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Original Article

Sleep quality and the menstrual cycle

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ABSTRACT

Objective: This study aimed to assess the temporal relationship of subjective sleep quality to menstrual cycle phase in a community (non help-seeking) sample of adult women over six months. Previous work has produced contradictory results and often used student samples.
Participants/Methods: Patients/Methods: This was a cohort study, using daily electronic data collection in the Greater Toronto Area, Ontario, Canada; 76 women aged 18–42 years recruited by random digit telephone dialing, recorded mood, sleep quality, and other health variables on a daily basis for 24 weeks.
Results: Using linear mixed models, we assessed the relationship between subjective sleep quality and three menstrual cycle phases (menses, premenstrual and midcycle) over 395 cycles. Premenstrual sleep quality was poorer than during the rest of the cycle, with a mean difference of 1.32 between premenstrual and midcycle reference phase, on a 1–100 quality scale (higher score denotes poorer quality). This difference held when the independent variables of daily exercise and physical health were added to the model; it became non-significant when perceived stress and later, social support were also added to the model.
Conclusions: Sleep quality in adult non-help seeking women is statistically poorer in the premenstruum but the size of the difference is of little clinical significance and was no longer statistically significant with inclusion of the potentially confounding variables, perceived stress and social support.

1. Introduction

Women report more sleep disturbance than men [1,2]; the consensus on this finding was summarized in a meta-analysis, in which a female to male risk ratio for insomnia of 1.41 [95% confidence interval: 1.28–1.55] was reported [3]. This is curious, given that there are a number of studies reporting that women have either better objective sleep parameters [4,5] or no clear-cut differences from men in sleep architecture when assessed with objective methods such as polysomnography [6,7]. The discrepancy between subjective and objective sleep information has long been reported and reasons for it considered [8–11]. The higher prevalence of depression and anxiety is relevant to experiences of poor sleep [1,8,12,13]. Whenever a gendered medical phenomenon is discovered, a search is made to link the finding to female reproductive hormones; so it is with sleep. Driver, Baker and colleagues have been working on the links between women's objective and subjective sleep and the menstrual cycle for some years. In a 2008 review, they reported small changes in objective sleep measures during the menstrual cycle and examined a handful of papers showing poorer subjective sleep premenstrually and during menstruation [14]. Table 1 documents the studies we identified which address subjective sleep quality and a menstrual cycle phase variable; we have indexed the study characteristics. Of thirteen studies reviewed, nine showed some association with a menstrual cycle phase, although which phase was not consistent. In two studies, the phase was combined perimenstrual (premenstrual plus menses days); in two, women slept both worse and better premenstrually and in one, sleep was poorer in the follicular (non premenstrual) part of the cycle.

Several sociodemographic variables have also been associated with poor sleep and many of these afflict women more than men. In the three UK National Psychiatric Morbidity Surveys, in addition to female gender, factors such as increased age, lower educational attainment, depression, unemployment, economic

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Table 1
Published studies of subjective sleep quality and menstrual cycle (MC) phase in normal [a] adult women, listed chronologically.

