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Original Article

COVID-19 babies: auto-videosomnography and parent reports of infant sleep, screen time, and parent well-being in 2019 vs 2020

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ABSTRACT

Objective: The COVID-19 pandemic has profoundly impacted families, yet studies on its effects on infants and their parents have thus far been sparse and based mostly on retrospective parent reporting. This study aimed to prospectively evaluate the impact of COVID-19 living conditions on infant and parent sleep, as well as infant screen exposure, parent daytime sleepiness, and parent depression levels, using multi-method assessment.

Methods: Infant and parent data collected in 2020 were compared with a matched cohort collected in 2019. The total sample included 1518 US infants aged 1–18 months ($M = 8.5$, $SD = 4.6$; 54% boys). Auto-videosomnography metrics were obtained from the 14-day period prior to survey completion (number of analyzed nights: $M = 12.11$ $SD = 2.66$ in the 2019 cohort; and $M = 11.91$ $SD = 2.41$ in the 2020 cohort). Parents completed online questionnaires regarding their infant's sleep and screen exposure, as well as their own sleep quality, daytime sleepiness, and depression levels.

Results: Compared to 2019, infants in 2020 slept ~40 min more per night on average, as indicated by auto-videosomnography. Infants additionally had earlier sleep timing, and increased parent-reported sleep-onset latency and nocturnal wakefulness. Infant screen time rose by 18.3 min per day for older infants, but remained stable for younger infants. Parents reported lower daytime sleepiness and higher depression symptomology during 2020, whereas no change was apparent in their sleep quality ratings.

Conclusions: Restricted living conditions during COVID-19 in the USA led to increased infant screen exposure and parental depression, but also to increased infant sleep duration and reduced parent sleepiness. Future research is needed to examine the mechanistic pathways through which COVID-19 impacted on infant and parent well-being.

1. Introduction

The COVID-19 pandemic has had a profound effect on communities worldwide. Along with the uncertainty and stress of infection, measures imposed to curb infection rates have vastly disrupted daily living. In the USA, a series of stay-at-home orders was issued to mitigate the 'first wave' of COVID-19 in March–April 2020, resulting in acute restrictions in business, education, and leisure activities [1]. These orders led to a temporary delay in virus transmission, yet additional waves followed, and in December 2020 there were an incredible 200,000+ new confirmed cases per day on average in the USA, requiring implementation of additional restrictions to 'flatten the curve' [2].

Despite the lower risk the SARS-CoV2 virus (the coronavirus leading to COVID-19 infection) poses to children [3], young families have faced uniquely challenging circumstances during the pandemic. Day-care facilities, schools, and workplaces were closed or operated in limited capacity throughout 2020, requiring parents to perform their professional duties while juggling their compounded household and childcare responsibilities [4]. Social distancing, and the need to protect older adults from infection, often led to a loss of support from family members (eg, grandparents) and childcare providers (eg, nannies). Moreover, public facilities— such as libraries and parks— became inaccessible, rendering parents and children confined to the home, isolated from the 'village' that supported childrearing in pre-COVID times.

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Emerging evidence demonstrates the impact of these 'new normal' living conditions on parents and children in various physiological and psychological domains. One area that has been a focus of investigations is sleep, given its role in preserving both physical and mental health across the lifespan [5,6]. Studies examining parents' sleep have mostly reported increased difficulties initiating and maintaining sleep, inconsistent sleep patterns, and reduced sleep quality during the pandemic [7–11]. These findings have been interpreted in light of COVID-19-related disruptions in routines, and increased uncertainty and stress that may hinder good-quality sleep. Indeed, being a parent during the pandemic has been identified as a risk factor for psychological distress and elevated depressive symptomology [12–14].

As for children, several investigations have indicated a worsening of sleep quality during COVID-19. Studies of preschool children's sleep in France, Italy, and Chile have linked the pandemic with increased sleep difficulties and lower quality sleep [9,15–17]. Conversely, Liu et al. [18] found fewer parent-reported sleep disturbances (eg, nighttime awakenings) in Chinese preschool children during the COVID-19 lockdown, compared to an equivalent 2018 preschool cohort. These authors also reported that young children slept for longer durations in 2020, presumably due to the lack of scheduled activities or commuting constraints, which allowed for extended sleep opportunities. Indications of longer sleep durations throughout the COVID-19 pandemic have similarly been found in school aged children and adolescents [19–21].

