BMJ Open

Sleep patterns and intraindividual sleep variability in mothers and fathers at 6 months postpartum: a population-based, cross-sectional study

Christopher Kalogeropoulos ,[1,2] Rebecca Burdayron,[1,2] Christine Laganière,[1,2] Karine Dubois-Comtois,[2,3] Marie-Julie Béliveau,[2,4] Marie-Helene Pennestri[1,2]

To cite: Kalogeropoulos C, Burdayron R, Laganière C, *et al*. Sleep patterns and intraindividual sleep variability in mothers and fathers at 6 months postpartum: a population-based, cross-sectional study. *BMJ Open* 2022;**12**:e060558. doi:10.1136/bmjopen-2021-060558

► Prepublication history for this paper is available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2021-060558).

Received 29 December 2021
Accepted 13 June 2022

[1]Department of Educational and Counselling Psychology, McGill University, Montreal, Quebec, Canada
[2]Hôpital en santé mentale Rivière-des-Prairies (CIUSSS-NIM), Montreal, Quebec, Canada
[3]Département de psychologie, Université du Québec à Trois-Rivières, Trois-Rivières, QC, Canada
[4]Département de psychologie, Université de Montréal, Montreal, QC, Canada

Correspondence to
Dr Marie-Helene Pennestri; marie-helene.pennestri@mcgill.ca

ABSTRACT

Objectives Given that postpartum sleep is an important family process, further investigations including both mothers and fathers are necessary. The present study aimed to describe and compare sleep patterns and intraindividual night-to-night variability in mothers and fathers at 6 months postpartum using subjective and objective sleep measures.

Design Cross-sectional study.

Setting General community-based study in Montreal, QC, Canada.

Participants Thirty-three couples (mothers and fathers) with no self-reported history of medical and mental health conditions participated in this study.

Results Parental sleep was measured across 10 consecutive nights using both a daily sleep diary and actigraphy. Results demonstrated that mothers' subjective and objective sleep was more fragmented compared with fathers (shorter longest consecutive sleep duration and more nocturnal awakenings; p<0.001). While mothers and fathers did not differ in their self-reported nocturnal sleep duration (p>0.05), actigraphy indicated that mothers obtained significantly longer nocturnal sleep duration (448.07 min±36.49 min) than fathers (400.96 min±45.42 min; p<0.001). Intraindividual sleep variability was revealed by relatively high coefficients of variation for parents across both subjective and objective indices related to sleep fragmentation (between 0.25 and 1.32). Actigraphy also demonstrated variability by mothers sleeping 6 hours consecutively on less than 3 nights, 27.27% (±22.81), and fathers on less than 6 nights, 57.27% (±24.53), out of 10. Associations were also found between parental sleep and family factors, such as age and infant sleep location (p<0.05).

Conclusions These findings advance our knowledge of how sleep unfolds within the family system beyond the early postpartum weeks and/or months. Given the link between disturbed sleep and family functioning, the current research accentuates the importance of examining postpartum sleep patterns and variability in parents.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ The present study included both subjective and objective measures of sleep.
⇒ Examining sleep across 10 nights allowed for a more comprehensive understanding of parental sleep variability.
⇒ Inclusion of both mothers' and fathers' sleep patterns.
⇒ The generalisability may be limited due to the modest sample size and less varied sample.
⇒ The cross-sectional design limited causal inference.

INTRODUCTION

Sleep represents an important family process that significantly contributes to familial health and well-being.[1 2] Family sleep processes are particularly vulnerable in the postpartum period due to developing infant sleep-wake patterns. Accordingly, parents are susceptible to significant sleep disturbances, including sleep fragmentation and deprivation.[3–5] Given that mothers are often considered to have a more primary role in infant nighttime caregiving, much of the postpartum sleep literature has focused predominately on maternal and infant sleep.[6 7] Although infant sleep patterns also influence paternal sleep and well-being,[8 9] less is known about this population and it is therefore less clear how fathers' sleep patterns compared to mothers. Because sleep is an important factor linked to family functioning,[1 10] it is necessary to advance our understanding of mothers' and fathers' sleep patterns.

The few studies which have examined both mothers and fathers in a postpartum context have produced mixed findings depending on whether sleep patterns were measured subjectively or objectively in the weeks following childbirth. For instance, Insana and Montgomery-Downs found that, based on self-report measures, mothers and fathers did not significantly differ in their sleep quality (captured by the Pittsburgh Sleep Quality Index—PSQI) and fatigue between 3 and 8 weeks postpartum.[11] However, when

examined via actigraphy, these same mothers were found to have longer nocturnal sleep duration, but more disturbed and fragmented sleep than fathers.[11] Gay and colleagues found that while mothers self-reported more sleep disturbances, fathers objectively achieved shorter sleep durations over a 24-hour period in the first month postpartum.[3] These findings highlight that fathers also demonstrate sleep disturbances in the early postnatal period (ie, first few weeks or months) while also underscoring the utility of employing both subjective and objective measures to obtain a more complete understanding of postpartum sleep patterns in parents.