	Reference location	Sample & Method, number of MCs & MC phases studied	Findings on sleep quality	Conclusion: Pos or Neg
1	Patkai et al. 1974 [15] Stockholm Sweden	N = 6, convenience sample, aged 22–35. Daily records on work days only. 2 MCs, 4 MC phases	Sleep quality was poorest & sleep duration longest in premenstrual phase ($p < 0.01$) Old, small study.	Pos. Sleep worse premenst.
2	Halbreich et al. 1982 [16] New York USA	N = 154, 2 convenience samples, aged 20–53. Retrospective summary 1 MC phase (premenst)	'Bipolar' sleep item, sleep both increased & decreased premenst (in 25% of women l)	Pos. Both directions premenst.
3	Stewart 1989 [17] Toronto Canada	N = 100, well women clinic patients, aged 29.6 ± 7.1 yrs, 34% OC users Retrospective summary, 1 MC phase (premenst)	25% recalled sleeping more & 10% sleeping less premenst.	Pos. Both directions premenst.
4	Laessle et al. 1990 [18] Munich Germany	N = 30, 24.4 ± 2.5 yrs healthy students, no OC users. Daily diary for sleep quality & stress, hormonal assays. 1 MC, 5 MC phases	No MC effect for sleep duration or quality. Sleep quality worse if ↑interpersonal stress (in premenstrual phase only)	Neg. Sleep worse with stress
5	Chaturvedi et al. 1993 [19] Bangalore India	n = 112 Indian college students aged 17–22. Retrospective summary 1 MC phase (premenst)	50% recalled negative sleep change premenst. (mean 2.6 ± 3.5 out of 10).	Pos. Sleep worse premenst.
6	Driver et al. 1996 [20] Zurich Switzerland	N = 9 healthy students aged 20–30, regular menstrual cycles, daily sleep log, PSG alternate nights for one month 1MC, ?2 MC phases	No MC phase diffs in sleep quality, or objective sleep measures (total sleep time, sleep & REM latencies, or slow wave sleep	Neg. No sleep-MC phase association
7	Manber & Bootzin 1997 [21] Arizona USA	N = 32 univ. admin staff, aged 38.7 ± 5.3, 3[b] had PMS. Sleep diaries 2x daily Mid follicular vs late luteal means compared. 2 MCs, 2 MC phases	↓sleep efficiency & quality, & ↑ sleep onset latency in the luteal phase. No diffs in sleep duration	Pos. Sleep worse premenst
8	Cited in Driver et al. 2008 [14] National Survey USA	National Sleep Foundation telephone survey 1998 n = 514 (Not able to be checked)	70% retrospectively stated their sleep was disturbed by premenst & menstrual physical symptoms	Pos. Sleep worse premenst AND during menses
9	Baker & Driver 2004 [22] Witwater-srand, South Africa	N = 26, mean age 21, (18-31yrs) healthy university students, no medication, no OCs. Daily sleep diaries, Ovulation date assessed by urinary hormones 1 MC, 5 MC phases	Subjective sleep quality↓ premenst & during menses cf midfollicular & early luteal phases. No diffs in sleep continuity. Premens and menses not separated	Pos: ↓sleep quality premenst AND during menses
10	Brown et al. 2008 [23] Hawaii USA	N = 89 healthy students, non OC users daily diaries. Salivary hormone assay. 1-3MCs, 5 MC phases	Sleep quality poorer premenst but no sleep duration x MC phase diffs. No diffs in sleep quality by sexual activity.	Pos. ↓sleep quality premenst.
11	Guillermo et al. 2010 [24] Las Vegas USA	N = 40 healthy students, 20 OC users, salivary hormone assay, questionnaires 1MC, 3 MC phases	Sleep disturbances↑follicular. No midcycle-luteal diffs. No diffs between OC vs non-OC users	Pos: sleep worse in early follicular phase
12	Stanicic & Jokic-Begic 2010 [25] Zagreb Croatia	N = 51 convenience healthy sample 26.7 ± 7yrs, diaries 3xdaily for 4 premenst days & 4 follicular days (8–11). 2MC, 2 MC phases	'Sleep deprivation' not diff between two phases	Neg.
13	Hachul et al. 2013 [26] San Paulo Brazil	N = 126, gen pop sample, each studied on one day (126 follicular, 69 luteal phase and 102 OC users) MC coding: NA	No difference ins sleep quality between 3 groups (nb: different women in each group)	Neg.

[a] i.e. not perimenopausal, elderly or with premenstrual tension/syndrome/dysphoric disorder.
[b] PMS using Rubinow and Roy-Byrne 1984 criteria.
LEGEND: DNA = does not apply, MC = menstrual cycle, neg = no menstrual cycle phase association with sleep quality, OC = oral contraceptives, premenstr = premenstrual(ly), PSG = polysomnography, pos = reports a menstrual cycle phase association with sleep quality.

inactivity, and widowed, divorced, or separated status were all linked to poor sleep [2]. Similarly, in Hong Kong, female gender, psychiatric disturbance, older age, unemployment-low socioeconomic status, alcohol, medication, and for women only, marital status and a noisy sleep environment predicted insomnia [27].

