Sleep Measurements in Women

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KEYWORDS

• Objective sleep • Subjective sleep • Gender • Review • Sex differences

KEY POINTS

- Both objective and subjective measures of sleep and sleep-related variables seem to show differences between women and men.
- Most methods and instruments assessing sleep have not been substantially tested for sex or gender differences, and only few studies had the primary aim to investigate sex or gender differences.
- There are to date no guidelines as to whether or not the set up or scoring of sleep studies should be performed differently in women and men.
- Future studies need to be specifically designed to study sex or gender differences of sleep variables and focus on sex and gender differences and the interaction with age, along with possible effects of sex hormones across the life-span.

INTRODUCTION

Sleep in women and men has been investigated in several studies, showing higher prevalence of sleep complaints in women compared with men and with an increasing difference with increasing age.¹ However, polysomnography (PSG) has not clearly shown this, and some studies have also shown better objectively measured sleep in women compared with men.^{2–4} In addition, chronotype has been compared between gender, showing women to be less evening type than men. However, there seems to be attenuation of this relationship with increasing age.⁵

Several factors can affect sleep, including psychological factors such as anxiety and depression. In addition, anxiety and depression have an impact on sleep and are more common in women^{6,7}; this could be argued to contribute to sex differences in general sleep. Women have nonetheless been shown to be less affected by external stressors,² thereby arguably being less prone to stress-related sleep issues. Hormonal changes after

puberty have also been suggested as a factor contributing to sex differences in sleep seen in the adult population.^{7,8} Yet another factor is age, with increasing sleep disturbances with increasing age. Nonetheless, there are some evidence that subjective sleep quality increase with increasing age in women regardless of objective measures.⁹

Because there is still a lack of knowledge on sleep measurements in women, the present review aims to produce an overview of the current knowledge of objective and subjective sleep measurements in women.

APPROACH

For this review, “sleep measurement” was defined as both objective and subjective sleep-related measurements, and we wanted to include a wide variety of measurements that are validated and used internationally. Sex and gender are terms that are often used interchangeably and have also been used interchangeably in research over the years. The term “sex” however usually

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describes characteristics that are biologically defined, whereas gender is based on socially constructed features. Nonetheless, it is recognized that there are variations in how people experience gender based on self-perception and expression and how they behave. For this review, we have chosen to use both terms within the text, as different studies included in the review have used both of the terms.

We performed structured searches in the databases PubMed and Google Scholar using the following search terms: Polysomnography, Polygraphy, Actigraphy, Psychomotor Vigilance Test, Multiple Sleep Latency Test, Maintenance of Wakefulness Test, Sleep Apnea Syndromes, Sleep Wake Disorders, Sex, Gender, Women, Sleep Diary, STOP-BANG, Epworth Sleepiness Scale, Consensus Sleep Diary, Pittsburgh Sleep Diary, Pittsburgh Sleep Quality Index, Munich Chronotype Questionnaire, and Horne-Östberg Diurnal Type Scale. We also identified further studies through reference lists in already identified studies.

CURRENT EVIDENCE

Objective Measurements of Sleep and Sleep Apnea

Polysomnography, polygraphy, and actigraphy Objective measurements of sleep include PSG, polygraphy (PG), and actigraphy. PSG is considered gold standard when assessing sleep and common sleep disorders as well as sleep-related movement disorders such as restless legs syndrome/periodic limb movement disorder, and rare sleep disorders such as narcolepsy.^{10,11} PG is used for assessing sleep-related breathing disorders such as obstructive sleep apnea (OSA),¹¹ and actigraphy is used to record movement,^{12–14} which can be further analyzed to estimate wake/sleep patterns.¹²