The impact of the pandemic on *infant* sleep, however, has received less research attention. Sleep markedly evolves throughout the beginning of life, and is considerably sensitive to environmental cues, such as changes in parent and household routines [22,23]. The restricted living conditions of COVID-19 may have therefore had a distinct impact on infant sleep patterns. A longitudinal investigation of infant sleep during the first wave of COVID-19 in the US found that infants of mothers in home-confinement had longer nighttime sleep durations and later sleep-offset times compared to infants of mothers who were working as usual [24]. Furthermore, during the first 2-weeks of the imposed lockdown, these infants additionally had earlier sleep-onset times and more fragmented sleep, though these differences were not apparent in later assessments (April–May 2020). Correspondingly, Markovic and colleagues [25] reported an acute decline in infant sleep quality at the initial stage of the pandemic in Europe, followed by a return to baseline as the first wave abated. Taken together, these findings suggest that COVID-19 restrictions may have led to a temporary disruption in infant sleep consolidation. However, the long-term consequences of these restrictions are yet to be determined.

An additional domain that has been impacted by the COVID-19 pandemic is children's media screen exposure. With the shift of both academic and non-academic activities into the home, screens became a major bridge to the outside world, allowing for education, social interaction, and distraction from the challenges of COVID-19 [26]. Consequentially, bourgeoning evidence reveal a drastic rise in youth's screen exposure throughout 2020. For example, a study of 2426 Chinese children and adolescents found a ~150% increase (450 vs 170) in minutes of weekly screen time during the initial phases of the pandemic [27]. Correspondingly, Lim et al. found that preschool children's non-academic screen time rose from 1.05 h per day to 2.49 h during the lockdown in Singapore. Similar increases in screen time have been found in children as young as 18 months in Germany, Turkey, and Japan [28–30].

To the best of our knowledge, the effects of COVID-19 on infant screen time, have yet to be examined. Recent investigations have demonstrated that despite guidelines discouraging exposure to screens under two years of age [31], US infants as young as 1-month-old are regularly exposed to digital media [32,33]. Young children's exposure to screens has been associated with increased risk of adiposity, impeded cognitive and motor development, poorer psychosocial health, and poorer sleep [34,35]. The links between increased screen exposure and decreased sleep duration have recently been demonstrated in infant populations, with stronger associations indexed in younger compared to older children [32,36,37]. Given the potential adverse consequences of extended screen time early on in development, the present study assessed whether COVID-19 living restrictions led to increases in screen exposure in infants aged 1–18 months old.

Furthermore, this study aimed to gauge the impact of close-to-a-year of restricted living conditions on infant and parent sleep, as well as parent sleepiness and depression levels using a prospective design, and multi-method assessment. Most previous studies have relied solely on parent-reports, which have often been retrospective (ie, parents asked during COVID to report on pre-COVID routines). Such subjective reporting may be substantially affected by social desirability and recall bias, particularly with regards to nighttime sleep [38]. The present study used auto-videosomnography [39] along with parent reports, to prospectively compare a 2020– with a 2019–matched infant and parent cohort.

2. Methods

2.1. Participants and procedures

Participants were 1518 US infants aged 1–18 months ($M = 8.5$ months, $SD = 4.6$, 54% boys) from two separate cohorts. Data from the first cohort were collected as part of a study examining the links between infant sleep and digital media screen exposure in Nov–Dec of 2019, prior to the onset of COVID-19 in the United States. Parent users of the Nanit baby monitor were invited to participate in an online survey about their infant's sleep and screen exposure, as well as their own sleep and well-being. Data collected from this cohort were ideally suited for prospective evaluation of the impact of COVID-19 on infant and parent constructs. Thus, a second group of parent users of the Nanit monitor was invited to participate in an equivalent online survey in Nov 2020. This timing of data collection was chosen to control for seasonal effects when creating the COVID-19 cohort, hence data were collected between mid-Nov and mid-Dec in each 2019 and 2020.

For each cohort, parents received an email inviting them to participate in an online survey if they had previously consented to making their infants' objective sleep data available for research purposes. Informed consent was additionally obtained electronically prior to survey completion. Data were collected anonymously, using participant ID codes. Participants who completed the survey were offered a respondent reward (raffle prize for a $500 gift card). All procedures were approved by IntegReview institutional review board (Protocol identifier: Nanit 2017–01; integreview.com).

Participants were included in this study if they identified as the mother or father of an infant aged 1–18 months, resided in the US, and had a minimum of four codable nights of auto-videosomnography within the 14-day period prior to survey completion. Auto-videosomnography nights were considered valid if sleep-onset times were detected within the 5pm-12am range, sleep-offset times were detected within the 4am–10am range, and sleep duration was $\geq$5 h. Cohorts were tested for potential duplicates, and in case surveys were completed for the same infant on both occasions (eg, in Nov 2019 when the infant was three months old, and in Nov 2020 when the infant was 15 months old), the participant was removed from the 2020 cohort and retained in the 2019 cohort, to minimize confounding effects of repeated administration of measures.