In infants, sleep-wake cycles evolve in the months following birth as their sleep progresses towards a process commonly referred to as 'sleeping through the night.'[12 13] This process is often characterised as achieving either 6 or 8 hours of consecutive sleep without parental responses.[14] While consolidated sleep may be achieved in infants at 6-months-old, studies have also revealed significant interindividual variability in infant sleep consolidation.[15–18] In a literature review, Henderson and colleagues also showed important variability in infant sleep, with 53% of infants sleeping through the night at 6 months (ie, achieving 8 hours of consecutive sleep).[14]

In addition to interindividual variability, intraindividual sleep variability has been documented in infants.[19–21] Infant sleep variability reflects the dynamic nature of sleep consolidation and is best described as a developmental process that evolves throughout infancy rather than a milestone reached at a specific point in time.[19] Since previous research has indicated that infants tend to have variable sleep patterns from nigh-to-night[19 22] and that sleep is a family process, parents are also expected to demonstrate high night-to-night variability in the postpartum period.

To our knowledge, few studies have examined postpartum sleep variability among parents. One study using a small sample of 19 mothers, demonstrated night-to-night objective sleep variability across seven nights (1 week postpartum) in total sleep duration, sleep efficiency, wake after sleep onset and number of sleep episodes.[23] More is known about sleep patterns within the general adult population as greater variability in actigraphy sleep duration has been strongly associated with poor subjective sleep quality and mood.[24] Mezick and colleagues found that adult women demonstrated greater intraindividual sleep variability compared with men in actigraphy measured sleep duration across nine nights after controlling for covariates (eg, sex, age, body mass index and medication use).[25] These authors also found greater variability in actigraphy derived sleep duration and fragmentation in women and men experiencing stressful life-events, independent of demographic and health factors.[25] The initial evidence for postnatal sleep variability in mothers,[23] combined with findings on both the general adult population and infants, highlight the importance of examining night-to-night variability among mothers and fathers in the postpartum period.

The current study sought to address the aforementioned limitations in the postpartum sleep literature. To achieve a more comprehensive understanding of parents' sleep patterns, we examined mothers and fathers using both subjective and objective sleep measures over the course of 10 consecutive nights at 6 months postpartum. While parental sleep has been examined in the first few weeks and months postpartum,[3 5 11 23] the current time point was selected based on research demonstrating high sleep variability in 6-month-old infants,[14 15] suggesting that parents may experience disturbed sleep across this period of time. Additionally, parents may be expecting to experience less sleep fragmentation at 6 months due to the commonly held belief that most infants should achieve sleep consolidation by this age.[26 27] As such, the aims of the study were to: (1) describe and compare sleep patterns in mothers and fathers as well as their intraindividual night-to-night variability at 6 months postpartum and (2) assess associations between parental sleep and family factors (ie, age, education level, employment status, number of children, infant feeding method, infant sleep location and infant nocturnal sleep variables).

METHODS

Participants

A total of 33 couples (mothers and fathers) were recruited from the Greater Montreal area (Québec). Mothers in the sample ranged in age from 26 to 39 (M=32.42±3.79 years) and fathers ranged in age from 26 to 41 (M=34.55±4.12 years). Participants took part in a larger longitudinal study investigating sleep in parents during the transition to parenthood. The current study used cross-sectional data from the first time point at 6 months postpartum. Recruitment occurred through online advertisements posted on social media forums for parents. Participation was voluntary and informed consent was obtained. The following inclusion criteria were met: (1) English-speaking or French-speaking parents, (2) 18 years and older, (3) no self-reported history of chronic medical illness, (4) no self-reported past or current diagnosed mental health conditions, (5) no self-reported sleep apnoea or use of sleep medication and (6) no parental report of diagnosed medical illness among infants. Considering the aims of the present study (examining sleep patterns and intraindividual night-to-night variability), only participants who completed at least 10 consecutive nights of sleep data were included in the sample. There were no significant differences between demographic characteristics and sleep variables of participants included and excluded from the study (n=10 excluded participants, with less than 10 nights of sleep data; p>0.05).

