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Original Article

Original Article

Night-time smartphone use, sleep duration, sleep quality, and menstrual disturbances in young adult women: A population-based study with high-resolution tracking data

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Abstract

Study Objectives: To explore the relationship among night-time smartphone use, sleep duration, sleep quality, and menstrual disturbances in young adult women.

Methods: Women aged 18–40 years were included in the *SmartSleep Study* in which they objectively tracked their smartphone use via the *SmartSleep* app between self-reported sleep onset and offset times (n = 764) and responded to a survey (n = 1068), which included background characteristics, sleep duration, sleep quality (Karolinska Sleep Questionnaire), and menstrual characteristics (International Federation of Gynecology and Obstetrics' definitions).

Results: The median tracking time was four nights (interquartile range: 2–8). Higher frequency (p = .05) and longer duration (p = .02) of night-time smartphone use were associated with long sleep duration (≥9 h), but not with poor sleep quality or short sleep duration (<7 h). Short sleep duration was associated with menstrual disturbances (OR = 1.84, 95% confidence interval [CI] = 1.09 to 3.04) and irregular menstruation (OR = 2.17, 95% CI = 1.08 to 4.10), and poor sleep quality was associated with menstrual disturbances (OR = 1.43, 95% CI = 1.19 to 1.71), irregular menstruation (OR = 1.34, 95% CI = 1.04 to 1.72), prolonged bleedings (OR = 2.50, 95% CI = 1.44 to 4.43) and short-cycle duration (OR = 1.40, 95% CI = 1.06 to 1.84). Neither duration nor frequency of night-time smartphone use was associated with menstrual disturbances.

Conclusions: Night-time smartphone use was associated with longer sleep duration, but not with menstrual disturbances in adult women. Short sleep duration and sleep quality were associated with menstrual disturbances. Further investigation of the effects of night-time smartphone use on sleep and female reproductive function in large prospective studies is needed.

Key words: smartphone behavior; sleep; reproductive function; menstruation; adults

Statement of Significance

We report pioneering work on the relationship between night-time smartphone use and the female reproductive system, expressed by menstrual function, in a population-based study with objectively tracked smartphone use. Contrary to our hypothesis, night-time smartphone use was not associated with menstrual disturbances. Objectively measured smartphone use was associated with long sleep duration, but otherwise unrelated to sleep measures, which may explain the lack of association with menstrual disturbances. As expected, poor sleep quality and short sleep duration were associated with menstrual disturbances. We recommend prospective studies to further evaluate potential effects on the female reproductive system including the underlying mechanisms through sleep as night-time smartphone use is very prevalent and therefore potential effects are of clinical and societal importance.

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Introduction

Smartphones are ubiquitously and frequently used during the night, which may harm health by disturbing sleep [1–4]. Night-time smartphone use is most common among young adults [1], and a Danish study found that 41% of young adults occasionally used their smartphone during sleep hours [2]. Short sleep duration and decreased sleep quality are identified as negative consequences of night-time phone use [1, 5–10]. Furthermore, a recent intervention study suggests that avoiding smartphone use 30 min prior to bedtime could increase both sleep duration and sleep quality [11].

Reproduction is a key marker of health, essential to societal development and personal life paths, and it is well-established that sufficient and restful sleep is important for a normal menstrual function and reproduction [12–16]. A cross-sectional study found a correlation between night-time electronic media device use and decreased sperm quality in 116 male adults [3], and the authors suggest that night-time smartphone use may impair normal reproductive function. The relationship between night-time smartphone use and reproduction is an emerging field of research, but studies in women are currently lacking.

Three physiological mechanisms have been suggested for how night-time smartphone activity affects sleep: (1) direct displacement resulting in shorter sleep, (2) increases in mental, emotional, and/or physiological arousal, and (3) bright light exposure which can disrupt the circadian rhythm [17]. The displacement of sleep may result in hormonal dysregulation as observed with partial sleep deprivation [18]. Sleep deprivation and mental arousal cause activation of the hypothalamic–pituitary–adrenal hormonal axis. This activation suppresses the hypothalamic–pituitary–gonadal axis and affects the circadian hormones; prolactin, thyroid stimulating hormone, and melatonin, all of which play a crucial role in the female reproductive function [12, 19].

In addition, studies show that insomnia and short sleep duration are associated with an increased risk of developing menstrual irregularity [20–22]. The effect of poor sleep on the female reproductive system has been studied in a prospective study in which the shortest time to pregnancy was associated with 8 h of sleep and no trouble sleeping, indicating that duration and quality of sleep are important for optimal reproductive function [16].

Thus, we hypothesize that night-time smartphone use may lead to sleep and menstrual disturbances. Smartphone use during sleep hours is associated with poor sleep [10], and we speculate that such sleep impairments may cause hormonal dysregulations and thereby result in menstrual disturbances. This hypothesis will be tested using detailed information on menstrual cycles from survey data combined with high-resolution smartphone tracking data among young adult women aged 18–40 years.

Methods

Study population and design

We use data collected in the *SmartSleep Study,* which aims to provide insight into health consequences associated with smartphone use during sleep hours. The *SmartSleep Study* includes three independent subsamples; the *Population Sample*, the *Citizen Science Sample*, and the *Clinical Sample* in which survey data and smartphone tracking data were obtained using identical measurement methods. A total of 1068 women were included in this study derived from the three subsamples of the *SmartSleep Study.* (Figure 1) Participants were asked to download the *SmartSleep* app, which was specifically developed for the project (see GitHub repository for the development code: https://github.com/smartsleepku) on their smartphone (either iOS or Android), complete a comprehensive survey embedded in the app, and track their night-time smartphone use for up to 14 nights. When enabled, the *SmartSleep* app was designed to continuously record all screen activations based on data from the accelerometer and the light in the screen. Participants were asked to open the app and allow it to run in the background without turning it off during sleep hours. Furthermore, participants were asked to enter sleep onset and offset times, which could be specified for each night. Participants, in either sample, were enrolled in this study if they had responded to the survey and provided full data on sleep duration, sleep quality, and menstrual cycle characteristics and were presumed fertile with a natural cycle by reporting (1) being "women" or "other," (2) being 18–40 years of age, (3) not being pregnant or nursing, and (4) not using hormonal contraception. We expected approximately 40% of the invited women aged 18–40 years to be eligible based on publicly available statistics on hormonal contraception use (~50%), pregnancy (~5%),

