Sleep Medicine 16 (2015) 1217–1224

Contents lists available at ScienceDirect

Sleep Medicine

journal homepage: www.elsevier.com/locate/sleep

Original Article

Actigraphic and self-reported sleep quality in women: associations with ovarian hormones and mood

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ARTICLE INFO

Article history:
Received 12 March 2015
Accepted 23 June 2015
Available online 26 June 2015

Keywords:
Women's health
Progesterone
Estrogen
Sleep
Actigraphy
Mood

ABSTRACT

Background: Sleep and mood disturbances in women have often been linked to the menstrual cycle, implying an ovarian hormonal causation. However, most studies in this area have used self-reported menstrual cycle phase rather than direct measurement of ovarian hormone concentrations. Further, many studies have focused primarily on peri- and postmenopausal populations reporting clinical sleep difficulty. In this study, we examined the associations among sleep quality, mood, and ovarian hormone concentration in a random sample of community-dwelling, nonclinical women of reproductive age.
Methods: Our sample consisted of 19 non-help-seeking women aged 18–43 years, each contributing an average of 39.5 nights of data. Over the 42 days of the study, we collected self-reported and actigraphic sleep-quality data, concentrations of urinary estrogen and progesterone metabolites (estrone-3-glucuronide (E1G) and pregnanediol-3-glucuronide [PdG], respectively), and daily mood ratings. Linear-mixed models were used to estimate associations, clustering longitudinal observations by the participant.
Results: We found a significant positive association between Sleep Efficiency and E1G, and a significant negative association between Sleep Efficiency and PdG. Otherwise, the self-reported and actigraphic sleep measures were not associated with ovarian hormone concentrations. Self-reported sleep was strongly associated with mood, whereas actigraphic sleep was associated with only two of the 11 individual mood items, "Feeling on Top of Things" and "Difficulty Coping."
Conclusions: In this community sample of women of reproductive age, ovarian hormones play little, if any, role in day-to-day sleep quality. Our findings additionally highlight the different associations that self-reported and actigraphic sleep show with hormones and mood.

1. Introduction

Women report poorer sleep quality, and they have a 41% increased risk of insomnia compared with men [1–3]. Self-reported sleep disturbance in women of reproductive age has been traditionally linked with menstrual cycle phase, and sleep disturbance remains a core symptom of premenstrual syndrome (PMS) and premenstrual dysphoric disorder (PMDD) [4–6]. A physiologic link between ovarian hormones and sleep quality is plausible; however, evidence supporting a direct causal relationship remains sparse. For instance, although one ovarian hormone study has shown that estradiol (E2) is negatively associated with self-reported quality of the previous night's sleep in women of reproductive age [7], other studies have failed to identify any significant associations between directly measured ovarian hormones and either self-reported or actigraphic sleep quality [8,9].

The lack of consensus across these studies may arise from three factors: first, some sleep studies have used ovarian hormones to determine menstrual phase [5,10], whereas others have used the more subjective measure of self-reported menstrual phase [11]. Second, some sleep studies have used objective measures of sleep, such as actigraphy and polysomnography, whereas others have used self-report [5,10]. Third, some sleep studies have examined the effects of exogenous hormone administration in perimenopausal women on sleep quality, making it difficult to compare them to studies assessing endogenous hormones in younger women of reproductive age [12–14]. One study in premenopausal women showed that women taking oral contraceptives exhibited higher levels of

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http://dx.doi.org/10.1016/j.sleep.2015.06.009
1389-9457/

stage-two non-rapid eye movement sleep, with no significant differences in self-reported sleep quality [11]. Thus, the administration of synthetic steroid hormones may be associated with different sleep patterns compared with those seen with "endogenous, naturally occurring cyclical alterations in hormone concentrations."

Sleep quality has long been linked to mood state; disturbed sleep is a key criterion in the definition of major depression [15]. Self-reported sleep disturbance has been associated with reduced positive and increased negative affect [16–19]. There are also apparent linkages between mood and menstrual phase: in some studies, women of reproductive age report an increased negative mood and a reduced positive mood during the luteal phase [20,21]. Although these psychological factors may confound the sleep–ovarian hormone relationship, in past studies they have not been routinely assessed [22].

In order to address these current gaps in the literature and to determine the relationship, if any, between ovarian hormones, sleep, and mood, we undertook a study to obtain daily recordings in four domains – self-reported sleep, actigraphic sleep, urinary ovarian hormone concentrations, and mood – in a community sample of women. This paper adds to a previous report published in this journal on sleep quality and menstrual cycle phase by including daily gonadal hormonal measures taken in a subsample [23].