All 33 couples included in the present study were either married or in a common-law union and living with their infant. Table 1 describes family factors. Eleven couples (33.30%) reported being first-time parents, while 22 couples (66.70%) reported having 2 or more children. Most fathers (90.90%) reported current full-time paid

Table 1 Family factors

	Mothers (*n*=33)		Fathers (n=33)		Couples (*N*=33)	
	n	%	n	%	n	%
Age						
25–34	20	60.61	15	45.45		
35–44	13	39.39	18	54.55		
Education level						
High school	0	0	1	3		
College	1	3	9	27.3		
University	32	97	23	69.7		
Employment status						
Full-time paid employment or full-time student	6	18.2	30	90.9		
Part-time paid employment, student or both	0	0	2	6.1		
Home due to maternity or paternity leave	27	81.8	1	3		
Number of children						
1					11	33.3
2+					22	66.7
Infant feeding method						
Partial breast feeding					5	15.2
Exclusive breast feeding					28	84.8
Infant sleep location						
Solitary					16	48.5
Bed-sharing or cosleeping					17	51.5

employment and 81.80% of mothers reported being on maternity leave. Additionally, 84.80% of the sample indicated exclusive breast feeding as their primary infant feeding method and 51.50% of couples indicated cosleeping with their infant. Regarding infant sleep variables, nocturnal sleep duration ranged from 454.50 to 672.00 min (*M*=576.3±54.80) and nocturnal awakenings ranged from 0.70 to 4.90 (*M*=2.71±1.04).

Procedures

Participants recruited by online advertisements were contacted via telephone and a short phone screen was conducted to assess inclusion criteria. A home visit was scheduled with eligible couples who agreed to participate. During the home visit, trained members of our research team explained the measures (including the actigraphy recording) and procedures. Mothers and fathers were asked to complete the sleep diary and questionnaires, along with wearing the Actiwatch daily during the participation period. Participants were contacted shortly after the home visit to clarify potential questions and/or difficulties. Compensation was received on retrieval of the study materials. The opportunity of obtaining a larger sample size was limited due to COVID-19 restrictions implemented by government officials at the time of the recruitment process. However, analyses demonstrated significant results with the current sample size.

Measures

Sleep measures

Subjective sleep was assessed through a modified sleep diary adapted from Acebo and colleagues.[28] The diary consisted of a visual representation of each night with one box corresponding to 1 hour (which was further divided by lines denoting 15 min blocks). Parents were instructed to shade in the boxes corresponding to their estimated sleep period every morning to report their nocturnal sleep patterns (unshaded boxes represented wake period during the night). Three subjective sleep variables were then derived by computing means of the sleep diary data across 10 consecutive nights: (1) nocturnal sleep duration, (2) longest consecutive nocturnal sleep duration and (3) nocturnal awakenings.

Objective sleep was assessed using actigraphy. Actigraphy is a watch-like device that is placed on the wrist of participants' non-dominant arm. The present study used the Actiwatch Spectrum Plus (Philips Respironics), a triaxial, piezoelectric accelerometer. Participants were instructed to wear the watch daily and remove the device only for immersed, water-based activities (eg, bathing, swimming and so on). The Actiwatch was sampled at a rate of 32 Hz. Data were recorded in 1 min epochs[29 30] and downloaded using Philips Actiware Software (V.6.0.9). Data were scored using a standardised actigraphy scoring protocol.[31] Objective sleep variables were derived by

computing means of the actigraphy data across 10 consecutive nights: (1) nocturnal sleep duration, (2) longest consecutive nocturnal sleep duration and (3) nocturnal awakenings. Additionally, the longest consecutive sleep duration per night was obtained using raw data of minute-by-minute epochs recorded by the actigraphy. For all participants, activity status was defined as active, rest or rest-sleep. Active and rest were considered wake states. Wake states after nocturnal sleep onset were manually determined when activity level per minute was equal or above the 40-activity count threshold (medium sensitivity) for at least five consecutive epochs. The longest sleep period for each night indicated consecutive sleep duration. To verify whether parents engaged in daytime sleep, mean 24-hour sleep duration across 10 nights was also derived.

Family factors

Participants completed a demographic questionnaire to obtain information on their age, education level, employment status and number of children. A questionnaire about sleep-related parental practices during the postpartum period (adapted from the Sleep Practices Questionnaire)[32–34] was used to assess: (1) infant feeding method (ie, no breast feeding, partial breast feeding—mixed feeding or exclusive breast feeding) and (2) infant sleep location (ie, solitary or cosleeping). Solitary sleep referred to the infant sleeping in his/her own room either alone or with siblings on a nightly basis, whereas cosleeping was defined as the infant sleeping in the same room as parents (ie, same bed, bassinet or crib). Mothers completed a separate sleep diary to record their perceived estimates of infants' nocturnal sleep duration and nocturnal awakenings across the same 10 consecutive nights; means were then calculated for every infant.