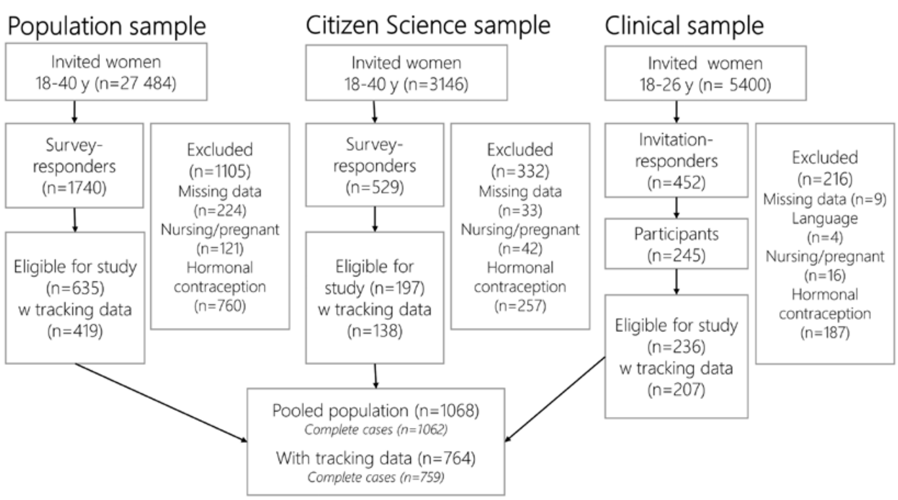

Figure 1. Flowchart of the study population sampled from the subsamples of the SmartSleep Study. Complete cases are with full data available on covariates.

and breastfeeding (~2%) [23–27]. A flow diagram of the sampling along with the subsequent selection is presented in Figure 1.

The *Population Sample* was randomly sampled from the Central Population Register where 27 484 women 18–40 years of age were invited to participate through a secure public digital post-box between July and October 2020. A total of 1740 women (6%) responded to the survey. Based on the inclusion criteria, 635 women were eligible for this study. Of the 635 participants, 419 women also provided tracking data.

The *Citizen Science Sample* was sampled among participants who previously participated in a citizen science project of the *SmartSleep Study* on smartphone use and sleep in 2018 [10, 28]. A total of 3146 women aged 18–40 years were invited and 529 women (17%) responded to the survey, of whom 197 women were eligible for this study, and of these women 138 participants provided tracking data. Invitations were sent to their personal email address between February and July 2020. The *Clinical Sample* was based on a random sample of 5400 women from the Central Population Register aged 18–25 years and living in postal codes in proximity to the examination site (Copenhagen city area). They were invited through a secure digital post-box between November 2019 and October 2020. The invitation targeted healthy individuals and clearly stated the exclusion criteria of the study; being pregnant, nursing, or using hormonal contraception. The estimated response rate was ~8% of whom 236 women were eligible for this study, and 207 women provided tracking data. (Figure 1) All participants gave written informed consent when entering the study as a clinical examination was performed and biological samples were collected from this subsample. Participants received DKK 500 (approx. € 67) and the possibility to receive personal test results as compensation for their participation in the study.

Data were sampled between November 2019 and December 2020 which were overlapping the COVID-19 pandemic, however, no invitations were distributed during the first month of nation-wide lock-down in Denmark. SARS-CoV-2 vaccination was not approved or used until the end of December 2020 in Denmark, and due to the national vaccination strategy, no participants were presumed vaccinated at the time of participation.

The *SmartSleep Study* was approved by the Danish Data Protection Agency through the notification of the Faculty of Health and Medical Sciences at the University of Copenhagen (approval nos. 514/0288/19-3000 and 514-0344/19-3000). The data collection for the *Clinical Sample* additionally required an ethical approval, which was obtained by the Regional Committee on Health Research Ethics (Approval number: 67074) as a clinical examination was performed and biological samples were collected.

Measures

Tracked night-time smartphone use

Night-time smartphone use was objectively tracked using the *SmartSleep* app. "Night-time smartphone use" was defined as smartphone use between self-reported sleep onset and offset times on a particular night. We derived variables on frequency and duration of night-time smartphone use from the raw tracking data and self-reported sleep times retrieved from the *SmartSleep* app.

"Frequency of night-time smartphone use" was calculated as the percentage of nights with screen activity in relation to the total number of tracked nights. To avoid overestimation, only nights with 5% or more smartphone activity were considered to have screen activity at all. This was to avoid the inclusion of nights with smartphone activity outside the actual sleep period but within the tracking period, for example, if a participant reported to fall asleep at 10 pm but uses their smartphone in bed before falling asleep for a few minutes. "Frequency of night-time smartphone use" was categorized into three groups based on the lower 25% (lower quartile [Q1]), the middle 50% (interquartile range [IQR]), and the upper 25% (upper quartile [Q4]). See Supplementary Figure S1 for further information.

"Duration of night-time smartphone use" was calculated based on the percentage duration of smartphone activity of the total sleep period for a tracked night. This was to account for differences in sleep duration. Duration of night-time smartphone activity below 5% of the self-reported sleep period was treated as an inactive night. We report "duration of night-time smartphone use" as the average percentage of duration of night-time smartphone activity based on all tracked nights adjusted with the inactive/active threshold of 5%. Duration of night-time smartphone use was categorized into three groups based on the lower 25% (Q1), the middle 50% (IQR), and the upper 25% (Q4). See Supplementary Figure S1 for further information.

Self-reported sleep duration and sleep quality

Sleep duration was measured and calculated by asking about average sleep onset and offset times on weekdays. Sleep duration was categorized as short (<7 h), recommended (7–9 h), and long (≥9 h) in accordance with recommendations set out in the literature [29]. Sleep quality was measured by the sleep quality dimension of the validated Karolinska Sleep questionnaire (KSQ) (Cronbach's α of 0.80 for women) [30]. The dimension is based on four items: difficulty falling asleep, awakenings with difficulty falling asleep, premature awakenings as well as disturbed and restless sleep. Each dimension is rated on a five-point Likert scale, ranging from 1 "never" to 5 "every night or almost every night" [30]. The score is an average of the items (score 1–5) where a higher score indicates worse sleep quality. For the specific analyses, we categorized into poor sleep and not poor sleep based on the upper quartile (score = 3) and for a visual presentation into one-point categories (1–<2, 2–<3, 3–<4, and 4–≤5).

Menstrual disturbances

Menstrual cycle characteristics included typical bleeding length, cycle length, and cycle variation. In the survey, an introductory text explained that the menstrual cycle is the period from the first day of bleeding in one menstruation and until the first day of bleeding in the consecutive menstruation. We asked (1) "Is your menstrual cycle irregular, so the length of the cycle varies from one cycle to the other?" with the response options: "No, my cycle is almost always the same length," "Yes, 1–7 days," "Yes, 8–9 days," "Yes, 10 days or above," (2) "How many days is your cycle normally?" with the response options: "23 days or less," "24–38 days," "39 days or more" and finally (3) "How many days do you bleed when you have menstruation?" with the response options: "Less than 3 days," "3–4 days," "5–6 days," "7–8 days," and "9 days or more".