The initial 2019 and 2020 cohorts included 853 and 3322 infants, respectively. Given this imbalance, and given that random allocation to condition (before or during COVID-19) was not possible, propensity-score matching was used to create two equivalent cohorts [40]. To ensure valid comparisons, cohorts were matched on infant age and gender, as well as parent age, gender, ethnicity, education, marital status, and the number of available nights of auto-videosomnography. This procedure yielded two equivalent cohorts, each consisting of 759 infants (overall $N = 1518$). Table 1 presents participant characteristics for the matched 2019 and 2020 cohorts. The demographic characteristics of cohorts before and after matching are presented in Supplementary Table S1, demonstrating the lack of differences between matched– as opposed to unmatched– cohorts.

2.2. Measures

2.2.1. Auto-videosomnography

Infant sleep was measured objectively in the natural home environment using auto-videosomnography derived from camera monitors (Nanit, Udisense LTD., NY, USA). Monitor devices were mounted above the infant's crib, and continuously recorded motion within it during the nocturnal period. Motion-stillness patterns were automatically translated into sleep-wake patterns using a computer-vision algorithm. Like actigraphy, the algorithmic approach quantifies movements per epoch as wakefulness, and stillness as sleep. Unlike actigraphy, not only wrist or ankle movements are recorded, but rather movements of the entire body. Participants were real-world consumers of these 'nearable' devices, and no additional instructions were provided. Derived metrics have been previously validated against both actigraphy and polysomnography in a small ($N = 7$) pilot study [41].

As done in previous studies [24,32], the following auto-videosomnography metrics were derived: (a) *Nighttime sleep duration*, indicated by the total accumulated minutes scored as sleep within the sleep period; (b) *Sleep-onset time*, specified as the first minute of five consecutive minutes of sleep; (c) *Sleep-offset time*, defined as the first minute of wakefulness following the last sleep segment, prior to the infant being taken out of the crib for the final time that night (d) *Number of nighttime awakenings*, characterised as awakenings lasting a minimum of 3 min within the nocturnal sleep period; and (e) *Number of parental nighttime crib visits*, indicated as the number of times parents were detected within the crib area throughout the night.

2.2.2. Parent-reported infant sleep

Parents reported their infant's sleep using the Brief Infant Sleep Questionnaire (BISQ) [42], as part of the online surveys. This well-validated questionnaire aims to assess parent perceived infant sleep patterns. It served as a complimentary measure to auto-videosomnography, since auto-videosomnography does not capture all aspects of infant sleep (eg, daytime sleep). BISQ metrics that were not assessed by auto-videosomnography were used in this study, including the following: (a) *Daytime sleep duration*, reported in hours and minutes; (b) *Lights-out time*; (c) *Sleep-onset latency*, reported on a 5-point scale, from 1 ("*less than 5 min to fall asleep*") to 5 ("*more than 60 min to fall asleep*"); (d) *Nighttime sleep quality*, reported on a 5-point scale, from 1

Table 1
Participant characteristics in the matched 2019 and 2020 cohorts.

	2019 $N = 759$	2020 $N = 759$	t/χ2
Infant age (months)	8.5 (4.6)	8.5 (4.6)	0.03 (0.97)
Infant gender, *n* (%) boys	411 (54.1%)	410 (54.0%)	0.003 (0.96)
Room sharing with parents	79 (10.4%)	103 (13.6%)	3.60 (0.06)
Parent gender, *n* (%) mothers	480 (63.2%)	456 (60.1%)	1.61 (0.20)
Parent age (years)			11.35 (0.08)
21–24	4 (0.5%)	11 (1.4%)	
25–29	133 (17.5%)	131 (17.3%)	
30–34	365 (48.1%)	387 (51.0%)	
35–39	206 (27.1%)	165 (21.7%)	
40–44	41 (5.4%)	57 (7.5%)	
45–49	8 (1.1%)	6 (0.8%)	
50 or older	2 (0.3%)	2 (0.3%)	
Parent education			2.38 (0.67)
Highschool degree or Less	12 (1.6%)	14 (1.8%)	
Some college	81 (10.7%)	82 (10.8%)	
College degree	373 (49.1%)	392 (51.6%)	
Postgraduate degree	293 (38.6%)	271 (35.7%)	
Parent ethnicity			2.70 (0.75)
White/Caucasian	616 (81.2%)	607 (80.0%)	
Asian	55 (7.2%)	67 (8.8%)	
Hispanic	53 (7.0%)	50 (6.6%)	
African American	13 (1.7%)	15 (2.0%)	
Other	22 (2.9%)	20 (2.6%)	
Parent marital status			3.91 (0.27)
Domestic partnership or married	749 (98.7%)	743 (97.9%)	
Never married	5 (0.7%)	4 (0.5%)	
Separated, divorced or widowed	5 (0.7%)	12 (1.6%)	
Household income			4.55 (0.60)
< $50,000	22 (3.1%)	29 (4.2%)	
$50,000–$100,000	126 (17.8%)	129 (18.8%)	
$100,000–$150,000	179 (25.4%)	174 (25.3%)	
$150,000–$200,000	141 (20.0%)	135 (19.6%)	
>$200,000	237 (33.6%)	221 (32.1%)	
Number of available auto-videosomnography nights	12.11 (2.66)	11.91 (2.41)	1.58 (0.11)

Data are presented as means (standard deviations) unless otherwise indicated.