Statistical analyses

The data was normally distributed; univariate outliers ($z>|3.29|$) were converted to the nearest non-outlying value (with $z<|3.29|$).[35] Descriptive statistics were computed for all subjective and objective sleep variables to describe parental sleep patterns. Paired sample *t*-tests were then used to compare mothers' and fathers' indices of sleep (ie, nocturnal sleep duration, longest consecutive sleep duration and nocturnal awakenings). Intraindividual night-to-night variability in parents' sleep was examined by calculating a coefficient of variation (CV—ratio of the SD/mean)[19 24 36] for all sleep diary and actigraphy variables. To further describe variability in mothers' and fathers' sleep process, the number of nights parents slept 6 hours consecutively was examined (ie, consolidated sleep). Consistent with previous research, 6 hours of consecutive sleep represents a commonly used criterion for consolidated sleep.[14 15 19 37] Using the subjective and objective longest consecutive sleep duration variable, the number of nights (out of 10) each mother and father slept 6 hours consecutively was calculated and transformed into percentages. Last, Pearson's correlations and independent sample *t*-tests were used to assess the associations between parental sleep and family factors (ie, age, education level, employment status, number of children, infant feeding method, infant sleep location and infant nocturnal sleep variables). Across analyses, statistical significance was determined based on $p<0.05$. All data were analysed using IBM SPSS V.24.0 for Windows (SPSS, Chicago, Illinois, USA).

Patient and public involvement

There were no patients involved in the current study. Additionally, participants and members of the public were not involved in the design, conduct, reporting or dissemination plans of the current research.

RESULTS

Parental sleep patterns

Table 2 demonstrates a descriptive representation of subjective and objective sleep patterns in mothers and fathers. Results pertaining to the sleep diary variables indicated more maternal sleep fragmentation compared with fathers. Specifically, mothers demonstrated shorter longest consecutive nocturnal sleep duration (240.86 min±65.40 min) than fathers (376.77 min±67.46 min; $p<0.001$) and more nocturnal awakenings (2.27±1.01) than fathers (.60±0.56; $p<0.001$). There was no significant difference in self-reported nocturnal sleep duration between mothers and fathers ($p>0.05$). Results of the actigraphy sleep variables revealed that mothers demonstrated longer nocturnal sleep duration (448.07 min±36.49 min) than fathers (400.96 min±45.42 min; $p<0.001$). Actigraphy also revealed more sleep fragmentation in mothers with more nocturnal awakenings (2.46±0.99) than fathers (1.65±0.68; $p<0.001$) and shorter longest consecutive sleep duration (299.45 min±70.83 min) than fathers (376.73 min±63.39 min; $p<0.001$). Additionally, mothers demonstrated more objective 24-hour sleep duration (512.15 min±34.86 min) than fathers (446.71 min±44.19 min; $p<0.001$).

Intraindividual night-to-night variability

CV values for all subjective and objective sleep variables are presented in table 3. A higher CV signifies greater dispersion around the mean and greater variability. A visual inspection of sleep variables CV suggests that mothers and fathers demonstrated higher levels of variability in both subjective and objective indices related to sleep fragmentation (longest consecutive nocturnal sleep duration and nocturnal awakenings) compared with nocturnal sleep duration (table 3).

To further describe variability in mothers' and fathers' sleep, the number of nights parents slept 6 hours sequentially was examined (ie, consolidated sleep). Table 4 represents the percentage of nights mothers and fathers slept 6 hours consecutively across 10 nights (indicated by the sleep diary and actigraphy). Mothers self-reported

Table 2 Parental sleeping patterns

	M±SD	Range	*n*
Sleep diary (subjective sleep)			
Mothers			
Nocturnal sleep duration (min)	437.67±45.81	337.50–516.00	33
Longest consecutive sleep duration (min)	240.86±65.40	132.00–405.00	33
Nocturnal awakenings	2.27±1.01	0.90–4.60	33
Fathers			
Nocturnal sleep duration (min)	434.95±45.56	348.00–528.00	33
Longest consecutive sleep duration (min)	376.77±67.46	223.50–505.50	33
Nocturnal awakenings	0.60±0.56	0.00–2.10	33
Actigraphy (objective sleep)			
Mothers			
Nocturnal sleep duration (min)	448.07±36.49	348.70–517.10	33
Longest consecutive sleep duration (min)	299.45±70.83	114.10–500.10	33
Nocturnal awakenings	2.46±0.99	0.61–5.83	33
Fathers			
Nocturnal sleep duration (min)	400.96±45.42	293.40–493.00	33
Longest consecutive sleep duration (min)	376.73±63.39	224.30–476.30	33
Nocturnal awakenings	1.65±0.68	0.49–3.19	33

Note: Means (*M),* SD and ranges of sleep variable totals across 10 nights.