We used the International Federation of Gynecology and Obstetrics' (FIGO) revision of the nomenclature of symptoms of normal and abnormal uterine bleeding in the reproductive years (*FIGO-AUB System 1*) [31] to categorize cycle frequency, cycle regularity, and bleeding duration. Cycle frequency was categorized as short-cycle duration (<24 days), normal-cycle duration (≥24 to ≤38 days), and long-cycle duration (>38 days). Cycle regularity was categorized as having a normal variation or having irregular menstruation (shortest cycle to longest cycle variation within a year of ≥8 days [26–41 years of age] or ≥10 days [18–25 years of age]). Bleeding duration was categorized as normal (≤8 days) and prolonged bleedings (>8 days). An individual was categorized as having *menstrual disturbances* if reporting short-/long-cycle duration, irregular menstruation, and/or prolonged bleedings.

Covariates

Covariates included age, educational level (students were categorized as students, otherwise categorized as; primary school or other, low education, short-/medium-cycle higher education, long-cycle higher education), shift work (any night work within the past month: yes/no), and body mass index (BMI), which was calculated from self-reported height and weight.

Statistical analyses

We present data with medians and IQR for asymmetrically distributed variables and for categorical variables counts and percentages. The association between sleep measures and night-time smartphone measures was analyzed using the chi-square test. The associations between menstrual disturbance, night-time smartphone measures, and sleep measures were presented as relative frequencies in percentages along with 95% confidence intervals (CI) for any menstrual disturbance and specific disturbances (irregular menstruation, prolonged bleedings, and abnormal cycle duration). chi-square tests were conducted to test for association. If an association for abnormal cycle duration was statistically significant, we performed pairwise chi-square tests of long versus normal and short versus normal cycle duration, respectively. Age, educational level, shift work, and BMI were considered confounders to the association investigated. We performed multivariate logistic regression analyses and estimated adjusted odds ratios (OR) for menstrual disturbances and specific menstrual disturbances according to night-time smartphone measures and sleep measures adjusting for potential confounders. For the analyses on long and short menstrual cycle duration, individuals with a short and long cycle were excluded, respectively.

We retrieved data from three independent subsamples, where identical exclusion criteria and measurement methods were used. The multivariate logistic regression analyses were therefore also performed for each subsample. For these analyses, we showed results for overall menstrual disturbances due to privacy considerations and lacking statistical power for addressing the specific menstrual disturbances in the individual subsamples. Regression analyses were complete case analyses and each table states the sample size. A supplementary mediation analysis [32] was performed to estimate direct and indirect effects under a natural effects model [33], where nigh-time smartphone use (frequency or duration) was considered the exposure, sleep characteristics (sleep quality or sleep duration) were considered the mediators, and the occurrence of any menstrual disturbance was considered the outcome. The model estimates an OR associated with the direct effect of the smartphone use on menstrual disturbance occurrence while controlling the sleep characteristics at levels naturally observed, for any given fixed level of the smartphone use. Also, the model estimates an OR associated with the indirect effect of the smartphone use on menstrual disturbance occurrence through sleep characteristics, which is to be understood as the effect of altering the levels of the sleep characteristics according to what would have been observed at different levels of smartphone use, while at the same time controlling the smartphone use at any given fixed level. In that way, the effect that is mediated by sleep characteristics is isolated by means of potential mediator values and is identifiable under the validity of the mediation analysis framework. All statistical analyses were conducted using the statistical software R 4.1.1.

Results

The study population (n = 1068) sampled from the *Population* (n = 635), the *Citizen Science* (n = 197), and the *Clinical* (n = 236) samples of the *SmartSleep Study* had a median age of 28 years (IQR 24–35), 21% had an educational level of a long-cycle higher education and one-third (35%) were currently students. (Table 1) The characteristics of the independent subsamples are shown in Supplementary Table S1. The study population included few individuals with short sleep duration (8%), but a considerable number of individuals with poor sleep quality (24%) and long sleep duration (17%). A total of 764 women contributed with tracking data, and the median tracking time was four nights (IQR 2–8). Women with tracking data used their smartphones 33% (median, IQR 0%–67%) of the tracked nights and the median duration was 4% (IQR 0%–11.1%) of the sleep period. (Supplementary Figure S1) We found that women with the highest frequency of night-time smartphone use (Q4) were slightly younger, had slightly more shift work, and were more likely to be students compared to the other groups (Table 1).

Figure 2 shows the distribution of poor sleep quality, short and long sleep duration according to the frequency and duration of night-time smartphone use respectively. We found that a greater frequency of night-time smartphone use was associated with long sleep duration (p = .05) but not short sleep duration. There was a tendency towards poorer sleep quality with more frequent night-time smartphone use (p = .06). Duration of night-time smartphone use was also associated with long sleep duration (p = .02), and there was a tendency that longer duration of night-time smartphone use was associated with short sleep duration, however, this finding was not statistically significant (p = .09).

Figure 3 presents the prevalence of menstrual disturbances according to night-time smartphone use measures and sleep measures, respectively, for any menstrual disturbance (n = 225), irregular menstruation (n = 110), prolonged bleedings (n = 18), and abnormal cycle duration (n = 180). We found no association between neither frequency nor duration of night-time smartphone use and any type of menstrual disturbance. However, sleep duration was associated with menstrual disturbance (p = .005). Short sleep duration was also associated with irregular menstruation (p = .02). Furthermore, worse sleep quality scores were associated with menstrual disturbance (p < .001) and prolonged bleedings (p < .001). There was a tendency towards an association between worse sleep quality scores and irregular menstruation (p = .06) and a cycle duration <24 days (p = .05).

Table 2 shows the association between menstrual disturbances and measures of night-time smartphone use when adjusting for potential confounders (n = 759). We found that neither frequency nor duration of night-time smartphone activity was associated with menstrual disturbance or any specific menstrual disturbances. The estimates did not change when we analyzed the three subsamples independently, except for the *Citizen Science Sample* where the association with menstrual disturbances became stronger (OR = 3.83 95% CI = 1.00 to 16.30). (Supplementary Table S2)

Table 1. Background characteristics by night-time smartphone use

		Frequency of night-time smartphone use			
Variable	**Level**	**Q1 (*n* = 232)**	**IQR (*n* = 344)**	**Q4 (*n* = 188)**	**Total (*n* = 1068)**
Age (years)	Median [IQR]	30 [25, 36]	27 [24, 35]	26 [23, 33]	28 [24, 35]
Education *N* (%)	Student	66 (28)	129 (38)	82 (44)	373 (35)
	Primary school or other	4 (2)	12 (4)	8 (4)	40 (4)
	Low education	31 (13)	43 (13)	37 (20)	172 (16)
	Short/Med.-cycle high. edu	62 (26)	81 (24)	35 (19)	255 (24)
	Long-cycle higher edu.	69 (30)	79 (23)	26 (14)	228 (21)
Shift work *N* (%)		17 (7)	20 (6)	19 (10)	86 (8)
BMI (kg/m^2)	Median [IQR]	23 [21, 26]	23 [21, 27]	23 [21, 27]	23 [21, 27]
	Missing*	<5	–	<5	6
Number of tracked nights	Median [IQR]	2 [1, 5]	6 [3, 10]	3 [1, 7]	4 [2, 8]
	Missing	–	–	–	304
Sample *N* (%)	Clinical	47 (20)	105 (31)	55 (29)	236 (22)
	Citizen-Science	44 (19)	61 (18)	33 (18)	197 (18)
	Population	141 (61)	178 (52)	100 (53)	635 (60)

Background characteristics of the study population by frequency of night-time smartphone use. A total of 764 participants contributed with tracking data while 304 did not. Q1: Lower 25% (0%), IQR: Middle 50% (0–66.7%), Q4: Upper 25% (>66.7%). Med.-cycle high. edu: medium-cycle higher education.
*Not exact numbers due to privacy considerations.