("*sleeps very poorly*") to 5 ("*sleeps very well*"); and (e) *Wake after sleep-onset*, reported in minutes.

2.2.3. Infant screen exposure

Parents completed a series of questions regarding their child's media screen exposure as part of the online surveys. Items were based on previous investigations of screen time in young children [32,43,44]. To increase precision, average exposure times were reported separately for each TV and touchscreen devices (smartphones, tablets, laptops, and handheld game players), at four different times of the day (morning, afternoon, the hour before bed, and during the night). Exposure durations were selected from 10-min response categories (eg, 0, 1–10 min, etc.). Numeric values were then assigned to categories (eg, 0, 5.5 min, etc.) to generate quasi-continuous measures. Exposure times were aggregated across devices and times of day to construct a daily screen exposure metric.

2.2.4. Parent sleepiness and sleep quality

The Epworth Sleepiness Scale (ESS) was administered to assess subjective parental sleepiness [45]. Parents were asked to rate the likelihood of dozing on eight daytime situations (eg, while watching TV) on a 4-point scale, with higher scores indicating higher sleep propensity. The ESS has previously been validated against the objective Multiple Sleep Latency Test [45], and internal consistency was found to be adequate in the present study (Cronbach's alpha = 0.75). To capture sleep quality, parents were asked to rate the quality of their sleep on a 5-point Likert-scale, from 1 ("*very poor*") to 5 ("*very good*"). This measure has been used to assess adult sleep quality in prior studies [eg, [46,47]].

2.2.5. Parent depression levels

The Edinburgh Postnatal Depression Scale (EPDS) was used to assess parental depression levels. The questionnaire consists of 10 items, that are rated on a 4-point scale, with higher scores reflecting increased depression symptomology. The reliability and validity of the EPDS have previously been established [48]. In the present sample, internal consistency of the scale was high, as indicated by Cronbach's alpha of 0.86.

2.2.6. Demographic characteristics

Parents completed a demographic questionnaire, which included items regarding their age, education, ethnicity, employment status, marital status, and family annual income. Parents were additionally asked to report their infant's age and gender, whether their child currently breastfed, and whether the infant usually slept in the same room as the parents.

2.3. Data analysis plan

Outliers were identified using the interquartile rule [49], and replaced with the closest value not identified as an outlier [50]. Within the matched samples, data were missing for several parent-report items (0–9.1% for demographic characteristics, 0–8.7% for parent-reported sleep metrics, 14.7% for screen exposure duration, and 16.6–17.1% for parent well-being variables). All infants had at least four nights of auto-videosomnography data, with missingness of 14.2% of nights out of the 14-night assessment period, resulting in an average of 12.01 nights per infant (SD = 2.53). Rates of missingness were equivalent between the 2019 and 2020 cohorts. Multiple imputations were applied to preserve representativeness and size of the samples [51]. Sensitivity analyses were additionally performed with the complete-case samples (using list-wise deletion), revealing a very similar pattern of results (see supplementary Table S2 for a complete account of these analyses).

Processing of auto-videosomnography data was conducted in R using RStudio [R v3.6.3, RStudio v1.2.5033; [52]]. Linear mixed models were computed for each sleep metric, using the 'lme4' package [53]. Mixed modelling allows for estimation of parameters using all available nights of objective sleep data nested within infant, accounting for random intercepts and slopes. Models were first computed to test the effects of cohort (2019 vs 2020). Given the dramatic developmental changes in the first 18 months of life, infant age-by-cohort interaction terms were then added to each model, to test whether differences between cohorts varied as a function of age. Restricted maximum likelihood estimation (REML) was used for estimation. The following covariates were tested and added to each model based on backward selection procedures [54]: infant age, gender, breastfeeding, room sharing, and parent age, gender, education, marital status, employment status, ethnicity, income, and depression levels. Infant screen time was additionally considered as a covariate to models testing effects on infant sleep outcomes. To further examine significant interaction effects, infant age was grouped into three categories (1–6, 7–12, and 13–18 months), and pairwise comparisons were computed using the 'emmeans' package [55]. Nightly data were visualized using raincloud plots [56].

Parent-reported data were analyzed using MANCOVAs in SPSS version 26.0 (IBM Corporation, Unites States). These data were not nested within participants, and thus did not require multi-level modeling. As with auto-videosomnography modeling, models included main effects of cohort, and age-by-cohort interaction terms were subsequently added. Backward selection procedures were implemented to determine which covariates would be added to each model.