6 hours of uninterrupted sleep 15.45% (±20.48) of nights (less than 2 nights out of 10). As illustrated in figure 1A, almost half of the mothers (n=16; 48.5%) never reported sleeping 6 hours sequentially and no mother met the criterion for all 10 nights. More fathers self-reported sleeping 6 hours consecutively, with a proportion of

Table 3 Intraindividual night-to-night variability in parents' sleep (coefficients of variation)

	M±SD	Range	n
Sleep diary (subjective sleep)			
Mothers			
Nocturnal sleep duration (min)	0.15±0.05	0.08–0.34	33
Longest consecutive sleep duration (min)	0.32±0.11	0.13–0.62	33
Nocturnal awakenings	0.53±0.23	0.26–1.33	33
Fathers			
Nocturnal sleep duration (min)	0.16±0.06	0.06–0.31	33
Longest consecutive sleep duration (min)	0.26±0.09	0.06–0.49	33
Nocturnal awakenings	1.32±0.93	0.00–3.20	33
Actigraphy (objective sleep)			
Mothers			
Nocturnal sleep duration (min)	0.12±0.03	0.06–0.18	33
Longest consecutive sleep duration (min)	0.29±0.09	0.06–0.50	33
Nocturnal awakenings	0.27±0.09	0.11–0.51	33
Fathers			
Nocturnal sleep duration (min)	0.15±0.07	0.06–0.38	33
Longest consecutive sleep duration (min)	0.25±0.10	0.11–0.47	33
Nocturnal awakenings	0.26±0.15	0.08–0.93	33

Note: Means (*M),* SD and ranges of sleep variable coefficients of variation (CV—ratio of the SD/mean) across 10 nights.

Table 4 Percentage of nights parents are sleeping 6 hours consecutively

	M±SD	Range	n
Sleep diary (subjective sleep)			
Mothers			
Nights 6-hour criterion is met (%)	15.45%±20.48	0.00–70.00	33
Fathers			
Nights 6-hour criterion is met (%)	61.81%±26.98	10.00–100.00	33
Actigraphy (objective sleep)			
Mothers			
Nights 6- hour criterion is met (%)	27.27%±22.81	0.00–100.00	33
Fathers			
Nights 6-hour criterion is met (%)	57.27%±24.53	10.00–100.00	33

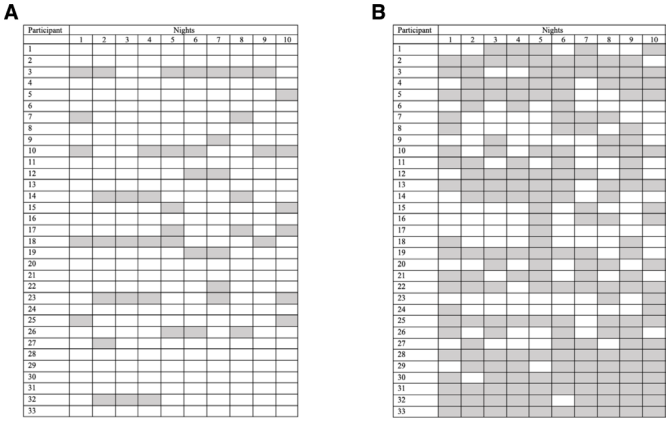

Figure 1 (A) Variability in 6 hours of consecutive sleep duration (sleep diary) in mothers across 10 nights. White: not sleeping 6 hours consecutively; Grey: sleeping 6 hours consecutively. (B) Variability in 6 hours of consecutive sleep duration (sleep diary) in fathers across 10 nights. White: not sleeping 6 hours consecutively; Grey: sleeping 6 hours consecutively.

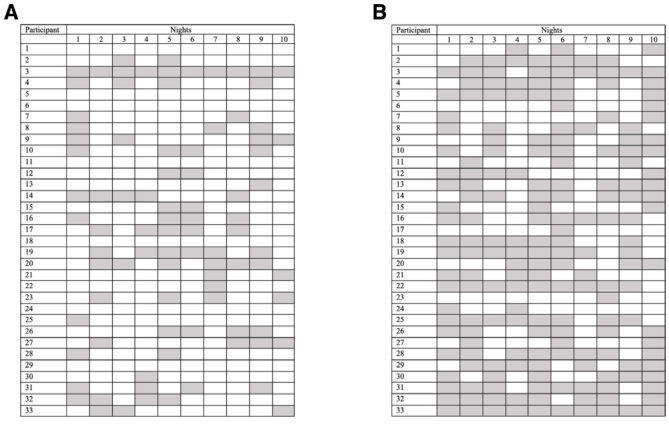

Figure 2 (A) Variability in 6 hours of consecutive sleep duration (actigraphy) in mothers across 10 nights. White: not sleeping 6 hours consecutively; Grey: sleeping 6 hours consecutively. (B) Variability in 6 hours of consecutive sleep duration (actigraphy) in fathers across 10 nights. White: not sleeping 6 hours consecutively; Grey: sleeping 6 hours consecutively.

61.81% (±26.98) of nights (approximately 6 nights out of 10; $t(32)=-7.24$, $p<0.001$)). Figure 1B shows that all fathers slept 6 hours for at least 1 night and three fathers (9.1%) met the 6-hour criterion every night.

