4.04)	0.790	−0.06 (4.11)	0.988
Any electronic device in the bedroom (Yes/No)	7.16 (3.77)	0.058	1.27 (3.71)	0.732	−10.80 (3.76)	0.004	−11.61 (3.83)	0.003

[a] Corresponding father's and mother's sleep parameters were used for each outcome variable.

level, and employment status, child's nap duration, outdoor activity duration, and screen time. (Tables 2–3). Weekend bedtime and weekend average daily sleep duration, however, were not significantly influenced by the pandemic.

Age was also found to be a significant factor associated with sleep patterns in the subjects. Increase in age was associated with decreased nap duration ($r = -0.184$; $p < 0.05$) ($r = -0.192$; $p < 0.05$) and decrease in average daily sleep duration ($r = -0.112$; $p < 0.05$) ($r = -0.148$; $p < 0.05$) on both weekdays and weekends (Table 4). Parental sleep patterns and durations were associated with their children's sleep patterns and duration. Changes in parents' sleep parameters during the pandemic were associated with a change in

Table 4
Factors associated with changes in child's weekday sleep parameters before and after the COVID-19 pandemic.

	Change in bedtime	Change in wake time	Change in nap duration	Change in nocturnal sleep time	Change in total sleep time
Change in age	0.022	0.087	*-0.184	0.056	*-0.112
Father's change in corresponding sleep parameter	*0.215	*0.139	0.089	*0.165	*0.153
Mother's change in corresponding sleep parameter	*0.332	*0.357	0.090	*0.307	*0.148
Change in outdoor time	0.069	0.027	−0.007	−0.027	−0.046
Change in TV viewing time	0.073	0.038	−0.039	−0.017	−0.070
Change in other screen time	*0.103	0.048	0.008	−0.042	−0.017

Spearman correlation coefficients are shown.
*P < 0.05.

their child's bedtime ($r = 0.215$ and 0.332; $p < 0.05$), wake time ($r = 0.139$ and 0.357; $p < 0.05$), nocturnal sleep time ($r = 0.165$ and 0.307; $p < 0.05$) and average sleep duration ($r = 0.153$ and 0.148; $p < 0.05$) during weekdays (Table 4). A similar association was also found during the weekends in addition to the child's nap duration ($r = 0.107$ and 0.111, $p < 0.05$) (Table 5). Mothers' changes in sleep parameters were found to have a higher association with the change in their child's sleep parameters than the father's. Maternal employment status was negatively associated with their children's nocturnal sleep duration (β(SE): −7.54 (3.80); $p = 0.048$) during weekdays and their children's weekend bedtime (β(SE): 10.74 (4.04); $p = 0.008$), nocturnal sleep duration (β(SE): −11.74 (3.79); $p = 0.002$) and average daily sleep duration (β(SE): −12.15 (3.86); $p = 0.002$) during weekends. Father's employment status was not associated with their children's sleep nor were parental education levels (Tables 2–3). Increase in television screen time was associated with delayed bedtime ($r = 0.096$; $p < 0.05$) and shorter nocturnal sleep duration ($r = -0.092$; $p < 0.05$) and average daily sleep duration ($r = -0.107$; $p < 0.05$) (Table 5). However, it was only associated with the sleep parameters during the weekends but not on weekdays (Table 4). Similarly, watching television 1 h before bedtime was only associated with weekend bedtime (β(SE): 7.48 (3.68); $p = 0.042$) but not other sleep parameters during weekdays and weekends. An increase in electronic device screen time was associated with a delay in bedtime on both weekdays and weekends ($r = 0.103$ and $r = 0.094$ respectively; $p < 0.05$). Use of electronic devices screen time 1 h before bedtime was positively associated with bedtime on weekdays (β(SE): 8.61 (4.01); $p = 0.032$) and weekends (β(SE): 10.43 (4.00); $p = 0.009$), and also weekend wake time (β(SE): 8.21 (3.96); $p = 0.039$). Presence of electronic devices in the bedroom was negatively associated with nocturnal sleep duration (weekday: β(SE): −9.84 (3.68); $p = 0.008$; weekend: β(SE): −10.80 (3.76); $p = 0.004$) and average daily sleep duration (weekday: β(SE): −9.86 (3.73); $p = 0.008$; weekend: β(SE): −11.61 (3.83); $p = 0.003$), on weekdays and weekends (Tables 2–3).