Several PSG studies have shown differences in objective sleep variables in women compared with men. These studies have shown longer sleep latency,¹⁵ shorter total sleep time,¹⁵ more slow wave sleep (SWS), and less nonrapid eye movement (NREM) sleep stage 1 and 2 in women compared with men.¹⁶ In older adults, less delta activity (indicates so-called deep sleep) have been shown in women compared with men.¹⁷ Also, actigraphy data have shown differences in sleep variables between women and men. However, in older adults, results have shown somewhat conflicting evidence.^{18–20} In a large population-based Japanese study, Li and colleagues showed shorter testosterone (TST) in women and later bedtimes.¹⁸ In addition, women older than 50

years had a larger reduction in sleep efficiency with aging, due mainly to increasing durations of nighttime awakening.¹⁸ In contrast, actigraphy data in an elderly population from the Rotterdam study showed women to have longer and less-fragmented sleep than men,¹⁹ which was also supported in a large meta-analysis of data from the Netherlands, United States, and United Kingdom, showing women (>41 years) sleep longer and somewhat more efficiently than men of similar age.²⁰

From PG data, several studies have shown lower apnea-hypopnea index (AHI), more partial obstruction, and shorter events in women compared with men.^{21–23} In one of the largest studies of polysomnographic features of OSA, O'Connor and colleagues showed²⁴ that despite similar overall severity of OSA in women and men during rapid eye movement (REM) sleep, women had less severe OSA during NREM sleep.²⁴ In effect, women therefore seemed to have a higher prevalence of REM-related OSA events.²⁴ Also, Basoglu and colleagues showed higher REM-AHI in female patients compared with male patients and in addition, lower overall AHI and oxygen desaturation index (ODI), less events in supine position, and at the same time lower mean and lowest oxygen saturation (SaO₂).²³ Furthermore, women have shown more respiratory effort-related arousal events and upper airway resistance syndrome.^{21,22,24–26} The clinical relevance of these results are still unclear, but it may indicate that women in effect do not have less severe OSA (especially as women seem to have more REM-OSA and hence deeper desaturations) but rather do not in fact fit well with current scoring criteria and hence could be undertreated.

In an attempt to produce normative values for PSG also adjusted for sex and age, Boulos and colleagues compiled data from 169 research studies, comprising 5273 healthy participants and showed female sex was associated with higher REM latency and mean SaO₂.²⁷ Female sex was also associated with lower mean arousal index and lower AHI.²⁷ In a big data analysis of the dynamics of sleep architecture and effects of individual differences, Yetton and colleagues showed that in addition to sleep architecture being dependent on time of day, total sleep time, and age, sleep architecture also depends on sex.²⁸ Sex primarily influenced the transition between sleep stages rather than durations of sleep stages, and the investigators state that sex differences in sleep architecture are not due to a reduced tendency to stay in various stages such as SWS but a difficulty in transitioning to them (so-called transition difficulty; ie, going in to for instance SWS).²⁸

In addition, interactions between sex and age were apparent, particularly in measure of SWS where women had less deficit in SWS with increasing age. Men on the other hand had less total minutes in SWS as well as reduced proportions of SWS, less probability to transition to SWS, and shorter durations in each SWS epoch.²⁸ The effect of sex and age on SWS has also been assessed in a data-driven approach by Rosinvil and colleagues aiming to adapt SWS criteria to sex and age. In this data-driven approach, they defined age- and sex-adapted SWS criteria in a cohort of young and older individuals (the so-called learning cohort) based on previous SWS criteria that were adapted to age and sex differences defined in the data-driven process, and then validated the criteria in an independent second cohort (so called testing cohort). In contrast to previous studies showing sex differences, Rosinvil and colleagues showed that when applying the sex- and age-adapted SWS criteria, sex differences vanished, whereas age differences maintained.²⁹

The set up for PSG, PG, and actigraphy, respectively, does not specify any differences for women as opposed to men, and scoring criteria are not different between sexes.^{11,30} To our knowledge, no studies have assessed whether setup should be different for men and women. However, it has been discussed whether or not signals of PSG are different in men compared with women due to differences in skull characteristics.³¹