3. Results

3.1. Auto-videosomnography

Linear mixed modelling yielded significant cohort effects for objectively assessed nighttime sleep duration, sleep-onset time, and sleep-offset time (see Table 2 and Fig. 1). Compared to December 2019, at the end of 2020 infants slept 39.6 min longer per night (SE = 4.4, $p < 0.001$), fell asleep 9.5 min earlier (SE = 4.2, $p = 0.02$), spent 16.9 min less out of their cribs at night (SE = 2.2, $p < 0.001$), and woke up 10.8 min earlier in the morning on average (SE = 2.5, $p < 0.001$). Cohorts did not differ in the number of nighttime awakenings, nor did they differ in the number of parental nightly crib visits. Moreover, models yielded non-significant age-by-cohort interaction effects, indicating that the increase in sleep duration and advance in sleep timing occurred regardless of infant age.

3.2. Parent-reported infant sleep

MANCOVAs for BISQ measures revealed significant differences between 2019 and 2020 cohorts in sleep-onset latency and wake after sleep-onset (see Table 2). Whereas no significant difference between cohorts was found in daytime sleep duration, infants in 2020 had longer sleep-onset latencies ($M_{\text{difference}} = 0.36$, $SE = 0.05$, $p < 0.001$), and more wakefulness after sleep-onset ($M_{\text{difference}} = 12.7$ min, $SE = 2.4$, $p < 0.001$). Cohorts did not differ in parent-reported lights-out times or infant sleep quality, and cohort effects did not differ as a function of infant age.

3.3. Infant screen time

As shown in Table 2, infant screen time was significantly greater in the 2020 infant cohort compared to 2019 infant cohort. Infants in

Table 2
Descriptive statistics, cohort, and cohort by age interaction effects of infant and parent measures in 2019 vs 2020. Objective sleep metrics were analyzed using linear mixed models, and parent-report measures were analyzed using MANCOVAs.[a]

		Cohort *M (SE)*		Cohort effect	Age X Cohort effect
		2019 N = 759	2020 N = 759	*t* (*p*)	*t* (*p*)
Auto-videosomnography	Nighttime sleep duration (h)	9.3 (0.08)	9.9 (0.07)	**8.49 (<0.001)**	−0.66 (0.51)
	Sleep-onset time	20:07 (0:04)	19:58 (0:04)	**−2.28 (0.02)**	0.97 (0. 33)
	Sleep-offset time	07:03 (0:02)	06:53 (0:02)	**−4.42 (<0.001)**	0.93 (0.35)
	Number of nighttime awakenings	3.65 (0.06)	3.72 (0.07)	−0.51 (0.61)	−1.65 (0.10)
	Number of parental nighttime crib visits	2.06 (0.13)	1.93 (0.12)	−0.96 (0.34)	−0.086 (0.39)
				F (*p*)	*F* (*p*)
Parent-reported infant metrics	Daytime sleep duration (h)	3.12 (0.19)	3.15 (0.19)	0.41 (0.52)	0.53 (0.47)
	Lights-out time	19:22 (0:17)	19:15 (0:17)	3.91 (0.05)	2.59 (0.13)
	Sleep-onset latency (5-point scale)	2.07 (0.08)	2.44 (0.07)	**59.54 (<0.001)**	1.95 (0.19)
	Nighttime sleep quality (5-point scale)	5.04 (0.06)	5.00 (0.06)	0.50 (0.48)	0.43 (0.52)
	Wake after sleep-onset (min)	32.65 (1.69)	45.32 (1.69)	**24.34 (<0.001)**	3.13 (0.08)
	Infant screen time (mins)	23.61 (1.56)	32.46 (1.63)	**10.40 (0.001)**	**4.03 (0.04)**
Parent well-being	Parental sleep quality	3.35 (0.04)	3.37 (0.04)	0.30 (0.62)	0.49 (0.54)
	Parental sleepiness (ESS)	6.00 (0.13)	5.36 (0.13)	**12.60 (<0.001)**	0.70 (0.41)
	Parental depression (EPDS)	8.66 (1.18)	9.10 (1.19)	**3.91 (0.04)**	0.54 (0.47)

Significant cohort and age by cohort interaction effects are marked in bold.
[a] All models were adjusted for some or all of the following covariates, as determined using backward selection: infant age, gender, breastfeeding, room sharing, and screen exposure time (for infant sleep outcomes), as well as parent age, gender, education, marital status, employment status, ethnicity, income, and depression levels.

2020 were exposed to touchscreens and televisions for 8.8 more minutes per day on average ($SE = 2.2$, $p = 0.001$), representing a 37.5% increase in screen time compared to 2019. Additionally, a significant age-by-time interaction effect was found ($p = 0.04$). Pairwise comparisons indicated that daily screen exposure was significantly greater in 2020 for older infants (13–18-month-old; $M_{\text{difference}} = 18.3$ min, $SE = 4.6$, $p < 0.001$), whereas differences were not significant for infants 12 months or younger (see Fig. 2).