Given the natural chronological changes in sleep parameters, to ascertain that age did not play a part in the changes in the sleep-wake patterns documented, and these changes were secondary to the different infection control/social distancing interventions implemented during the COVID-19 pandemic, further analysis was carried out. Three hundred and fifty-two pairs of age and sex-matched children were identified from the baseline and follow-up cohorts via a case-control matching algorithm. Table 6 demonstrates the comparison of their sleep parameters. The findings would suggest the changes in the sleep-wake patterns were therefore likely secondary to the infection control/social distancing measures that had been implemented during the COVID-19 pandemic rather than an age effect. The reduction in nap time during the week and physical activities was likely a result of an increase in screen time during the pandemic.

4. Discussion

This was a follow-up study to explore the changes in sleep patterns, physical activity, and screen time in a cohort of preschool children during the period of the COVID-19 pandemic under the implementation of social restriction and school suspension. We found that the pandemic and the related policy such as school closure were associated with changes in the sleep-wake patterns of preschool children and their parents with a delay in both bedtime and wakeup times with an increase in nocturnal sleep duration. Average daily sleep duration however was shortened as a result of decreased nap duration. The increase in screen time had displaced time for naps and physical activities. These findings were observed on both weekdays and weekends. Subgroup analysis demonstrated that the influence of the pandemic on sleep-wake patterns was more obvious in children who napped at baseline. In our cohort, the significant reduction in the nap duration in those who napped at baseline was the major reason for the decrease in the average daily sleep duration, despite the increase in the nocturnal sleep duration. Parental sleep and wake times were also delayed with longer sleep durations, especially in mothers during weekdays. Although the aging effect would affect sleep duration, the COVID-19 pandemic was an independent factor that contributed to a change in a child's sleep/wake patterns and sleep duration. Parents, especially mothers' sleep/wake patterns and sleep duration exerted a great influence on children's sleep/wake patterns and their nocturnal as well as average daily sleep duration [14]. Television screen time was positively associated with children's bedtime and negatively associated with sleep duration, while the use of other electronic devices was associated with bedtime and wake time but not sleep duration [15].

Delay in sleep/wake times and increase in nocturnal sleep duration during the COVID-19 pandemic were also observed in children in other territories such as Mainland China [9] and Italy [4,16]. Hong Kong pre-schoolers showed an increase in nocturnal sleep duration by about 15–30 min which was slightly less than the 30- to 55-min increase reported in mainland China preschool children [9]. Similar to the findings by *Liu et al* [9], pre-schoolers in Hong Kong also had shorter naps during COVID-19. Nap time reduction may be related to an increase in nocturnal sleep duration as suggested by *Liu et al* findings in non-nappers [9]. Also with home confinement, children were expected to have reduced activity and attention effort compared with school days, and their need for naps may have decreased. On the other hand, with a lack of routine, and absence of peer interaction during the COVID-19 pandemic, children may have an increase in the opportunity to nap. A systemic review by *Camacho-Montano et al* found that some studies reported a decrease in napping in children during COVID-19

Table 5
Factors associated with the change in child's weekend sleep parameters before and after the COVID-19 pandemic.

	Change in bedtime	Change in wake time	Change in nap duration	Change in nocturnal sleep time	Change in total sleep time
Change in age	0.050	0.042	*-0.192	−0.009	*-0.148
Father's change in corresponding sleep parameter	*0.222	*0.125	*0.107	*0.216	*0.111
Mother's change in corresponding sleep parameter	*0.258	*0.385	*0.111	*0.245	*0.198
Change in outdoor time	−0.014	−0.012	0.004	−0.003	−0.005
Change in TV viewing time	*0.096	−0.020	−0.017	*-0.092	*-0.107
Change in other screen time	*0.094	0.062	0.030	−0.010	0.008

Spearman correlation coefficients are shown.
*P < 0.05.

Table 6
Comparisons between 352 pairs of age- (age difference within 1 month) and sex-matched children from the pre-COVID-19 and during-COVID-19 cohorts.