2. Methods

2.1. Participants

A community sample of women of reproductive age (18–43) was recruited by a random-digit dialing from the Greater Toronto Area, ON, Canada. Participants were recruited into the Mood in Daily Life (MiDL) study, a larger study to examine self-reported mood changes across the menstrual cycle [24]. Potential participants were contacted via telephone by a professional random-digit dialing service, and they were completely informed about the study protocol and objectives; the focus of the study on the menstrual cycle was obscured to avoid potential priming effects [25]. At the initial interview, demographic and health-related data were collected. The full study extended over 24 weeks, during which time self-reported mood ratings and menstrual cycle data were collected daily via a smartphone. A total of 78 women completed the full study.

A subset of participants from the parent MiDL study agreed to participate in a 6-week-long intensive sub-study adding actigraphy and urine. Twenty-two MiDL participants were recruited. In addition to completing the MiDL daily mood questionnaire, these sub-study participants also collected urine samples (first morning void) daily, and they wore an Actiwatch for 42 consecutive days. An Actiwatch is a movement-monitoring wrist device that provides reliable data about sleep patterns [26,27].

The study protocol was approved by the Sunnybrook and Women's College Hospital Research Ethics Boards. All participants provided informed consent, and they were compensated monetarily for their participation.

2.2. Mood data collection

Daily mood was assessed using the Daily Life Questionnaire (DLQ) [19]. The DLQ is a 42-item questionnaire developed specifically for the MiDL study with questions taken from other mood questionnaires [28–32]. It assesses positive and negative mood as well as self-reported sleep, Perceived Stress, and Physical Health. DLQ items used in this study are presented in Table 1. Participants were provided with a smartphone programmed with the DLQ; each day, at the participant's preferred time, the smartphone prompted the participant to complete the DLQ. A 1-h window was allotted for the completion of the DLQ, which took 2–3 min. The order of the questions was varied daily to ensure attention to the items. We also alternated the anchor points at the ends of the visual analog scale (VAS) randomly to prevent a mind-set developing. In the study debrief, no participants mentioned study fatigue as an issue.

Table 1
Daily Life Questionnaire (DLQ) prompts and associated anchor points.

DLQ item	Anchor points	
	0	100
Subjective sleep items		
Last night, how well did you sleep? (Previous Night's Sleep)	Worst ever	Best ever
In the past day, how sleepy have you felt? (Daytime Sleepiness)	Not at all	Very much
Positive mood items		
In the past day, how happy have you felt? (Happiness)	Not at all	Very much
In the past day, how confident have you felt? (Confidence)	Not at all	Very much
In the past day, how much have you enjoyed things? (Enjoyment)	Not at all	Very much
In the past day, how energetic have you felt? (Energy)	Not at all	Very much
In the past day, how much have you felt on top of things? (Feeling on Top of Things)	Not at all	Very much
In the past day, how motivated have you felt? (Motivation)	Not at all	Very much
Negative mood items		
In the past day, how irritable have you felt? (Irritability)	Not at all	Very much
In the past day, how sad or blue have you felt? (Sadness)	Not at all	Very much
In the past day, how anxious and worried have you felt? (Anxiety)	Not at all	Very much
In the past day, how much have you felt that you just "couldn't cope" or were overwhelmed by ordinary demands? (Difficulty Coping)	Not at all	Very much
Psychosocial items		
In the past day, how much have you felt under stress? (Perceived Stress)	Not at all	Very much
In the past day, how was your (overall) physical health? (Physical Health)	Worst ever	Best ever

Data were automatically sent via an encrypted e-mail to the research computer. Each item was scored between 0 and 100, with the magnitude of the score corresponding to the relative position of the mark on the VAS. Smartphone data collection has shown adequate validity and reliability when compared with traditional paper-based mood assessment questionnaires [33,34], and it has been utilized successfully in other longitudinal studies [35].

2.3. Sleep data collection

2.3.1. Self-reported sleep

Two self-reported sleep measures, Previous Night's Sleep and Daytime Sleepiness, were assessed using the DLQ items "Last night, how well did you sleep?" and "In the past day, how sleepy have you felt?", respectively (Table 1).

2.3.2. Actigraphic sleep

Actigraphic sleep quality was assessed using an Actiwatch 64 device (Philips Respironics, Andover, MA, USA) worn on the nondominant wrist. By comparing periods of relative wrist activity and inactivity, sleep and wake patterns were calculated. Although actigraphy measures movement rather than brain activity, it is widely accepted as a functional assessment of sleep in the participant's home environment [26,27,36]. The evaluation of the actigraph score suggests that the interunit reliability for actigraphy is "excellent." [36] As actigraphy is both portable and relatively inexpensive, it has been used in non-laboratory sleep studies [35]. In this study,