3.4. Parent sleep quality, sleepiness, and depression

Parent sleep quality did not differ between the 2019 and 2020 cohorts (see Table 2). Parent daytime sleepiness, however, was significantly lower in 2020 compared to 2019 ($M_{\text{difference}} = 0.64$, $SE = 0.18$, $p < 0.001$). Moreover, depression levels were significantly higher in 2020, as reported by parents on the EPDS ($M_{\text{difference}} = 0.44$, $SE = 0.22$, $p = 0.04$). Infant age-by-cohort interaction effects were not significant for any parent well-being measures.

4. Discussion

The results of the present study demonstrate significant differences in infant sleep and screen-time, as well as parent sleepiness and depression levels between a cohort of infants and parents assessed in Dec 2019 and a matched cohort assessed in Dec 2020. These differences are discussed in the following sections.

4.1. Infant sleep in COVID-19 compared to 2019

In 2020 US infants slept approximately 40 min more per night on average, as indicated by auto-videosomnography. No difference was found in the duration of daytime sleep, suggesting that infant sleep duration per 24-hrs increased during the COVID-19 year. These findings are in line with evidence of longer sleep durations in older children during the 2020 pandemic [19–21]. They also correspond with our recent findings, indicating that infants of mothers in home-confinement had objectively longer nighttime sleep durations, compared to infants of mothers who were working as usual throughout the first weeks of COVID-19 stay-at-home orders in the USA [24]. The clinical implications of the additional 40 min of sleep per night found in the present study may be substantial (eg, up to 280 min of extra sleep per week), as extended sleep has been linked with a myriad of beneficial outcomes in young children, including improved physical development, health, emotion regulation, and cognitive functioning [57].

Auto-videosomnography also indexed an advance in sleep timing in 2020 compared to 2019, with earlier sleep-onset and sleep-offset times. These may have been due to the lack of evening professional or social activities during COVID-19, or to parents spending more time with their infants during the day, thus being less inclined to extend evening routines to gain more time with them. With regards to sleep quality, no significant changes were found between the 2019 and 2020 cohorts in the number of objectively measured infant nighttime awakenings or parental crib visits. Similarly, parents reported equivalent infant sleep quality in both cohorts. However, parent reports yielded increases in infants' sleep onset latency and wake after sleep onset in the COVID-19 cohort, compared to the 2019 cohort. These differences may be explained by parents being more aware of their infants' wakefulness during COVID-19, possibly due to their own extended wakefulness during the night. While these postulations cannot be tested within the present study, it is important to note that objective data did not attest to a worsening of infant sleep quality during COVID-19, as opposed to previous reports of pediatric populations [9,15]. These discrepancies stress the importance of mutli-method assessment of children's sleep [38], to obtain a comprehensive account of this multifaceted phenomena.

Our analyses additionally revealed that differences between cohorts in infant sleep metrics did not vary as a function of infant age. Previous investigations have yielded age moderation effects, whereby the sleep of older children was more profoundly affected by COVID-19 [21,58]. However, these studies included older and broader age ranges, and mostly demonstrated differences between young children and adolescents. Despite the rapid evolution in sleep during the first 18 months of life [59], it seems that younger and older infants' sleep was similarly affected by the new living conditions related to COVID-19.