	Weekday			Weekend		
	Pre-COVID	During COVID	p	Pre-COVID	During COVID	p
Age, y	5.4 ± 0.8	5.4 ± 0.8	0.90			
Male, n (%)	183 (52%)	183 (52%)	1.000			
Child bedtime, hh:mm	22:11 ± 0:46	22:41 ± 0:59	<0.001	22:43 ± 0:49	22:53 ± 0:57	0.016
Child wake time, hh:mm	7:58 ± 0:51	8:57 ± 1:08	<0.001	8:46 ± 1:04	9:11 ± 1:09	<0.001
Child nap duration, min	60 (0–90)	0 (0–56)	<0.001[a]	0 (0–90)	0 (0–0)	<0.001[a]
Child nocturnal sleep duration, min	587 ± 55	616 ± 56	<0.001	602 ± 60	618 ± 57	<0.001
Child average daily sleep duration, min	640 ± 62	639 ± 59	0.79	644 ± 78	637 ± 60	0.20
Outdoor activity duration, min	60 (30–90)	0 (0–30)	<0.001[a]	180 (120–240)	60 (0–120)	<0.001[a]
TV screen time duration, min	60 (30–120)	120 (60–180)	<0.001[a]	120 (60–180)	120 (60–180)	0.012[a]
Other screen time, min	30 (5–60)	60 (30–120)	<0.001[a]	60 (30–120)	60 (30–120)	0.96[a]

Comparison between age and sex-matched children from pre-COVID and during COVID-19 was performed by *t*-test unless otherwise specified.
[a] Comparison between age and sex-matched children from pre-COVID and during COVID-19 was tested by the Mann-Whitney *U* test for skewed data.

home confinement while others reported an increase in napping [17]. Although nap duration tends to decrease as a child grows, which is a natural evolution of sleep patterns with age [18,19], our age-matched analysis showed that the decrease in nap duration was related to the pandemic rather than the change in the age of the cohort.

Parents' sleep pattern has also changed during the pandemic, in particular, mothers' sleep pattern during weekdays. Although maternal employment status would affect children's sleep parameters during the weekday, mothers' employment status, however, was similar to the pre-COVID-19 pandemic. Therefore, such changes were more likely related to parents working from home, and with school closure, they were allowed to wake up later, and hence longer nocturnal sleep duration. It is known that mother-child has a stronger association in sleep-wake patterns than father-child sleep-wake patterns [14,20]. With the traditional role of the mother being the main carer of young children, school closure likely had more effects on maternal sleep/wake patterns, which explained our findings that mothers had more changes in sleep-wake patterns and longer sleep during the pandemic than fathers.

The COVID-19 pandemic was found to be an independent factor associated with sleep-wake patterns and sleep duration. This phenomenon may be explained by the change in the daily schedule of both children and parents during the pandemic. A previous study found that school start time was the strongest predictor of the sleep/wake patterns of children [14]. Parents especially mothers' sleep/wake patterns and sleep duration were also known to affect their children's sleep [14,20,21]. During the pandemic, schools were closed and parents probably were working at home, hence sleep/wake patterns and sleep duration of the whole family were affected. Changes in parents' sleep parameters were found to be associated with the change in the child's sleep pattern and duration in this study, which supported this explanation. Age and nap duration were also found to be negatively associated with sleep/wake patterns and sleep duration in our study. The change in age was negatively associated with the change in nap duration and hence total sleep duration during the study period. This was consistent with our knowledge that total sleep time and daytime sleep decrease as a child grows [18,19]. Although the decrease in nap duration during the pandemic could be related to the natural chronological change, our age-matched analysis suggested that it was more likely related to the pandemic. We also found that increased media use was associated with a later sleep schedule and shorter sleep duration, especially with their use within 1 h before children's bedtime and the presence of electronic devices in their bedrooms. Such a negative association between media use and sleep pattern was consistent with findings of other studies [12,14,15,22] and during the COVID-19 pandemic [23]. However, interestingly, we did not find an association between changes in screen time and changes in waketime or sleep durations during weekdays in this study. A possible explanation is the effect of screen time on sleep/wake patterns and sleep duration was partially cancelled out by the delay in wake time and longer nocturnal sleep duration due to school closure during the pandemic.