Several researchers have implicated the complexity of women's social and paid work lives [5,28–32]. Walseben has suggested that the different context of women's lives compared to men (eg, sleep being disrupted by children's needs or caregiver responsibilities to the wider family) may need to be implicated when analyzing women's sleep quality data. The type of paid employment women undertake is part of the social context; there are a small number of studies, mostly from Scandinavia, linking sleep quality directly to job characteristics [29,33–36]. Social support has also been implicated in sleep quality [29,37].

Several reviews of gender and sleep or women and sleep have been published in recent years; these have tended to focus on objective sleep studies, polysomnography or actigraphy, as these are where the greater amount of data can be found [4,38–44]. These reviews agree that there are frequent methodological problems with the published sleep studies (small number of projects, small sample sizes, inconsistent ways of subdividing the menstrual cycle into its component phases and using only one or two cycles, which does not deal with the well-recognized intercycle variability). These are common problems also found in menstrual cycle research methodology in general [45,46].

Exercise has been thought to be helpful in promoting good quality sleep since biblical times [47] cited by Youngstedt and colleagues [48]. A recent mini-review outlined likely physiological links between exercise, both acute and 'chronic', and sleep [49]. The current evidence on associations between sleep quality and exercise/physical activity is contradictory, with some studies reporting a positive link [31,50,51] and others not [48]. The 2013 annual poll by the National Sleep Foundation, the independent, non-profit, sleep education, research and advocacy US organization, examined the sleep-exercise association; this found a dose relationship between sleep quality (four levels) and exercise (also four levels) [52]. Youngstedt and colleagues have suggested that epidemiological studies are more

likely to report a link than are experimental designs [48]. This complex literature has studied perimenopausal and older women more often than reproductive aged women, the target age group of the Mood in Daily Life (MiDL) study, being reported here. The MiDL study addressed a range of mood and health variables throughout several menstrual cycles, in a random sample of Canadian women aged 18–40 years. We have previously reported that daily mood is less determined by menstrual cycle phase than by physical health, perceived stress and social support [46].

The study hypothesis was that the mean self-reported sleep quality does not vary by menstrual cycle phase. The study design allowed quantification of any differences in sleep quality as well as their statistical significance.

2. Method

The participants enrolled in the MiDL study were a community sample of women aged 18–40 years living in the Greater Toronto Area, assembled in 2005 using random digital dialing. Ethical permission for the MiDL study was obtained from the Sunnybrook and Women's College Research Ethical Board, Toronto. As previously described [46], participants were issued a Palm™ Treo 650 Smart Phone, a cell phone with a touch screen and stylus user interface with which to record daily moods, physical health status, menstrual cycle phase and physical activity, at their chosen time each day over twenty-four weeks. Social support was assessed weekly in the same way. Sociodemographic information was gathered at an initial interview when the participants received their phone and were shown how to use it; there was also a study exit interview when participants returned their phone and were asked about their understanding of the study goals.

2.1. Repeated variables

Sleep quality: each day, a visual analogue scale (VAS) sleep item probed "*Last night, how well did you sleep?*", with anchor points "worst ever" (scored as 100) and "best ever" (scored as 0), so that each participant was using her own previous sleep experience as a comparator. A higher score indicated poorer sleep quality. VAS probes have good psychometric properties [53].

Physical activity: we assessed physical activity using the short form International Physical Activity Questionnaire, IPAQ [54]; this instrument, designed for population surveys, has robust psychometric reliability and validity properties assessed in twelve countries. It asks about the time (in minutes) each day spent on each of these three types of activity: walking, moderate physical activities like light lifting or bicycling, and vigorous physical activities like heavy lifting or aerobics. Participants' responses for each day were categorized into low, medium, and high exercisers, according to criteria recommended by the IPAQ tool authors.