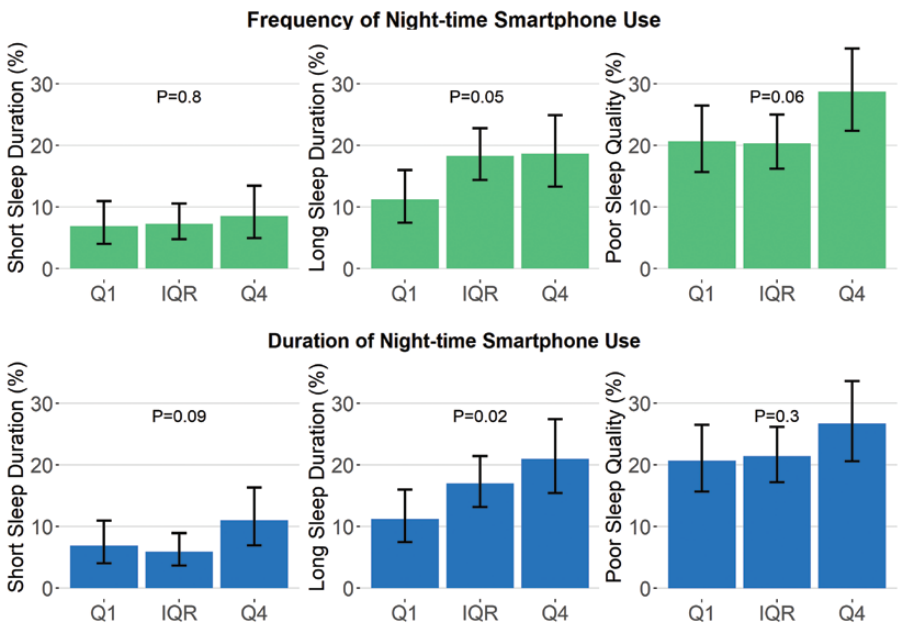

Figure 2. Short sleep duration, long sleep duration, and poor sleep according to frequency and duration of night-time smartphone use based on 764 participants with tracking data. p: *p*-values for the chi-square test., Q1: lower 25% (0%), IQR: middle 50% (0–67%), Q4: upper 25% (>67%).

Table 2 also shows the association between menstrual disturbance and sleep measures when adjusting for potential confounders (*n* = 1062). We found that short sleep duration was associated with any menstrual disturbances (OR = 1.84, 95% CI = 1.09 to 3.04) and irregular menstruation (OR = 2.17, 95% CI = 1.08 to 4.10). However, sleep duration was not significantly associated with short- or long-cycle duration when adjusting for the potential confounders. Poor sleep quality was associated with higher odds of having any menstrual disturbances (OR = 1.43, 95% CI = 1.19 to 1.71) when adjusting for potential confounders. In addition, poor sleep quality was associated with irregular menstruation (OR = 1.34, 95% CI = 1.04 to 1.72), prolonged bleedings (OR = 2.50, 95% CI = 1.44 to 4.43), and short cycle duration (OR = 1.40, 95% CI = 1.06 to 1.84). When analyzing the three *SmartSleep* subsamples separately, we found that sleep duration was only statistically significantly associated with menstrual disturbances in the *Clinical Sample*. Furthermore, sleep quality was only associated with menstrual disturbances in the *Clinical*

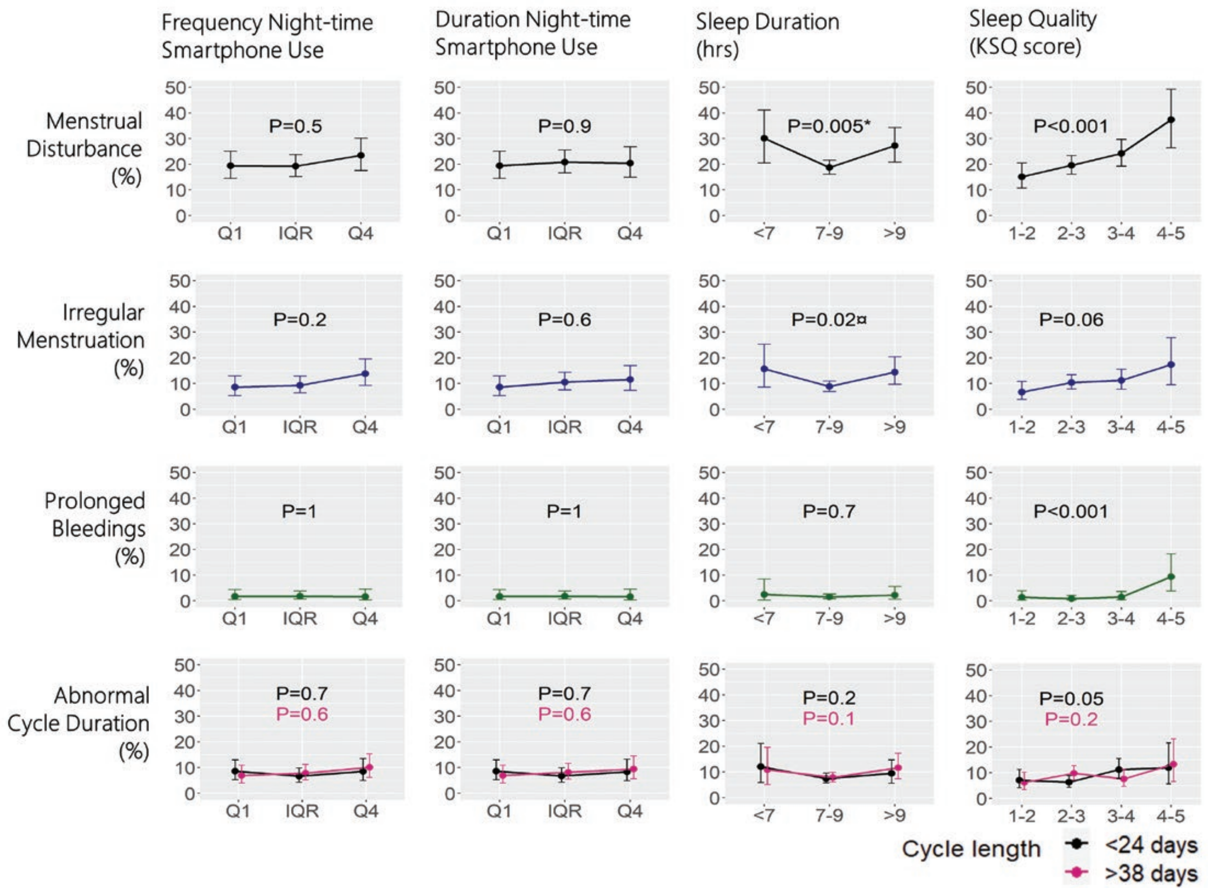

Figure 3. Prevalence of menstrual disturbances or specific menstrual disturbances according to frequency of night-time smartphone use, duration of night-time smartphone use, sleep duration, and sleep quality. p: *p*-values for chi-square tests. *Pairwise chi-square test statistically significant for <7 h versus 7–9 h and 7–9 h versus ≥9 h. ¤ Pairwise chi-square test statistically significant for 7–9 h versus ≥9 h.