Objective Measures of Alertness and Sleepiness

Objective measures of alertness and sleepiness are key tools for diagnosis of excessive somnolence and commonly used in research studies to assess sleepiness. These include the Multiple Sleep Latency Test (MSLT), which measures daytime sleepiness by the propensity to fall asleep during repeated nap opportunities^{32,33}; the Maintenance of Wakefulness Test (MWT), which measures ability to stay awake under soporific circumstances, rather than propensity to fall asleep³⁴; and the Psychomotor Vigilance task (PVT), which is a reaction-time task testing vigilance³⁵ and sensitive to sleep deprivation.³⁶

Multiple sleep latency test

Studies that include analyses of potential sex differences on the MSLT range from cohorts drawn from in the general population, to various clinical groups. In general, men exhibit shorter sleep latencies,^{37–41} and higher prevalence of sleep-onset REM,^{41–44} whereas Won and colleagues found shorter sleep onset latency (SOL) in

narcoleptic women.⁴⁵ However, several studies find no sex differences in MSLT.^{3,46,47}

Maintenance of wakefulness test

As outlined for MSLT, there are reports indicating that men and women might differ in ability to stay awake. Although that is a valid reason to explore potential sex differences also for the MWT, such studies are to a large extent lacking. Sprecher and colleagues⁴⁸ investigated sleep restriction and circadian misalignment in 8 women and 12 men, thus not sufficiently powered for analyses of sex differences. However, exploratory analyses did not find differences by sex on MWT.⁴⁸ This is in line with Mitler and colleagues who reported no sex differences on MWT in patients with narcolepsy.⁴⁹

Psychomotor vigilance task

Even though PVT is a common tool in research, there are few studies assessing possible differences between women and men in PVT performance.^{48,50–53} Blatter and colleagues investigated PVT performance during sleep deprivation and a protocol with multiple naps (lower sleep pressure), showing women in general having slower reaction times compared with men.⁵¹ The investigators speculate that women and men might use different strategies when performing the PVT, because women tended to have fewer instances of premature key presses. This is in line with Batool-Anwar and colleagues in which 61 patients under investigation for OSA performed the PVT.⁵² Women tended to have worse performance on the PVT compared with men; however, this result was derived from a subgroup analysis, and the data were not shown in the paper. Sprecher and colleagues⁴⁸ also performed exploratory analyses with respect to potential sex differences and found that women performed worse on the PVT; however, only 8 women and 12 men were included in the study. In contrast, Thomann and colleagues did not notice any sex differences on PVT performance in patients with sleep-wake disorders and healthy controls.⁵³

Subjective and Semiobjective Sleep-Related Measurements

Sleep diaries

Sleep diaries ask respondents to assess their sleep patterns, (eg, bedtimes, rise times, sleep onset, wake up time) and various other subjective experiences related to sleep quality and/or daytime functioning. Examples of validated sleep diaries include the Pittsburgh Sleep Diary and the Consensus Sleep Diary.^{54,55}

Sleep diaries are typically validated against sleep questionnaires, actigraphy, or PSG.^{55–57}

Although there are validation studies for some sleep diaries in both nonclinical^{57–63} and various clinical samples (eg, insomnia,⁶⁴ comorbid insomnia and depression,¹⁴ chronic pain,⁶⁵ breast cancer⁶⁶), and most validation studies have included both men and women, gender differences in the measurement properties of sleep diaries are typically not reported. There are some indications, however, that gender might affect the correlation between sleep diary data and other sleep measurements. In a study in community-dwelling elderly comparing sleep diary data, van der Berg and colleagues⁶² found that the agreement between total sleep time as assessed by a sleep diary and actigraphy was greater in women than in men and that, in comparison to men, women tended to underestimate their total sleep time in their diaries, whereas men tended to overestimate theirs. However, in another study in older adults, Landry and colleagues⁶⁷ reported that gender did not have any marked effect on the association between Consensus Sleep Diary data, Pittsburgh Sleep Quality Index (PSQI), and actigraphy data. Mallinson and colleagues⁵⁶ compared the association between sleep diary total sleep time and responses to questions about habitual sleep duration in weekdays and weekends, respectively. They found a larger disagreement between sleep diary and questionnaire data in women than in men, although the difference was small (8 minutes). Miller and colleagues,⁶⁸ however, found no significant differences between men and women in a large-scale online study comparing sleep diary data with questions about habitual sleep duration.