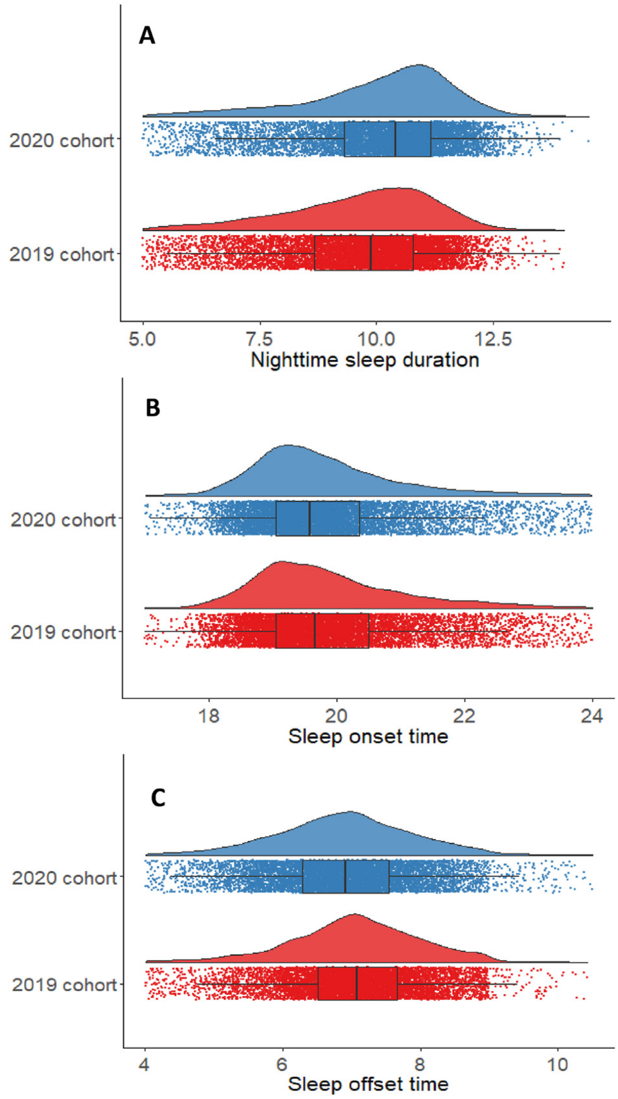

Fig. 1. Raincloud plots of nighttime sleep duration (A), sleep onset time (B), and sleep-offset time (C) in 2019 vs 2020 assessed using auto-videosomnography. The distribution (probability density function of observations), jittered data points of individual nights, and medians alongside interquartile ranges (illustrated as horizontal boxplots) are depicted for each cohort.

4.2. Infant screen exposure in COVID-19 compared to 2019

The results of the present study additionally reveal a significant increase in infants' exposure to screens during the pandemic. This finding is in line with the mounting evidence for increased screen time in children, adolescents, and adults during COVID-19 [19,27,60], and extends this body of evidence to the infant age group. Importantly, the lengthening of screen time was significantly moderated by age, as infants aged 13–18 months were exposed to screens for 18.3 more mins per day in 2020 compared to 2019, whereas increases in screen time for infants 12 months and younger did not reach statistical significance. This age moderation dovetails with Schmidt et al.'s [28] report of child and adolescent screen time during the COVID-19 lockdown in Germany, showing larger increases in screen exposure with increased age.

The rise in screen exposure time in older as opposed to younger infants may reflect specific caregiving requirements related to developmental stage. During the first half of the second year of life infants develop gross motor skills that allow greater mobility (eg, walking, running), requiring closer care to assure safety [61]. Parents of older infants might not afford to 'take their eyes off' them, whereas younger infants remain relatively stationary, allowing caregivers to simultaneously perform professional or household tasks while looking after their child. Considering the sizable burden on families during COVID-19 [4], parents may have been more inclined to employ media screens to occupy older infants, clearing time for them to complete their professional and domestic tasks. Given that younger infants spend more time asleep during the day [59], more time becomes available for parents to complete other responsibilities, thus reducing the need to engage infants using screens. Finally, parental adherence to recommendations that discourage screen time may erode as the child grows older, since older children may be perceived as less vulnerable to the deleterious effects of screens [62].

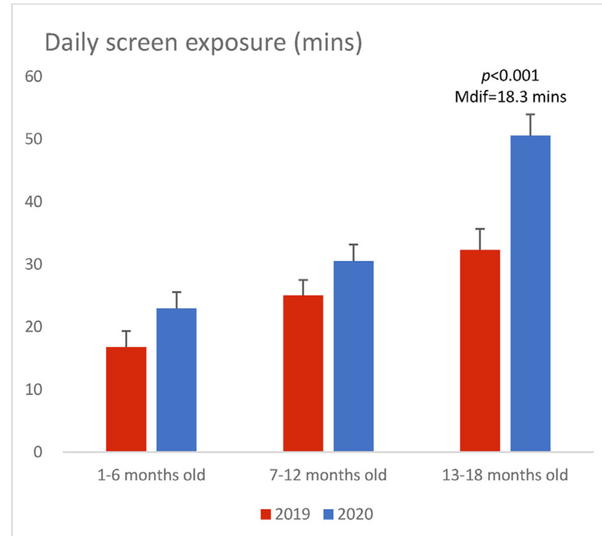

Fig. 2. Daily infant screen exposure by age in 2019 vs 2020.

Despite guidelines recommending that children under two years of age not be exposed to screens [31], 13-18-month-old infants had 50.6 min of daily media screen exposure during the pandemic, 7–12 month old infants had 30.5 min, and 1–6 month old infants had 23.0 min on average. These figures are concerning, given that infant screen exposure has been linked to a myriad of negative developmental, physiological, and psychological outcomes [34,63]. Nevertheless, previous evidence demonstrates that considering solely the duration of screen exposure may not provide an intricate enough account of the possible impact screens may have on children's health and well-being. Rather, the content and context in which digital media is consumed, in addition to duration, may be more indicative of its impact on youth [64]. Video-chatting, for example, has been regarded by the American Academy of Pediatrics as an exception to child media restrictions, given its potential to facilitate social connections. Employing media screens for video-chatting may have been particularly important during the social distancing requirements of COVID-19, which isolated them from relatives. Moreover, exposure to age-appropriate video content, especially when mediated by parents, has been associated with improved social and emotional development in young children [65]. In addition, extended screen time may be detrimental only to the extent that it displaces other beneficial activities, such as physical activity and sleep. In a recent actigraphy study, prolonged screen time was associated with more behavior problems only in preschool children who slept for less than 9.9 h per night [66]. Thus, the increase in infant sleep duration during COVID-19, as demonstrated in the present study, may have somewhat mitigated the potential adverse effects of increased screen exposure.