Sample and the *Population Sample*. These differences may partly be explained by differences in sample sizes in the three samples (Supplementary Table S2). We evaluated the mediated effects by sleep duration and sleep quality of the association between night-time smartphone use and menstrual disturbances with a natural effects model. However, there was no indication of a mediated effect as no association was established in neither the direct nor the sleep mediator models (Supplementary Figure S2).

Discussion

We utilized a novel combination of high-resolution smartphone tracking data and comprehensive survey information to explore the relationship among night-time smartphone use, sleep duration, sleep quality, and menstrual disturbances among young adult women. We found that the participants on average used their smartphone every third night and that the median duration was 4% of the sleep period. We found that the participants with the highest frequency and longest duration of night-time smartphone use had longer sleep duration compared to the participants with less night-time smartphone use. However, they did not seem to have shorter sleep duration or poorer sleep quality. Nevertheless, previous studies have shown that night-time smartphone use was associated with shorter sleep duration [2, 10], longer sleep duration [10], and poor sleep quality [1, 4]. Further, we have previously shown in a larger sample of the *SmartSleep Study* that subjective measures of night-time smartphone use were related to poorer sleep quality [10]. Thus, this suggests a potential difference between subjective and objective smartphone measures, which has previously been suggested [34] and needs further exploration.

Contrary to our hypothesis, objectively measured night-time smartphone use was not associated with menstrual disturbances in this study. We had hypothesized that night-time smartphone use may affect the reproductive system resulting in menstrual disturbances through impaired sleep, however, since night-time smartphone use was not associated with any of the sleep measures, apart from long sleep duration, this may explain the lack of association with menstrual disturbances in this study. Given the relatively well-established association between subjective measures of smartphone use and impaired sleep [1, 9, 10], these findings should be replicated in larger prospective samples with both objective and subjective smartphone measures before drawing firm conclusions. This would allow evaluation of the effects of smartphone activity mediated by for example, short sleep duration or sleep disturbances. Smartphone use in bed prior to sleep should also be considered as decreased sleep quality and increased sleep latency, heart rate, and awakenings during sleep hours are observed effects of in-bed smartphone use prior to sleep [35].

The finding that night-time smartphone use was associated with long sleep may in part be explained by compensation for smartphone use by extending the sleep period to achieve

Table 2. Multivariate logistic regression analysis of night-time smartphone use, sleep and menstrual disturbances

	Frequency of night-time smartphone use (*n* = 759)			Duration of night-time smartphone use (*n* = 759)			Sleep duration (*n* = 1062)		Sleep quality (*n* = 1062)	
	n	**OR (95% CI)**		***n***	**OR (95% CI)**		***n***	**OR (95% CI)**	***n***	**OR (95% CI)**
		Any menstrual disturbance						**Any menstrual disturbance**		
Q1	44/231	Ref	Q1	44/231	Ref	<7 h	25/82	1.84 (1.09–3.04)	222	1.43 (1.19–1.71)
IQR	66/344	0.98 (0.63–1.51)	IQR	70/339	1.07 (0.70–1.66)	7–9 h	148/801	Ref		
Q4	43/184	1.22 (0.75–2.00)	Q4	39/189	1.02 (0.62–1.68)	≥9 h	49/179	1.47 (0.99–2.16)		
		Irregurlar menstruation						**Irregular menstruation**		
Q1	20/231	Ref	Q1	20/231	Ref	<7 h	13/82	2.17 (1.08–4.10)	109	1.34 (1.04–1.72)
IQR	32/344	1.04 (0.57–1.94)	IQR	36/339	1.21 (0.67–2.25)	7–9 h	70/801	Ref		
Q4	26/184	1.83 (0.95–3.56)	Q4	22/189	1.40 (0.71–2.77)	≥9 h	26/179	1.53 (0.90–2.55)		
		Prolonged bleedings						**Prolonged bleedings**		
Q1	4/231	Ref	Q1	4/231	Ref		N/A due to small data cells		18	2.50 (1.44–4.43)
IQR	6/344	0.89 (0.24–3.58)	IQR	6/339	0.92 (0.25–3.73)					
Q4	3/184	0.72 (0.13–3.43)	Q4	3/189	0.68 (0.13–3.23)					
		Long-cycle duration (*n* = 701)						**Long-cycle duration (*n* = 976)**		
Q1	15/211	Ref	Q1	15/211	Ref	<7 h	9/72	1.63 (0.71–3.37)	91	1.07 (0.81–1.40)
IQR	27/321	1.09 (0.56–2.19)	IQR	28/317	1.17 (0.60–2.34)	7–9 h	61/742	Ref		
Q4	19/169	1.48 (0.70–3.16)	Q4	18/173	1.30 (0.60–2.79)	≥9 h	21/162	1.37 (0.77–2.37)		
		Short cycle duration (*n* = 698)						**Short cycle duration (*n* = 971)**		
Q1	20/216	Ref	Q1	20/216	Ref	<7 h	10/73	1.62 (0.74–3.27)	86	1.40 (1.06–1.84)
IQR	23/317	0.76 (0.40–1.44)	IQR	22/311	0.75 (0.39–1.44)	7–9 h	59/740	Ref		
Q4	15/165	0.88 (0.42–1.82)	Q4	16/171	0.89 (0.43–1.81)	≥9 h	17/158	1.48 (0.80–2.62)		

Multivariate logistic regression analysis of menstrual disturbances in relation to night-time smartphone use and sleep measures. Participants were categorized according to frequency of night-time smartphone use into the lower quartile, the IQR and the upper quartile and similarly for duration of night-time smartphone use. Participants were categorized based on their self-reported sleep duration into categories; <7 h, 7–9 h and ≥9 h. For sleep quality we used the numeric KSQ score. The count for participants with any or specific menstrual disturbances are shown along with the count in the exposure groups (*n*/*n*). For analysis of long and short cycle duration, individuals with short and long-cycle duration respectively where excluded. Models are adjusted for age, education, shift work and BMI. OR: odds ratio, CI: confidence interval, Q1: lower quartile, IQR: interquartile range, Q4: upper quartile.

sufficient sleep. A third of the study population are students and a majority at college or university level, and hence may be more flexible in regards to sleep and rise times compared to individuals with fixed working/school hours. Additionally, data were in part collected in the months following the COVID-19 outbreak, where work from home was recommended and other daily activities advised against. Changes in sleep patterns during the COVID-19 pandemic have been observed, however, to a lesser extend in Danish populations [36, 37]. These conditions may have affected the results of this study as the population to a greater extend may have been able to compensate for disturbed sleep by extending or postponing their sleep period.