Pittsburgh sleep quality index

PSQI was introduced by Buysse and colleagues to assess sleep quality.⁶⁹ It results in 7 component scores from 0 to 3, which can be added to a global score ranging from 0 to 21 (with higher scores indicating worse sleep quality and a cutoff score of 5 for good vs poor sleep quality). Most studies regarding psychometric properties of PSQI and gender have either studied gender differences in PSQI scores, in the factorial structure (ie, what items tend to correlate the strongest with each other), or in how PSQI scores are related to other sleep measurements. Regarding PSQI scores, some studies have found no gender differences,⁷⁰ whereas others have found gender-based differences^{19,71,72} (typically women having higher scores than men, although some have found the opposite⁷³) and that aging affects PSQI differently in men and women.⁷⁴

Both 1, 2, and 3 factor solutions have been suggested, as reviewed by Manzar and colleagues.⁷⁵

Morris and colleagues compared the results of separate principal component analyses and parallel analyses of PSQI in men and women, finding different factor loadings in men and women in their 3-factor solution.⁷⁶ Although in men overall sleep quality loaded on the same factor as sleep efficiency and sleep duration, in women it loaded with daytime dysfunction and sleep disturbances; this might indicate that men and women mean different things with sleep quality. Li and colleagues, however, found that a 2-factor solution identified using exploratory factor analysis was invariant with regard to gender.⁷¹ Most published factor analyses, however, have not included gender as an explicit covariate or tested for factor invariance across genders.

Aside from grouping items in a questionnaire together into factors, another possible approach to look for gender differences is to focus on subgroups among the respondents, using cluster analysis or latent class analysis. Doing so also allows comparisons of respondent subgroups among men and women. Buysse and colleagues⁷⁷ performed a cluster analysis of 187 middle-aged subjects based on their responses on PSQI and Epworth Sleepiness Scale (ESS) and found 4 clusters: low PSQI/low ESS, low PSQI/high ESS, high PSQI/low ESS, and high PSQI/high ESS. Women were significantly more likely than men to end up in the clusters with high PSQI than men. Similar findings were reported by Mondal and colleagues in a clinical sample of patients referred to a sleep clinic.⁷⁸ In a gender-specific latent class analysis of a community sample based on their responses to PSQI, Chen and colleagues found that although in men 2 latent classes could be identified (ie, good sleepers and poor sleepers), in women 4 latent classes were defined.⁷⁹ Apart from good sleep and poor sleep, there were also latent classes that were termed “inadequate sleep” and “daytime dysfunction,” consisting of subjects with PSQI global scores of 7 to 8 with either short sleep duration or significant subjective daytime dysfunction.

Insomnia severity index

Insomnia severity index (ISI) was published in 1993 by Morin, but the first psychometric assessment was published in 2001.⁸⁰ ISI scores range from 0 to 28, with higher scores indicating more severe insomnia symptoms. There are several cutoffs: 0 to 7 is considered normal, and 8, 15, and 22 are cutoffs for subthreshold, moderate, and severe insomnia, respectively. Various factor analyses, validations of translated versions, and psychometric evaluations in different patient groups have been published since (eg, primary care patients,⁸¹ patients with cancer,⁸² sickle cell anemia

patients,⁸³ military veterans,^{84,85} firefighters and rescue workers,⁸⁶ and general population⁸⁷. Some studies find higher ISI scores in women,^{87,88} but others have failed to find consistent gender differences.^{89,90} Factorial invariance across genders have been found reporting solutions with different number of factors^{91,92} (ie, the same factor structure is found in men and women, so items that tend to correlate strongly with each other in men also tend to correlate strongly in women and vice versa).