Using actigraphy, the number of nights each mother slept 6 hours consecutively increased to 27.27% (±22.81; almost 3 nights out of 10). Figure 2A shows that seven mothers (21.21%) never slept 6 hours consecutively across 10 nights and one mother met the criterion every night. Fathers reached the 6-hour criterion 57.27% (±24.53) of nights (approximately 6 nights out of 10) when measured with actigraphy ($t(32)=-5.79$, $p<0.001$). figure 2B shows that all fathers received 6 hours of uninterrupted sleep for at least 1 night and 1 father (3.03%) met the 6-hour criterion across all 10 nights.

Parental sleep and family factors

Older mothers self-reported shorter consecutive nocturnal sleep duration ($r=-0.445$; $p=0.009$) and had lower subjective nocturnal awakenings variability ($r=-0.411$; $p=0.017$). Mothers with more children self-reported shorter nocturnal sleep duration ($r=-0.375$; $p=0.031$) and shorter longest consecutive sleep duration ($r=-0.414$; $p=0.016$), and lower percentage of nights 6 hours of uninterrupted sleep was achieved ($r=-0.405$; $p=0.019$). Regarding objective sleep variables, results revealed that older mothers had more nocturnal sleep duration variability ($r=0.436$; $p=0.011$).

Mothers engaging in solitary sleep reported higher subjective mean longest consecutive sleep duration (272.63 min±65.82 min) compared with mothers engaging in cosleeping (210.97 min±50.34 min; $p=0.005$). Solitary sleeping mothers also had lower subjective mean nocturnal awakenings (1.73±0.71) than cosleeping mothers (2.78±0.99; $p=0.002$), but reported more variability in nocturnal awakenings (solitary: 0.63±0.28; cosleeping: 0.44±0.13; $p=0.016$). Mothers engaging in solitary sleep also self-reported a higher percentage of nights sleeping 6 hours consecutively (24.38%±25.02%) compared with cosleeping mothers (7.06%±9.85%; $p=0.013$). Additionally, mothers on maternity leave demonstrated more subjective nocturnal awakenings

(2.44±1.04) compared with actively working mothers (1.49±0.17; p<0.001). There were no associations between mothers' subjective sleep variables and education level or infant feeding method (p>0.05). However, longer subjective mothers' nocturnal sleep duration (r=0.380, p=0.029) and consecutive sleep duration (r=0.702, p<0.001), and fewer subjective night awakenings (r=−0.625, p<0.001) were associated with longer infant nocturnal sleep. Additionally, shorter subjective maternal consecutive sleep duration (r=−0.693, p<0.001) and more self-reported maternal night awakenings (r=0.848, p<0.001) were associated with more infant night awakenings. No associations between mothers' actigraphy sleep variables and employment status, education level, infant feeding method, infant sleep location, infant nocturnal sleep duration or infant nocturnal awakenings were found (p>0.05).

Older fathers reported fewer subjective nocturnal awakenings (r=−0.467; p=0.006) and shorter objective nocturnal sleep duration (r=−0.562; p=0.001). Employment status, education level, infant feeding method, infant sleep location and infant nocturnal sleep variables did not demonstrate associations with paternal sleep diary and actigraphy variables (p>0.05). Last, these family factors did not relate to fathers' subjective and objective reports of sleeping 6 hours consecutively (p>0.05).

DISCUSSION

The current study aimed to describe and compare sleep patterns and intraindividual variability in parents at 6 months postpartum. Results revealed that mothers' sleep was more fragmented compared with that of fathers, as mothers self-reported (ie, sleep diary) significantly shorter longest consecutive nocturnal sleep duration and more nocturnal awakenings than fathers. These results were also replicated with actigraphy given that mothers demonstrated more objective sleep fragmentation compared with fathers. Such findings parallel those of Montgomery-Downs and colleagues, which indicated high sleep fragmentation via actigraphy in mothers throughout the first 4 months postpartum.[5] Our findings also coincide with research suggesting that compared with fathers, mothers' objective sleep tends to be more disturbed by nocturnal awakenings earlier in the postpartum period (examined between 3 and 8 weeks postpartum).[11] Additionally, research has shown more self-reported sleep disturbances and higher frequencies of subjective nocturnal awakenings in mothers compared with fathers at both 1 month[3] and 3 months[38] following childbirth. Taken together, our findings demonstrate that subjective and objective sleep fragmentation persists at 6 months postpartum.