We found that short sleep duration was associated with menstrual disturbances and irregular menstruation. These findings are comparable to those of a previous study in which sleep of 6–7 h was associated with irregular menstruation [38]. Furthermore, another study suggests a relation between ≤7 h of sleep and sporadic anovulation and changes in hormonal fluctuations [39], though not statistically significant, and a recent study from 2019 found that short sleep duration was associated with decreased fecundability [16]. Yet other studies have not ratified an association between short sleep duration and menstrual disturbances [22, 39, 40].

We also found that poor sleep quality was associated with menstrual disturbances, irregular menstruation, prolonged bleedings, and short cycle duration. These findings add to previous research demonstrating that poor sleep quality and insomnia are associated with a higher prevalence of menstrual cycle irregularity [20, 40], and that trouble falling asleep and non-apnea sleeping disorders are associated with decreased fecundability [15, 16]. Despite the modest associations between short sleep duration, poor sleep quality, and menstrual disturbances, these findings may prove of clinical and societal importance as insufficient sleep and sleep problems are highly prevalent in the population [41–43]. Menstrual disturbances may cause absence from school and/or work, additional costs for the health care system, and psychological distress [44, 45]. In addition, menstrual disturbances often reflect a lack of ovulation and decreased reproductive function, thus, it may result in decreased fertility [19, 46, 47] as well as associated costs on a societal and personal level and finally, an increased long-term risk of diseases [48]. Moreover, sleep is not only important for reproductive function, but it is also associated with other major health consequences such as cardiovascular disease, type 2 diabetes, and all-cause mortality [49–52]. Consequently, due to our findings and the consistent associations between sleep impairment and reproductive health, a concern is still to be raised about the long-term consequences of night-time smartphone use, which may be an important target for public health interventions.

Limitations and strengths

This study is cross-sectional and thus limited to show associations between menstrual disturbances, night-time smartphone use, and sleep at a specific time. Few women in the study had specific menstrual disturbances, which may have limited our possibility to detect smaller increases in risks that are due to night-time smartphone behavior or sleep behaviors. Likewise, few women had short sleep duration, resulting in low statistical power to address associations with short sleep specifically. The high proportion of students and a timely overlap with the COVID-19 pandemic may have resulted in changes in sleep habits and fewer individuals with short sleep than expected [53].

Sleep duration was measured by self-reports on sleep onset and offset times on weekdays. As sleep duration may vary from night to night, these measures could potentially both underestimate and overestimate the actual sleep duration. Sleep quality is likewise based on self-reports, but the sleep quality dimension of the KSQ has shown a decent internal consistency for women [30]. Though self-reported sleep measures are only moderately or weakly associated with objective sleep measures [54–56], they are nonetheless associated with various health outcomes like mortality, cardiovascular disease, and fertility [16, 57, 58].

To avoid biases from self-reports on night-time smartphone use, we used objectively tracked information on smartphone activity. We did not distinguish between behavior on weekdays and weekends, which might be a limitation as night-time smartphone behavior may change during the week. In addition, the tracking data from the *SmartSleep* app may be misclassified to some degree as the app did not account for multiple device use and relied on self-reported sleep onset and offset times. Hence, if individuals were not sufficiently specific, or forgot to change sleep times from day-to-day, this may have introduced measurement errors to the tracking data. To circumvent overestimation from activity within the tracking time period, but outside the actual sleep period, we applied a 5% cutoff when estimating how many nights were considered active as smartphone use prior to sleep is very common [10], and the raw tracking data includes many data points in close proximity to the start or end of the tracking period. Night-time smartphone activity was a continuum from a high volume of activity to low, however, we decided to categorize the behavior into three categories to explore the extremes, which may also be most relevant from a clinical and preventive perspective. Also, we explored summary measures of frequency and duration, however, these measures may not have been able to capture time-varying behavior.

Reports on menstrual characteristics have a low accuracy when based on recall alone, for example, cycle variation and occurrence of cycles with extreme lengths are perceived as "unreliable" and "should be used and interpreted with caution" [59]. Therefore, there is a risk of both underestimation and overestimation of menstrual disturbances in our data, although most likely independent of objective smartphone behavior. Previous studies have especially examined irregular menstruation by asking participants about their personal experience of regularity [38, 46]. To improve comparison across studies, we followed the advised categorization by FIGO [31]. As these consensus recommendations are from 2018, and not yet widely implemented, few previous studies have applied and evaluated menstrual disturbance by the same categorizations as this study. We suggest that future studies endeavor to objectively measure cycle characteristics, for example, by using the personal records women may keep on their smartphones and to use expert-advised categorization to strengthen the ability to accumulate evidence.

We and others have shown that impaired sleep is a predictor for perceived stress and depressive symptoms [60] and that long bedtime phone use causes mental distress [61], hence mental health was not considered a confounder to the investigated associations and we advice diligence when investigating the complex interplay of smartphone use, sleep, and mental health.

The study population comprises a selected population of women. Two of the different sampling strategies relied on random samples from public registers, however, the response percentages were rather low. Meanwhile, we only selected women who were anticipated to have a natural menstrual cycle (no hormonal contraception use, no current pregnancy, or nursing), and hence, excluded an estimated 50% of the female population. Therefore, the presented results are not directly transferable to all adult women as women with a natural cycle may be different than women opting for hormonal contraception. Additionally, we did not require a waiting period before an individual could enter the study which could have introduced both overestimation and underestimation of regularity and duration of cycle and bleedings.

Conclusion

We found night-time smartphone use to be prevalent among young women and related to long sleep duration. While we found no direct association between night-time smartphone use and menstrual disturbance, our study demonstrates a higher risk of menstrual disturbances associated with short sleep duration as well as poor sleep quality. Previous studies have identified shorter sleep duration and poorer sleep quality as a consequence of night-time smartphone use, therefore, we propose a further investigation into the effects of night-time smartphone use on sleep and female reproductive function in large prospective studies. It is important to acquire further knowledge as night-time smartphone use is substantial and because any potential underlying hormonal dysregulations may potentially cause menstrual disturbances, which may have widespread implications by the associated decreased fertility and increased long-term risk of diseases.

Supplementary Material

Supplementary material is available at *SLEEP Advances* online.

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Data availability

The data set contains personally identifiable data, sensitive survey information and detailed tracking data. Hence, the original full data set cannot be made available according to the Act on Processing of Personal Data. The upon request interested researchers can be granted access to anonymous data without sensitive personal information according to the Danish Data Protection Act. Data inquiries should be addressed to the corresponding author.