Menstrual cycle phase: each cycle was divided into three phases: menses, mid-cycle, and premenstrual. One daily item asked, "*Did you have your menstrual period today*? The change from "no" to "yes" designated day 1 of each menstrual cycle, with 'Yes' responses indicating days of menses. A premenstrual phase of five days was constructed by counting back from Day 1. The remaining days (neither menses nor premenstrual) were designated as the mid-cycle phase (Society for Menstrual Cycle Research 1986).

Daily physical health: this VAS item read "*In the last day, how was your overall physical health"* with anchors of 'worst ever' (score of 100) and 'best ever' (score of 0).

Perceived stress: this VAS item read, *"In the past day, how much have you felt under stress?"* anchors "not at all" (score of 100), "very much" (score of 0).

Social support: this item was assessed weekly, and had three VAS parts, one each for support received at work, at home, and from female friends. These data were aggregated into a single variable by averaging the score from each domain for the previous week.

2.2. Basic descriptive demographic information

At the initial assessment interview, data were collected on a range of demographic and baseline health variables. Other variables displayed here because of their relevance from the subjective sleep literature were demographic (age, employment status, oral contraceptive use = yes or no).

2.3. Statistical analysis

Missing data for menstrual cycle phase were interpolated from completed records for preceding and succeeding days, using the participant's usual cycle length, where possible. If not possible due to missing data, the entire record for that woman was dropped; we did this when there was less than a 70% completion rate of menstrual cycle phase data over the 24 weeks.

The average sleep quality (means and SDs) were calculated using linear mixed models (LMM) which deal with the serially correlated nature of the data and allows for women having missing data for independent and/or dependent variables on some days. Several linear mixed models were created with sleep quality as the dependent variable. To examine potential sources of confounding, sequential models were created, adding independent variables (also measured over time) to menstrual cycle phase in the following order: daily measures of exercise, physical health, perceived stress, and the weekly measure of social support.

The covariance structure for the repeated measures aspect (day of observation) was examined for two competing potential covariance structures suitable for longitudinal data: autoregressive moving average (ARMA; 1, 1) and autoregressive (AR; 1). Akaike's information criterion (AIC) was used to choose the best covariance structure across the models [55]. In all instances, the ARMA (1, 1) covariance structure provided the better fit (ie, smallest AIC value) and so was used in all analyses. Data analysis was conducted in SAS 9.1 (SAS Institute, Cary, NC).

3. Results

3.1. The sample

Of the 107 participants initially enrolled who received a phone, 29 failed to complete data for 70% of their eligible days over the ensuing six months, and were dropped from analyses. Two other participants produced data with no menses recorded and were also omitted. This gave a sample of 76 women, with 395 complete menstrual cycles available for analysis. The sociodemographic and health characteristics of this final sample are shown in Table 2. The mean length of study participation was 182 ± 18 days, with participants providing data for 84% ± 11% of days). Sleep problems noted at intake included insomnia (n = 8), narcolepsy (n = 1), and restless legs (n = 5). Fifteen women were using oral contraceptives at the start of the study; their mean sleep quality did not differ from those not using oral contraceptives. This variable was therefore not included in the statistical analysis.

3.2. Relationship of menstrual cycle phase to sleep quality

The sample's sleep quality: The mean sleep quality value (based on the VAS scale, with 0 as best and 100 as poorest) for the mid cycle phase was 43.19 (standard deviation (sd) 10.1); for the menses phase the mean was 43.62 (sd 10.60); and for the premenstrual phase the mean was 44.73 (sd 11.00).

Table 2
Sociodemographic and health characteristics of the MiDL sample (n = 76).