4.3. Parent sleep quality, sleepiness, and depression in COVID-19 compared to 2019

The present study demonstrates mild changes in the well-being of parents of infants during the 2020 pandemic. Whilst there was no difference in the quality of sleep reported by parents, compared to 2019, parents reported lower daytime sleepiness levels during the pandemic, regardless of their infant's age. This coincides with the extension in infant nighttime sleep duration found in the present study. It is also in accord with objective data showing that parents of school aged children slept for 27 min longer during– compared to before– COVID-19 restrictions were imposed in Australia [67]. Additional adult studies have reported longer sleep opportunities (times spent in bed) during 2020, possibly due to the diminished need to commute when working from home, which may have allowed more time for sleep [68,69]. The results of the present study suggest that one of the consequences of this extended sleep time may be reduced sleepiness.

Our analyses additionally revealed a significant increase in parental depression symptomology in the 2020 cohort, compared to the 2019 cohort. This finding is consistent with previous accounts of increased depression rates among parents during the COVID-19 pandemic [12,14]. The closure of day-care centers, and the curtailment in additional childcare, household, and emotional support for parents, tremendously increased their domestic burden. These may have compounded the stress of social isolation, uncertainty, and health concerns during the pandemic, resulting in elevated depressive symptoms. Previous findings have attested to the relationship between postnatal depression and sleep loss in parents of young infants [70–72]. Such links have been understood in light of various mechanistic pathways, including alterations in emotional brain networks, increased physiological reactivity, and poor emotion regulation [72,73]. However, taken together with previous evidence for increased sleep durations in adults during the pandemic [67,69], our findings imply that the mechanism driving parental distress was not sleepiness or sleep deprivation. In fact, it may be postulated that additional sleep actually served as a protective factor, balancing the unfavourable consequences for parents during the pandemic. Future longitudinal studies may wish to examine the mechanistic pathways through which COVID-19 impacted on parent well-being.

4.4. Strengths and limitations

The present study has several evident strengths. These include its prospective nature, the use of both objective assessment and parent-reports within a large sample, and the adjustment for appropriate covariates. The study also has several limitations. First, while infant screen time was assessed using a detailed questionnaire, parent reporting may have been impacted by social desirability and bias imprecision. Aware of recommendations to avoid screen time in infancy, parents may have been prone to underreport infant exposure to screens. Moreover, as previously mentioned, the ways in which infants engaged with media screens, and the content they were exposed to, were not assessed in the present study. Since these may considerably impact the links between screen exposure and developmental outcomes, future studies could examine the impact of COVID-19 restrictions on the specific circumstances of engagement with screens, and content that infants are exposed to. The lack of comprehensive evaluation of parent sleep constitutes a further limitation of the present study. Parental sleep quality was assessed using a single self-report item. While this method has been applied in previous studies [46,47], a more detailed account of the different aspects of parent sleep (eg, sleep duration, number of nighttime awakenings) would have provided a broader representation of the pandemic's impact on the sleep of parents of infants. The exclusion of nights in which infants slept in their crib for <5 h implies that findings derived from auto-videosomnography may not pertain to infants who share a bed with their parents, or spend most of the night out of their crib. Finally, the generalizability of our findings is limited mostly to families of white/Caucasian ethnicity, middle–high education levels, and middle–high socio-economic status residing in the USA.

5. Conclusion

The present study indicates that the COVID-19 pandemic introduced several changes to the way infants and their parents lived. For infants, nighttime sleep duration increased, but so did screen exposure time. For parents of infants, daytime sleepiness decreased, yet mild increases in depressive symptoms occurred. As research evidence continues to unfold, policy makers, mental health practitioners, and parents should strive to be aware of and minimize the increases in screen exposure durations in infants during periods in which families are confined to their homes. Applying harm reduction strategies, such as encouraging parents to choose adequate digital media content, incorporate movement while using screens, and prioritize screen-free times may be an appropriate pragmatic approach [74]. Similarly, effective measures should be placed to mitigate the effects of living restrictions on parents' depressive symptoms. Raising awareness and enhancing accessibility to psychological support and treatment programs would be warranted in the event of further COVID-19 waves, or future pandemics.

Notwithstanding the negative consequences of COVID-19 living conditions, the increases in infant sleep duration and decrease in parent sleepiness suggest that these conditions may also have substantial benefits. Extending some of these conditions, such as allowing parents to work from home, should be considered within the efforts to improve the well-being of parents and infants as they transition to post-pandemic times.

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Conflict of interest

This work was supported by Nanit (Research grant to Flinders University).

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: https://doi.org/10.1016/j.sleep.2021.07.033.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sleep.2021.07.033.

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