Although preschool children had an increase in nocturnal sleep duration during the pandemic, a decrease in nap duration led to a slightly shorter average daily sleep duration than in the pre-pandemic period. The National Sleep Foundation (NSF) of the United States [24]and the American Academy of Sleep Medicine (AASM) [25] recommend 10–13 h of total sleep duration for preschool children. Preschool children in Hong Kong had just met the recommendation. In fact, children in Hong Kong are known to be sleeping less than children from Caucasian countries [26] and even their counterparts from Shanghai [27]. Asian children also have later bedtimes and increased parental perception of sleep problems compared with children from Caucasian countries [26]. Further studies are required to ascertain whether this difference is purely cultural, or if other factors are involved in this discrepancy in sleep-wake patterns between different racial groups. Inadequate sleep has a negative impact on children's physical and mental health. Short sleep duration was associated with various adverse outcomes such as obesity [28,29], poorer academic performance [30], and behavioural problems [31]. During the COVID-19 pandemic, children spent more time at home due to school closure and social distancing. Despite being allowed to catch up with sleep, children had a similar total sleep duration as pre-COVID-19. An increase in screen time might play a role. The American Academy of Paediatrics (AAP) recommends that the total screen time for pre-schoolers should be limited to no more than 60 min per day [32]. During the pandemic, preschool children had doubled the amount of screen time on television and electronic devices compared to the pre-COVID-19 period, with a total duration of almost three times the recommendation. An increase in screen time was a common phenomenon observed during the lockdown in other countries across other age groups as well [33–35], likely related to online classes and the lack of outdoor activities. Prolonged screen time is known to affect sleep in children including sleep onset delay, sleep anxiety, increase in bedtime resistance, decrease in sleep duration and increase in daytime sleepiness [14,22,36]. It also affects circadian rhythm, especially with the use of bedtime electronic devices [15]. Besides, it has a negative influence on children's verbal cognitive performance [37] and may even indirectly impede the development of motor skills and physical literacy [38]. Moreover, due to the social distancing policies, children had a marked decrease in outdoor physical activities, far less than the

recommended at least 180 min of physical activities by the World Health Organization (WHO) [39]. The loss of physical activity time might be replaced by the increase in screen time. The combination effect of delayed bedtime and/or inadequate sleep or exercise duration, and prolonged use of electronic devices were associated with high parental stress and more psychosocial problems among children [40,41]. Apart from screen time, the delayed parents' sleep patterns might also hinder the increase in sleep duration in children as parents' sleep patterns were closely related to their child's sleep pattern [14,20,21].

A major strength of our study was its longitudinal follow-up design of a previously established cohort before the COVID-19 pandemic. The time interval between the two survey points was around 1.5 years. This enabled us to investigate the changes in the different sleep parameters as a result of COVID-19. To the best of our knowledge, this study had the largest number of subjects involved in reported literature so far. There were, however, several limitations in this study. Only 17% of the cohort replied to the questionnaire. The low response rate limited the representativeness of the sample. The parents of the subjects included were more educated. It is known that socioeconomic status influences sleep in both children and parents [12,36], therefore the difference in socioeconomic status may have biased the effect on sleep duration in this study. However, we did not find any significant differences in the baseline sleep/wake patterns and sleep duration between the subjects included and not included in the analysis. Another limitation was that the data was collected via an online questionnaire. Parents may skip questions or misinterpret the questions leading to missing or wrong data. There may be recall bias and reliability may be an issue in parent-reported data.

In conclusion, this study provided information on how school suspension due to COVID-19 impacted sleep patterns in preschool children and their parents. During the COVID-19 pandemic, children had delayed sleep/wake times with an increase in nocturnal sleep duration but shorter nap duration. They spent more time at home due to school closure and social distancing with an increase in screen time and a marked decrease in outdoor activities duration. Parents also had delayed sleep/wake times and longer sleep duration likely due to working at home and school closure. However, despite being allowed to catch up with sleep, the total sleep duration in preschool children was similar to the pre-COVID-19 period. An increase in screen time played a role but parents' sleep pattern was also an important factor. Health education for parents is required to limit screen time in children and also to promote good sleep hygiene in the family. For future intervention studies, education and advice on parents' and especially mothers' sleep-wake patterns should be included.

Guarantor statement

The lead and corresponding authors, OY Wong, CT Au and KC Chan, affirm that the manuscript is an honest, accurate, and transparent account of the study being reported; and that no important aspects of the study have been omitted. The lead and corresponding authors, OY Wong, CT Au and KC Chan, had full access to all the data in the study and had final responsibility for the decision to submit for publication.

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CRediT authorship contribution statement

O.Y. Wong: Conceptualization, Formal analysis, Writing – first draft, review & editing. **C.T. Au:** Conceptualization, Formal analysis, Writing – review & editing. **H.M. Yuen:** Conceptualization, Data collection, Writing – review & editing. **K.N. Yu:** Conceptualization, Data collection, Writing – review & editing. **Q.Y. Lan:** Conceptualization, Writing – review & editing. **N.Y. Chan:** Conceptualization, Writing – review & editing. **C.C. Tsang:** Conceptualization, Writing – review & editing. **A.M. Li:** Conceptualization, Data collection, Writing – review & editing. **K.C. Chan:** Conceptualization, Data collection, Writing – review & editing.

Declaration of competing interest

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Appendix A. Supplementary data

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