Variable			
Age	18–24	20	26.3
	25–29	13	17.1
	30–34	12	15.8
	35–39	24	31.6
	40 plus	7	9.2
Marital	Single	38	50.0
	Married / common law	34	44.7
	Separated	2	2.6
	Divorced	2	2.6
Education	Secondary school only	5	4.3
	Community college	29	25.0
	University some/full	25	21.6
	University degree	12	10.3
	Postgrad study	5	4.3
Employment	Fulltime	21	27.6
	Part-Time	35	46.1
	None	20	26.3
Physical Health	Excellent	22	27.8
	Very Good	27	35.5
	Good	20	26.3
	Fair-poor	7	9.2
Income household	< $30k	9	12.0
	$30k-$60k	23	30.7
	$60k plus	44	57.3

The LMM explaining the simple relationship between menstrual cycle phase and the outcome of subjective sleep quality is summarised in the first column of Table 3. This table shows differences in the mean sleep quality for each menstrual cycle phase, relative to the mid cycle phase (set at zero as reference). A positive difference relative to midcycle sleep quality indicates poorer sleep quality for that menstrual cycle phase. Premenstrual sleep quality was significantly poorer than midcycle sleep quality (mean difference = 1.32, 95% CI 0.33, 2.31). Although statistically significant, this difference is small, 1.32 out of a 0–100 scale. Sleep quality during the menses days did not significantly differ from the midcycle phase.

3.3. *Relationship of menstrual cycle phase to sleep quality, with daily physical exercise, subjective physical health, perceived daily stress and weekly social support sequentially added (as potential confounders). See Table 3*

Menstrual cycle phase and daily exercise. The addition of daily physical exercise to the model did not change the relationship between MC phases and sleep quality. Premenstrual sleep quality was poorer than during the midcycle phase, and there was no significant difference between sleep quality during menses and the mid cycle.

Menstrual cycle phase, daily exercise and physical health. The next model also included daily physical health, measured on the day following the (previous) night's sleep record. Again, sleep quality during the premenstrual phase was poorer than that during the midcycle phase. Although the absolute figure for menstrual phase sleep quality was lower than that for midcycle, this was not statistically significant (mean difference -0.33; 95% CI -1.26, 0.6).

Menstrual cycle phase, daily exercise, physical health and daily perceived stress. With the addition of stress into the next LM model, menstrual cycle phase differences in sleep quality were no longer statistically significant, with the premenstrual versus mid cycle difference attenuated (mean difference = 0.83; 95% CI -0.12, 1.78) compared to previous models.

When social support (measured weekly) was added to the model, there were again no significant differences in sleep quality by menstrual cycle phase.

4. Discussion

The MiDL study results show a consistent set of relationships between menstrual cycle phase and subjective sleep quality. The main finding is that there is a statistically significant, small difference in sleep quality between the menstrual cycle phases, with poorer subjective sleep reported by women in their premenstrual phase than either during the days of menses or the midcycle phase. Analytic models sequentially added exercise, physical health, perceived stress (all measured on a daily basis), and then a weekly measure of social support as independent predictors. The finding of poorer premenstrual phase sleep quality persisted through the addition of exercise and physical health; it was only when perceived stress and then social support were added that menstrual cycle phase was no longer significantly related to sleep quality. This finding echoes an earlier conclusion from the MiDL study in which daily physical health status, perceived stress, and social support were much more important determinants of daily mood than menstrual cycle phase [46].

This study used a community sample of reproductive aged urban women, an age group whose sleep has been much less studied than that of either perimenopausal or older age (postmenopausal) women. The MiDL participants, blind to the menstrual cycle focus of the enquiry, prospectively collected daily data electronically over the six months study duration. This study gathered information each day about the previous night's sleep, without the participant being prompted about their previous day's record, thus minimizing social expectations and 'halo' effects. Paper and pencil health diaries have often been previously used to assemble daily prospective data, but there is concern that some information gathered in this way may be actually retrospective, when participants fill in missing days just prior to meeting with the research team [56]. We were able to ensure which hour of which day each participant recorded each of her entries. This type of methodology, known as Ecological Momentary Assessment, has many advantages [57] and is being used increasingly in different demographic and clinical groups to study recurrent experiences in real time in the participant's natural environment.

The longitudinal nature of the data is another major strength of the study, both in terms of the absolute number of women participating, but also in the number of repeated observations of

Table 3
Mean difference (95% CI) in sleep quality during menses and premenstrual phase compared to mid-cycle phase: all five models listed*.