References

1. Christensen MA, *et al*. Direct measurements of smartphone screen-time: relationships with demographics and sleep. *PLoS One*. 2016;**11**(11):e0165331. doi:10.1371/journal.pone.0165331
2. Rod NH, *et al*. Overnight smartphone use: a new public health challenge? A novel study design based on high-resolution smartphone data. *PLoS One*. 2018;**13**(10):e0204811. doi:10.1371/journal.pone.0204811
3. Green A, *et al*. Exposure by males to light emitted from media devices at night is linked with decline of sperm quality and correlated with sleep quality measures. *Chronobiol Int*. 2020;**37**(3):414–424. doi:10.1080/07420528.2020.1727918
4. Thomée S, *et al*. Mobile phone use and stress, sleep disturbances, and symptoms of depression among young adults—a prospective cohort study. *BMC Public Health*. 2011;**11**(1):66–77. doi:10.1186/1471-2458-11-66
5. Zarghami M, *et al*. The impact of using cell phones after light-out on sleep quality, headache, tiredness, and distractibility among students of a university in North of Iran. *Iran J Psychiatry Behav Sci*. 2015;**9**(4):e2010. doi:10.17795/ijpbs-2010
6. Gradisar M, *et al*. The sleep and technology use of Americans: findings from the National Sleep Foundation's 2011 sleep in America poll. *J Clin Sleep Med*. 2013;**9**(12):1291–1299. doi:10.5664/jcsm.3272
7. Exelmans L, *et al*. Bedtime mobile phone use and sleep in adults. *Soc Sci Med*. 2016;**148**(2016):93–101. doi:10.1016/j.socscimed.2015.11.037
8. Li J, *et al*. Locus of control and cell phone use: implications for sleep quality, academic performance, and subjective well-being. *Comput Human Behav*. 2015;**52**(2015):450–457. doi:10.1016/j.chb.2015.06.021
9. Bhat S, *et al*. "To sleep, perchance to tweet": in-bed electronic social media use and its associations with insomnia, daytime sleepiness, mood, and sleep duration in adults. *Sleep Heal*. 2018;**4**(2018):166–173. doi:10.1016/j.sleh.2017.12.004
10. Dissing AS, *et al*. Daytime and nighttime smartphone use: a study of associations between multidimensional smartphone behaviours and sleep among 24,856 Danish adults. *J Sleep Res*. 2021;**00**:e13356. doi:10.1111/jsr.13356
11. He JW, *et al*. Effect of restricting bedtime mobile phone use on sleep, arousal, mood, and working memory: a randomized pilot trial. *PLoS One*. 2020;**15**(2):e0228756. doi:10.1371/journal.pone.0228756
12. Kloss JD, *et al*. Sleep, sleep disturbance, and fertility in women. *Sleep Med Rev*. 2015;**22**(2015):78–87. doi:10.1016/j.smrv.2014.10.005
13. Willis SK, *et al*. Sleep and female reproduction. *Curr Opin Obstet Gynecol*. 2019;**31**(4):222–227. doi:10.1097/GCO.0000000000000554
14. Mills J, *et al*. Impact of circadian rhythms on female reproduction and infertility treatment success. *Curr Opin Endocrinol Diabetes Obes*. 2019;**26**(6):317–321. doi:10.1097/MED.0000000000000511
15. Wang ID, *et al*. Non-Apnea sleep disorder increases the risk of subsequent female infertility – a nationwide population-based cohort study. *Sleep*. 2018;**41**(1):zsx186. doi:10.1093/sleep/zsx186
16. Willis SK, *et al*. Female sleep patterns, shift work, and fecundability in a North American preconception cohort study. *Fertil Steril*. 2019;**111**(6):1201–1210.e1. doi:10.1016/j.fertnstert.2019.01.037
17. Cain N, *et al*. Electronic media use and sleep in school-aged children and adolescents: a review. *Sleep Med*. 2010;**11**(8):735–742. doi:10.1016/j.sleep.2010.02.006
18. Baumgartner A, *et al*. Influence of partial sleep deprivation on the secretion of thyrotropin, thyroid hormones, growth hormone, prolactin, luteinizing hormone, follicle stimulating hormone, and estradiol in healthy young women. *Psychiatry Res*. 1993;**48**(2):153–178. doi:10.1016/0165-1781(93)90039-j
19. Lateef OM, *et al*. Sleep and reproductive health. *J Circadian Rhythms*. 2020;**18**(1):1–11. doi:10.5334/jcr.190
20. Kang WY, *et al*. The menstrual cycle associated with insomnia in newly employed nurses performing shift work: a 12-month follow-up study. *Int Arch Occup Environ Health*. 2019;**92**(2):227–235. doi:10.1007/s00420-018-1371-y
21. Zeru AB, *et al*. Magnitude and associated factors of menstrual irregularity among undergraduate students of Debre Berhan University, Ethiopia. *Reprod Health*. 2021;**18**(1):101. doi:10.1186/s12978-021-01156-1
22. Kim T, *et al*. Associations of mental health and sleep duration with menstrual cycle irregularity: a population-based study. *Arch Womens Ment Health*. 2018;**21**(6):619–626. doi:10.1007/s00737-018-0872-8
23. Danmarks Statistik. FOLK1A: Folketal den 1. i kvartalet efter område, køn, alder og civilstand. www.statistikbanken.dk/FOLK1A. 2020. Accessed May 10, 2020.
24. Danmarks Statistik. FOD8: Enkelt- og flerfødsler efter fødselstype. www.statistikbanken.dk/FOD8. 2020. Accessed May 10, 2020.
25. Danmarks Statistik. FODIE: Levendefødte efter kommune, moders herkomst, moders oprindelsesland, moders statsborgerskab, moders alder og barnets køn. https://www.statistikbanken.dk/FODIE. 2020. Accessed May 10, 2020.
26. Sundhedsdatastyrelsen. Medstat. https://medstat.dk/. 2020. Accessed March 13, 2020.
27. Sundhedsdatastyrelsen. Den Nationale Børnedatabase. https://www.esundhed.dk/Registre/Den-nationale-boernedatabase. 2019. Accessed May 10, 2020.
28. Andersen TO, *et al*. The SmartSleep experiment: evaluation of changes in night-time smartphone behavior following a mass media citizen science campaign. *PLoS One*. 2021;**16**(7):e0253783. doi:10.1371/journal.pone.0253783
29. Watson NF, *et al*.; Consensus Conference PanelConsensus Conference Panel. Joint consensus statement of the American

Academy of Sleep Medicine and Sleep Research Society on the recommended amount of sleep for a healthy adult: methodology and discussion. *Sleep.* 2015;**38**(8):1161–1183. doi:10.5665/sleep.4886