The current study also revealed discrepancies between mothers and fathers pertaining to objectively measured nocturnal sleep duration. That is, while mothers and fathers did not differ in their self-reported sleep duration, actigraphy revealed that mothers obtained significantly more nocturnal sleep. These findings are congruent with previous research indicating no differences in parents' subjective sleep in the initial postpartum period,[3 11] yet mothers obtain longer objective postpartum sleep duration than fathers.[3] Subjective and objective sleep durations reported in the current sample fall within the range of sleep duration noted in healthy adults (7 to 9 hours).[4] The nocturnal sleep durations documented in our study are also comparable to previous literature investigating self-reported postpartum sleep in mothers and fathers.[39]

The increased sleep fragmentation and longer objective nocturnal sleep duration found in mothers may be explained by findings indicating that mothers tend to have a more primary role in infant nighttime caregiving than fathers.[6 7] Indeed, the majority of mothers in the present study reported that they were on maternity leave during the participation period, while most fathers reported full-time employment. Moreover, actigraphy data revealed that mothers slept more than fathers throughout a 24-hour period. Therefore, mothers likely had more flexible sleep schedules than fathers, whose opportunities for sleep were restricted to the nighttime. Furthermore, fathers' need for sleep at night may have been prioritised to facilitate adequate work functioning. As such, mothers were likely to be the designated parent to attend to their infant throughout the night, although this question was not specifically asked to participants in the current study. It is important to note that Québec's maternity leave is typically 12 months and that postpartum parental benefits vary in other countries. Our findings build on previous research documenting sleep disturbances and fragmentation among parents in the first few weeks and months following childbirth, yet uniquely contributes to the literature by demonstrating such patterns at 6 months postpartum especially in a context where mothers are on maternity leave.

The present study also represents a unique contribution to the literature by investigating intraindividual night-to-night sleep variability in parents over the course of 10 nights. Variability in sleep was revealed by relatively high coefficients of variation in longest consecutive sleep duration and nocturnal awakenings for both mothers and fathers across subjective and objective measures of sleep. Such findings are consistent with the limited existing research documenting variability in mothers' actigraphy measured sleep at 1 week postpartum.[23]

Further variability was demonstrated in the percentage of nights parents slept 6 hours consecutively. When examining sleep consolidation subjectively, mothers reported sleeping 6 hours without interruption on less than 2 nights out of 10 (15.45%), with no mother meeting the criterion every night. Similarly, actigraphy revealed that mothers slept 6 hours consecutively on almost 3 nights out of 10 (27.27%), with only one mother meeting the criterion nightly. Fathers slept 6 hours consecutively on approximately 6 nights out of 10 when measured with the sleep diary and actigraphy. Self-reports indicated that all fathers met the criterion for at least one night, but only three fathers (9.1%) slept 6 hours consecutively across all 10 nights. Actigraphy demonstrated similar findings, with

only one father (3.03%) meeting the criterion nightly. Hence, both mothers and fathers displayed night-to-night variability, but sleep consolidation was more present among fathers.

Overall, our findings demonstrating variability in parents' sleep at 6 months postpartum compliments previous research illustrating intraindividual night-to-night variability among infants at 6 and up to 12 months postpartum.[19 22] Given that sleep is a family process, parents' sleep is expected to vary according to whether their infants have achieved consolidated sleep. Indeed, infant nocturnal awakenings often require parental response, fostering more fragmented parental sleep.[3 13] A review of the literature has outlined links between sleep fragmentation and daytime functioning, daytime sleepiness, cognitive functioning and changes in mood among the general population.[40] In the postpartum period, objective sleep fragmentation was found to predict decreased cognitive functioning in mothers at 1 month following childbirth.[41] It is thus important to consider the effects fragmented sleep may have on mothers' and fathers' ability to assume important parental and familial responsibilities. Additionally, the intraindividual sleep variability demonstrated in parents of the current study may be explained by the potential stress they experienced throughout the nocturnal period as they anticipate the need to intervene during the night (ie, being 'on call' to soothe infant during nighttime awakenings). High stress has been associated with intraindividual sleep variability in the general adult population[24 25] and is perhaps more pronounced for parents considering the demands of caregiving.

Parental sleep and family factors

A secondary aim of the present study was to examine associations between parental sleep and family factors. While age has been associated with changes in sleep quality in the general population,[42] less is known about this relationship in the postpartum period. Our results revealed that older mothers self-reported shorter subjective longest consecutive sleep duration and fewer night awakenings. Older mothers also demonstrated more variability in actigraphy nocturnal sleep duration. Additionally, older fathers self-reported fewer night awakenings and lower actigraphy measured nocturnal sleep duration compared with younger fathers. Our findings coincide with literature conducted in the pregnancy period demonstrating that older maternal age was associated with poor sleep quality (captured by the PSQI).[43] It is thus important to consider the process of ageing as contributing to postpartum sleep difficulties in parents.