STOP-BANG questionnaire

The STOP-BANG (Snoring, Tiredness, Observed apneas, [high blood] Pressure, Body Mass Index, Age, Neck circumference and Gender) questionnaire^{93,94} was developed by Chung and colleagues⁹⁵ based on the previously published STOP questionnaire.⁹⁴ Its goal is to serve as a risk indicator to classify patients as having a low, moderate, or high risk of OSA.

TOP-BANG scores are by definition sensitive to gender (G stands for “gender”), and men are given a higher score to reflect the higher prevalence of OSA in men.

Several studies and review papers have indicated clinical differences between women and men with OSA,^{96–99} with potential relevance to the items in STOP-BANG. Witnessed snoring was a less common presenting symptom in women with OSA than in men in a matched case study.⁹⁶ Also, women had lower snoring index than men,¹⁰⁰ but the literature is conflicted as to whether there are any gender differences in snoring intensity.^{100,101} Age acts as an effect modifier on the relationship between snoring and gender.¹⁰²

Neither Zhang and colleagues⁹⁶ nor Basoglu and colleagues²³ found differences between women and men with OSA regarding daytime sleepiness. Other studies have reported a difference in that men are more likely to report excessive daytime sleepiness, whereas women are more likely to report insomnia or other symptoms that are not explicitly asked for in STOP-BANG.^{21,98,103}

Observed apnea is a less common presenting symptom in women than in men,¹⁰⁴ possibly because women with OSA tend to have fewer outright apneas, with more partially obstructive events instead.⁹⁸

There are also indications that the relationship between the risk of having OSA and anthropometric measures (ie, neck circumference and body mass index, in the case of STOP-BANG) is different between men and women. For example, fat distribution is different in men and women,¹⁰⁵

and fat distribution affects the risk of OSA.¹⁰⁶ Adding an item about fat distribution (ie, excess upper body fat) improves the accuracy of STOP-BANG.¹⁰⁷ There is conflicting evidence as to whether neck circumference (which is related to fat distribution) is associated to OSA risk and/or severity in both men and women: Polesel and colleagues,¹⁰⁸ Zhang and colleagues,⁹⁶ and Subramanian and colleagues¹⁰⁹ found a correlation between neck circumference and OSA severity in both men and women. Lim and colleagues¹¹⁰ found neck circumference to be associated to OSA in men but not in women. Onat and colleagues¹¹¹ found a correlation between neck circumference and AHI in both men and women, but in a logistic model where presence of OSA was modeled from age, neck circumference, and waist circumference, waist circumference, but not neck circumference, was significantly related to OSA in women.

Age is related to the risk of having OSA, but women tend to get OSA later in life than men,⁹⁸ meaning that the Age item might work differently in men and women. There have been studies suggesting alternative scoring criteria or cutoffs for STOP-BANG. Öztürk and colleagues¹¹² suggested different cutoffs for neck circumference in Turkish men and women, and other studies (not specifically examining STOP-BANG, but neck circumference) have found other cutoffs in other populations.^{113,114} Mou and colleagues compared STOP-BANG in patients referred for suspected sleep apnea with regard to its diagnostic accuracy.¹¹⁵ In summary, they found a low specificity for sleep apnea in men, and with higher AHI, the specificity improved in women but worsened in men. They proposed gender-specific scoring criteria that outperformed traditional scoring. They argue that the Gender item in the traditional STOP-BANG oversimplifies the matter of gender and its effects on OSA likelihood.