30. Nordin M, *et al*. Psychometric evaluation and normative data for the karolinska sleep questionnaire. *Sleep Biol Rhythms.* 2013;**11**(4):216–226. doi:10.1111/sbr.12024
31. Munro MG, *et al*. The two FIGO systems for normal and abnormal uterine bleeding symptoms and classification of causes of abnormal uterine bleeding in the reproductive years: 2018 revisions. *Int J Gynecol Obstet.* 2018;**143**(3):393–408. doi:10.1002/ijgo.12666
32. Steen J, *et al*. Medflex: an R package for flexible mediation analysis using natural effect models. *J Stat Softw.* 2017;**76**(1):1–46. doi:10.18637/jss.v076.i11
33. Lange T, *et al*. A simple unified approach for estimating natural direct and indirect effects. *Am J Epidemiol.* 2012;**176**(3):190–195. doi:10.1093/aje/kwr525
34. Shoval D, *et al*. Relationship of smartphone use at night with sleep quality and psychological well-being among healthy students: a pilot study. *Sleep Health.* 2020;**6**(4):495–497. doi:10.1016/j.sleh.2020.01.011
35. Kheirinejad S, *et al*. "Leave your smartphone out of bed": quantitative analysis of smartphone use effect on sleep quality. *Pers Ubiquitous Comput.* 2022 **Nov 9**:1–20. doi:10.1007/s00779-022-01694-w
36. Sun S, *et al*. Using smartphones and wearable devices to monitor behavioral changes during COVID-19. *J Med Internet Res.* 2020;**22**(9):e199921–e199919. doi:10.2196/19992
37. Lee PH, *et al*. Sleep pattern in the US and 16 European countries during the COVID-19 outbreak using crowdsourced smartphone data. *Eur J Public Health.* 2021;**31**(1):23–30. doi:10.1093/eurpub/ckaa208
38. Nam GE, *et al*. Association between sleep duration and menstrual cycle irregularity in Korean female adolescents. *Sleep Med.* 2017;**35**:62–66. doi:10.1016/j.sleep.2017.04.009
39. Michels KA, *et al*. The influences of sleep duration, chronotype, and nightwork on the ovarian cycle. *Chronobiol Int.* 2020;**37**(2):260–271. doi:10.1080/07420528.2019.1694938
40. Xing X, *et al*. Sleep disturbance is associated with an increased risk of menstrual problems in female Chinese university students. *Sleep Breath.* 2020;**24**(4):1719–1727. doi:10.1007/s11325-020-02105-1
41. Statens Institut for Folkesundhed. *Danskernes Sundhed: Den Nationale Sundhedsprofil 2021.* Copenhagen, Denmark: Sundhedsstyrelsen; 2022. https://www.sst.dk/-/media/Udgivelser/2022/Sundhedsprofil/Sundhedsprofilen.ashx. Accessed March10, 2022.
42. Bin YS, *et al*. Sleeping at the limits: the changing prevalence of short and long sleep durations in 10 countries. *Am J Epidemiol.* 2013;**177**(8):826–833. doi:10.1093/aje/kws308
43. Basner M, *et al*. Sleep duration in the United States 2003-2016: first signs of success in the fight against sleep deficiency? *Sleep.* 2018;**41**(4). doi:10.1093/sleep/zsy012
44. Critchley HOD, *et al*. Menstruation: science and society. *Am J Obstet Gynecol.* 2020;**223**(5):624–664. doi:10.1016/j.ajog.2020.06.004
45. Tanaka E, *et al*. Burden of menstrual symptoms in Japanese women: results from a survey-based study. *J Med Econ.* 2013;**16**(11):1255–1266. doi:10.3111/13696998.2013.830974
46. Wesselink AK, *et al*. Menstrual cycle characteristics and fecundability in a North American preconception cohort. *Ann Epidemiol.* 2016;**26**(7):482–487.e1. doi:10.1016/j.annepidem.2016.05.006
47. Bradley D, *et al*. Time to conception and the menstrual cycle: an observational study of fertility app users who conceived. *Hum Fertil.* 2021;**24**(4):267–275. doi:10.1080/14647273.2019.1613680
48. Solomon CG, *et al*. Menstrual cycle irregularity and risk for future cardiovascular disease. *J Clin Endocrinol Metab.* 2002;**87**(5):2013–2017. doi:10.1210/jcem.87.5.8471
49. Itani O, *et al*. Short sleep duration and health outcomes: a systematic review, meta-analysis, and meta-regression. *Sleep Med.* 2017;**32**:246–256. doi:10.1016/j.sleep.2016.08.006
50. Yeo Y, *et al*. A prospective cohort study on the relationship of sleep duration with all-cause and disease-specific mortality in the Korean Multi-Center Cancer Cohort Study. *J Prev Med Public Heal.* 2013;**46**(5):271–281. doi:10.3961/jpmph.2013.46.5.271
51. Li J, *et al*. Sleep duration and health outcomes: an umbrella review. *Sleep Breath.* 2022;**26**(3):1479–1501. doi:10.1007/s11325-021-02458-1
52. Seow LSE, *et al*. Independent and combined associations of sleep duration and sleep quality with common physical and mental disorders: results from a multi-ethnic population-based study. *PLoS One.* 2020;**15**(7):e0235816. doi:10.1371/journal.pone.0235816
53. Jennum P, *et al*. Søvn Og Sundhed. Copenhagen, Denmark: Vidensråd for Forebyggelse; 2015. http://www.vidensraad.dk/sites/default/files/vidensraad_soevn-og-sundhed_digital.pdf. Accessed November 18, 2019.
54. Lehrer HM, *et al*. Comparing polysomnography, actigraphy, and sleep diary in the home environment: The Study of Women's Health Across the Nation (SWAN) Sleep Study. *Sleep Adv.* 2022;**3**(1):1–12. doi:10.1093/sleepadvances/zpac001
55. Girschik J, *et al*. Validation of self-reported sleep against actigraphy. *J Epidemiol.* 2012;**22**(5):462–468. doi:10.2188/jea.je20120012
56. Westerlund A, *et al*. Relationships between questionnaire ratings of sleep quality and polysomnography in healthy adults. *Behav Sleep Med.* 2016;**14**(2):185–199. doi:10.1080/15402002.2014.974181
57. Hublin C, *et al*. Sleep and mortality: a population-based 22-year follow-up study. *Sleep.* 2007;**30**(10):1245–1253. doi:10.1093/sleep/30.10.1245
58. Fan M, *et al*. Sleep patterns, genetic susceptibility, and incident cardiovascular disease: a prospective study of 385 292 UK biobank participants. *Eur Heart J.* 2020;**41**:1182–1189. doi:10.1093/eurheartj/ehz849
59. Bean JA, *et al*. Variations in the reporting of menstrual histories. *Am J Epidemiol.* 1979;**109**(2):181–185. doi:10.1093/oxfordjournals.aje.a112673
60. Andersen TO, *et al*. Predicting stress and depressive symptoms using high-resolution smartphone data and sleep behavior in Danish adults. *Sleep.* 2022;**45**(6). doi:10.1093/sleep/zsac067
61. Liu S, *et al*. The associations of long-time mobile phone use with sleep disturbances and mental distress in technical college students: a prospective cohort study. *Sleep.* 2019;**42**(2). doi:10.1093/sleep/zsy213