Infant sleep represented an important family factor associated with postpartum sleep patterns in parents. Unsurprisingly, self-reports of increased maternal sleep duration and less sleep fragmentation were associated with more consolidated infant sleep. However, these associations with infant sleep were only found for mothers', and not fathers' subjective sleep variables. These findings make sense in light of the fact that mothers, and not fathers, were on maternity leave and were likely the designated parent tending to their infant at night. This further supports previous research describing mothers as infants' primary nocturnal caregivers.[6 7]

Mothers who had more than one child had shorter subjective nocturnal sleep duration, shorter longest consecutive sleep duration and lower percentage of nights sleeping 6 hours consecutively. Additionally, mothers on maternity leave reported more night awakenings than actively working mothers. While mothers on maternity leave likely tended to their infant during the nocturnal period, it is also plausible that they engaged in daytime sleep to compensate for nocturnal sleep disruptions. Increased time in bed throughout the day may have thus interfered with mothers' nocturnal sleep. Mothers engaging in solitary sleep self-reported longer consecutive sleep duration and fewer nocturnal awakenings. Solitary sleep was also associated to more variability in subjective maternal night awakenings and related to mothers' higher percentage of nights sleeping 6 hours consecutively. Previous literature revealed that cosleeping mothers experienced more sleep-related problems than solitary sleeping mothers.[29 44] This is consistent with our findings as solitary sleeping mothers reported less subjective sleep fragmentation. Importantly, associations between infant sleep location and objectively measured sleep were not found. It is therefore possible that cosleeping mothers are more conscious of their infant as they are physically closer to them during the nocturnal period and more likely to have brief awakenings that are not captured by actigraphy.

No associations were found between maternal sleep variables (subjective and objective) and education level or infant feeding method. No associations were observed between fathers' sleep variables (subjective and objective) and employment status, education level, number of children, infant feeding method, infant sleep location or infant nocturnal sleep variables.

Limitations, future directions and strengths

The generalisability of our findings may be limited due to the modest sample size consisting of healthy parents, who were mostly white, educated, married (or common law union) opposite sex couples, with most fathers working full-time and mothers on maternity leave. The inclusion of larger and more varied samples, including at-risk families (e.g., parents experiencing severe mood disturbances), is needed to expand our knowledge of postpartum family sleep processes. The present study was also limited given the cross-sectional research design, hindering our ability to draw conclusions about parental sleep patterns and variability prior to or beyond 6 months postpartum. Longitudinal investigations spanning from birth and across the first year of infancy are required to provide a more complete overview of the development of postpartum family sleep processes. Future studies should also investigate postpartum sleep patterns and variability

in dual-career families when mothers have returned to work. Additional examination of non-traditional families is also necessary to further contribute to the postpartum sleep literature.

Despite the limitations outlined above, the inclusion of mothers and fathers, along with measuring sleep subjectively and objectively represent key strengths of the current study. Examining sleep across 10 nights allowed for a more comprehensive understanding of parental sleep variability and meaningfully contributes to the existing literature. Additionally, despite the less varied sample, significant sleep fragmentation was captured in parents at 6 months postpartum.

Examining sleep patterns in both parents revealed that sleep was more fragmented in mothers, while nocturnal sleep duration (actigraphy) was shorter in fathers. Intraindividual night-to-night variability was observed in mothers' and fathers' subjective and objective sleep indices. Further variability was documented in parents' lack of consolidated sleep, especially in mothers, at 6 months postpartum.

Taken together, this study advanced our knowledge of how postpartum sleep unfolds within the family system beyond the early postpartum weeks and/or months. The current research underscores the importance of examining postpartum sleep variability in both mothers and fathers, an area of research that has been understudied in the parental postpartum sleep literature. Further investigations exploring variability in parental sleep is especially important considering the link between sleep and family functioning.

Acknowledgements The authors would like to thank the families who participated in the study and the members of our research team in the Once Upon a Night Sleep Laboratory. The authors would also like to thank Marjolaine Chicoine and Élyse Chevrier for assistance with actigraphy scoring.

Contributors CK participated in the study design, data collection, analysis, interpreted the data and drafted the initial manuscript. RB and CL participated in the study design, data collection, data extraction process, participated to the data interpretation and critically reviewed the manuscript for important intellectual content. KD-C and M-JB contributed to the study conceptualisation and design, the interpretation of data and critically reviewed the manuscript for important intellectual content. M-HP acted as the principal investigator of this study, designed the data collection instruments, coordinated and supervised the data collection, contributed to the interpretation of data, critically reviewed the manuscript for important intellectual content and is responsible for the overall content as the guarantor. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

Funding This work was supported by the Social Sciences and Humanities Research Council of Canada (SSHRC), the Fonds de recherche du Québec-santé (FRQS) and the Canadian Institutes of Health Research (CIHR).

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and was approved by (1) McGill University Ethics Board (REB-II)—Ethics ID number 385-0117 and (2) Hôpital en santé mentale Rivière-des-Prairies Ethics Board—Ethics ID number 16-14P, 2017-1821. Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available on reasonable request and as per Ethics Boards regulations.

ORCID iD

Christopher Kalogeropoulos http://orcid.org/0000-0003-0369-4389

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