Epworth sleepiness scale

ESS was developed by Johns and published in 1991 to assess daytime sleepiness.^{116,117} The scale ranges from 0 to 24, with higher scores indicating more daytime sleepiness. There are different findings regarding how ESS scores vary between men and women and to what extent this relationship is affected by age. In a normative sample in the United States,¹¹⁸ no significant gender differences were found, whereas a German sample found women to report less daytime sleepiness than men.¹¹⁹ In a meta-regression of factors associated to daytime sleepiness in medical students male gender was not found to be associated with reporting excessive daytime sleepiness.¹²⁰

However, in the Sleep Heart Health Study (SHHS), there was a significant difference with women both having lower mean scores than men and being less likely to score in the excessive daytime sleepiness range.¹²¹ SHHS participants were also asked how often they felt sleepy or unrested, and women were more likely to endorse the "unrested" item, whereas there was no gender difference in the daytime sleepiness item. These findings are also supported by data from the Wisconsin Sleep Cohort.¹²² There, 13 items about daytime sleepiness (including all eight items from the ESS) were factor analyzed into 3 factors (perceived sleepiness, sleep propensity in passive situations, and sleep propensity in active situations). The 2 sleep propensity factors mostly consisted of ESS items, and the scores on these factors were higher in men, whereas the perceived sleepiness factor (which consisted of items such as feeling sleepy or needing coffee during the day) was more endorsed in women. However, in a study by Thorarindottir and colleagues,¹²³ where community samples in Sweden and Iceland answered both ESS and the Basic Nordic Sleep Questionnaire (which includes an item about the frequency of feeling sleepy), there was no significant difference in gender distribution among subjects not reporting daytime sleepiness on any of the instruments, ie. people reporting daytime sleepiness only on ESS, people reporting it on BNSQ, and people reporting it on both.¹²³ Differential item functioning with regard to gender was found in one item (item 3, ie, sitting inactive in a public meeting).¹²⁴ There is also some evidence that age affects ESS scores differently in men and women. Peak ESS scores in women are reported earlier in life than in men^{125,126}; in men, the highest reported level of daytime sleepiness occurs in their seventh decade, whereas it occurs in the third to fifth decade in women. The reasons are not clear.

Chronotype questionnaires

Several questionnaires^{127–131} exist to assess chronotype, that is, a subject's inclination to prefer to be asleep or active at different times of the day/night cycle. Although some studies have indicated that women are more likely to express a preference for morningness,¹³² others report no gender differences.¹³³ In the Munich Chronotype Questionnaire, an adjusted score that takes age and gender into account can be applied¹³⁴ and is recommended in studies that examine genetics or epidemiology.¹³⁵ In a meta-analysis of studies published between 1986 and 2018,⁵ the gender differences decreased with increasing age, especially around menopause. There was also an effect of publication year, where the gender difference

was less pronounced in studies published later. The investigators speculate that this might be due to increased gender equality. The choice of instrument used in the studies, however, did not significantly affect the findings. A study by Dutarte and colleagues even suggested a reversal of the gender effect in older subjects (ie, with older men being more morning oriented than older women),¹³⁶ but more research is needed in postmenopausal women regarding chronotype.

DISCUSSION

Current evidence show differences in objective measures of sleep, OSA, and sleepiness, including variables from PSG, actigraphy, and PG, as well as MSLT and PVT, between women and men. When discussing the current knowledge, it is important to remember that to date we do not have a consensus on what measure shows "good sleep" and the perception of sleep seems to change with age.⁹ Objectively, women show shorter TST, shorter sleep latency, and longer REM sleep latency.^{15–20} However, women seem to have less fragmented sleep, lower arousal index, less NREM stage 1 and 2 sleep, more SWS, and longer bouts of sleep epochs.²⁷ With increasing age, studies show less delta activity in women compared with men,²⁷ although there is also contrasting evidence showing women having less deficits in SWS, exhibited by more total minutes in this stage, and less reduced SWS proportions, transition probabilities, and durations as compared with men.²⁸ As applying age- and sex-adapted SWS criteria to sleep scoring seems to counteract the effect of sex,²⁹ there is the possibility that age has a stronger effect on sleep variables than sex.^{27,29} Measures of sleep apnea also show sex differences, with women exhibiting lower AHI and ODI, more partial occlusion, higher REM-AHI, and less supine AHI.^{21–24,27,97,98} Mechanistic explanations for the sleep and sleep apnea differences between sexes have been suggested, such as age, differences in circadian rhythm, and hormones¹⁹ and for OSA, also other factors such as anatomy.^{98,137} In women, previous studies have shown increased sleep disruption after menopause¹³⁸; however, studies have also shown the opposite, with postmenopausal women exhibiting increased SWS.¹³⁹ Nonetheless, the mechanisms and also the clinical implications of these findings are still not fully elucidated.