MC phase	Model covariates				
	MC Phase only	+ Exercise	+ Physical health	+ Stress	+ Social support
Menses	0.19 (–0.76, 1.14)	0.17 (–0.78, 1.13)	–0.33 (–1.26, 0.6)	–0.49 (–1.41,0.42)	–0.47 (–1.47,0.54)
Pre-menstrual	1.32 (0.33, 2.31)	1.32 (0.34, 2.31)	1.08 (0.11, 2.05)	0.83 (–0.12,1.78)	0.73 (–0.3, 1.76)
Mid-cycle: Reference phase	0	0	0	0	0

* Higher numbers indicate poorer sleep quality (0–100 scale).
Exercise categorized into three groups (low, medium, high).
Physical health and stress measured on 0–100 scales, measured daily.
Social support is a weekly measure, 0–100 scale. Value refer to entire week.

menstrual cycles observed (76 women collecting information over six months). While this requires complex statistical analysis methods [58], the application of linear mixed models allows for both proper consideration of the serial correlation between observations from the same woman across adjacent days, and also allows for data to be included in analysis when women have missing data for some days.

There are some limitations to the design of the MiDL sleep study. Firstly, the study design precluded the regular collection of information on some variables which have been reported as important in sleep quality determination in this age group of women. Menstrual dysfunctions such as dysmenorrhea or menorrhagia (which has been associated with poor sleep) were not specifically studied, although they may have been subsumed in the daily physical health variable. Oral contraceptive use was studied only at the beginning and end of the study. Secondly, we had no verification whether menstrual cycles were ovulatory; we can assume that given the age of the women, most cycles were ovulatory but in the absence of hormone or ultrasound data, we cannot be sure. We took the approach outlined by Society for Menstrual Cycle Research, determining the premenstrual phase by counting back from the first day of menses. There is no agreed way to determine phases of the menstrual cycle (see Table 1); we had a simple, three-phase menstrual cycle division, days of menses, five premenstrual days, and the rest of each cycle which we labelled 'midcycle'; this approach obscures any late follicular (preovulation) versus early luteal (postovulation) phase differences. We selected this categorization as we were most interested in the premenstrual phase effect on sleep quality. In the absence of polysomnographic or actigraphic data, we could not add to the interesting, and complex debate about how subjective and objective sleep quality differs [20] [8,21] [10,11,22,28,59]. Finally, with respect to sample selection, there was attrition during various recruitment phases, as is usual with random digit dialing recruitment [46]. Despite this attrition, there are likely to be fewer biases than when participant samples are assembled through advertising (see Table 1). The MiDL dataset is the most rigorous to be developed to date, given its reasonable size sample, randomly selected from the community with each record being truly prospective, over several menstrual cycles.

When comparing the MiDL results with previous work, as shown in Table 1, seven studies examined menstrual cycle phase and sleep quality using prospective data gathered from health diaries [18] [20–25]. Five of the previous studies used student samples which because of their younger age and higher education may be atypical of women of reproductive age [18,20,22–24]. These student sample studies gave inconsistent results: two found no connection between sleep and menstrual cycle phase [18,20], one found a link but with the early follicular (it was not clear if this included days of menses or not) and not the late luteal phase [24], one reported poorer subjective sleep during both the premenstruum and menses [22], leaving only one in the five with a clear premenstrual phase only association with decreased sleep quality [23].

Focusing on the two studies with non-student samples and prospectively gathered information, we see that one reported poorer sleep quality (but not sleep duration) premenstrually [21] and one failed to find an association between menstrual cycle phase and sleep quality [25]. These studies had sample sizes of 32 and 51 respectively, and studied two menstrual cycles. The MiDL sample size, n = 76, is larger and has the one major strength of at least five menstrual cycles per woman studied across the six months; we had 395 complete menstrual cycles for analysis so intercycle variability was captured. Stanicic and Jokic-Begic (2010) [25], reporting no association between menstrual cycle phase and sleep deprivation ('lack of sleep'), collected health diary information, three times a day, for eight days each in two cycles, the four days immediately before menses and days 8–11. As the main focus of their research was change in self-image during the menstrual cycle, sleep deprivation was a small aspect of their project; the exact wording and quantitative data are not reported [25]. Manber and Bootzin [21], using a prospective design across two menstrual cycles with sleep diaries, recruited female administrative university staff at one university, not a community sample. They expected a sampling bias from preferential participation from women with pre-existing premenstrual problems or sleep problems. They tried to deal with this by vigorous follow-up of non-responders but ended with a very low response rate (32/363, 8.8%, of the total sample, or 32 out of the 134 women, 24%, who replied with normal menstrual cycles). Detailed sleep information (five sleep variables and three daytime sleepiness variables) were collapsed into two factors 'sleep disturbance' and 'daytime'. The luteal phase showed longer sleep onset, lower sleep efficiency and quality compared with the follicular phase.

The MiDL finding is of a small premenstrual worsening of sleep quality compared to the midcycle baseline; there was also a numerically poorer quality of sleep during menses which was not statistically significant. The quantitative difference, although statistically significant is small (1.32/100) and is likely to be of limited clinical significance. Manber and Bootzin [21] depicted their premenstrual-menses worsening of sleep as clinically significant, using an arbitrary yardstick of 5% of the sleep efficiency score. One third of their sample met this criterion, although they noted that another 11% experienced a 5% improvement of sleep efficiency premenstrually instead.

We included exercise in the model because of the published research, inconsistent as it is [48,60] linking sleep quality and physical exercise [31,50–52,61]. Several plausible physiological mechanisms linking both acute and chronic exercise to sleep quality have been proposed to explain such a link [49]. However, the MiDL results show that exercise did not confound the relationship between sleep and menstrual cycle phase, which is a different question to whether exercise improves sleep quality directly. Similarly, daily physical health did not alter the relationship between sleep quality and menstrual cycle phase when added to the model. A direct relationship between overall physical health and sleep quality has been found for those over 65 year olds [62]; it has been less studied in adults [63–66].

However, when perceived stress and social support were also added, the association between sleep quality and menstrual cycle phase was attenuated, suggesting that these two variables do confound the previous association. Stress, particularly when chronic, and poor sleep have been discussed as part of the allostatic load theory, which analyses the ways in which the human organism adapts to chronic stress from the social and physical environment [67,68]. Social support reduces the impact of stress, so these are linked concepts. As noted, work stress has been linked to sleep quality in a number of studies. It may not be the work stress per se but its combination with other responsible roles that women carry (mothering, caring for elderly) which causes stress, as noted by some reviews [5,41,42,69,70]. Walsleben highlighted the discrepancy between women's good objective sleep parameters and the frequency with which women complain of poor sleep quality [5]. She suggested two possible explanations: either the objective sleep measures are not sensitive enough to relevant sleep characteristics and miss subtle sleep disruptions; or alternatively, women may be describing something other than their own sleep patterns when asked about sleep quality (eg, partner's disturbed sleep as an example). Psychiatric problems have also been implicated [11,13,71]. Poor subjective sleep quality matters to people and often presents clinically as a problem needing active management. It may signal poor physical or mental health, difficult life circumstances or a primary sleep disorder. Our data suggest poor sleep should not be attributed to menstrual cycle phase among the general population (ie, in the absence of premenstrual dysphoric disorders).

Future research can benefit from EMA data collection methods such as MiDL used successfully.

In conclusion, the MiDL study was designed to examine critically a number of the accepted ideas about the effect of menstrual cycle phase on daily physical and mental health. Previously we reported that daily measures of physical health, perceived stress, and social support were much more important determinants of mood than menstrual cycle phase [46]. Here too, it seems that the role of menstrual cycle phase in determining self-reported sleep quality is of minimal clinical significance. Good clinical practice should assess physical and mental health and life circumstances when evaluating an adult woman's complaint of poor sleep.

Conflicts of interest

None of the authors have any conflict of interest to declare.

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: http://dx.doi.org/10.1016/j.sleep.2014.12.001.

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