Although differences in sleep and sleep apnea have been shown also in meta-analysis,^{27,28} there is still a lack of studies in women, and in addition, few studies to date are designed specifically for studying sex or gender differences of sleep

variables. This type of study is needed if we are to fully understand sleep differences in women and men. Therefore, future studies need to continue focusing on sex and gender differences and also the interaction with age along with possible effects of sex hormones across the life-span to further explore and determine differences in sleep measures in women compared with men.

Current evidence show some support for sex differences in objective measures of alertness and sleepiness, as there were some indications that results from MSLT can differ between women and men. Specifically, men seem to exhibit shorter sleep latencies and higher prevalence of sleep-onset REM, but there are also studies reporting shorter SOL in women or no sex differences on the MSLT.^{3,37–47} Regarding PVT, studies are few and findings mixed. Blatter and colleagues⁵¹ found that women had slower PVT reaction times but also tended to have fewer instances of premature key presses compared with men. It is possible that women and men tend to use different strategies when performing the PVT, even though they are given the same instructions. Considering how common PVT is in research studies, this is an area in urgent need of further investigation.

Clinically, there are today no differences in care guidelines depending on sex or gender but it could be argued that differences in care should depend on sex, as sleep and sleep apnea seem to have different features in women and men. To date, there are also no differences in setup of recording or scoring depending on sex,^{11,30} and in addition, it is not elucidated whether or not differences in physical characteristic (for instance skull characteristics³¹) may contribute to differences in signals. Data from Rosinvil and colleagues showed that including sex and also age in their model predictions affected the recorded/analyzed signal (SWS)²⁹ and that from Yetton and colleagues²⁸ showed an apparent interaction between sex and age. At least when it comes to the scoring of sleep and sleep-related variables, this raises the important issue of whether or not different scoring criteria should be applied in different groups.

To some extent, the issue of measuring sleep in women is the issue of to what extent gender or sex affects the methods we use to measure sleep, that is, many of the points we raise could also be relevant if the topic had been “measuring sleep in men.” It is not simply a question about whether men and women sleep differently or experience their sleep in different ways, although to some extent such differences may matter. If a sleep disorder is more common in one sex, such as OSA in men or insomnia or restless legs in women,¹⁴⁰ a measurement with the same sensitivity and

specificity to detect that disease in men and women, respectively, will have different positive and negative predictive values in men and women.¹⁴¹ This difference is caused by the fact that the rarer a disease is in a group, the higher is the likelihood that a positive test result will be falsely positive, which in turn leads to a lower positive predictive value in that group.

Regarding questionnaires, gender may affect the psychometric properties in various ways. Many questionnaires are based around the idea of summing scores of several items. In order for such a summed score to be theoretically sound, it is important that the items measure the same thing, or one might be comparing apples with oranges in a sense; this is typically shown using factor analysis, where items are grouped into factors based on their covariance matrix, so items to which the responses are typically strongly correlated are grouped together.¹⁴² It is, however, not necessarily the case that these factors are invariant with regard to gender, that is, items that correlate strongly in men may not correlate in women and vice versa. There are some indications that this is an issue with the PSQI, for example, an instrument for which there are several factor structures published.^{71,75,76} Another issue is differential item functioning, where an individual item has different psychometric properties in different groups of respondents (eg, men and women), and this can lead to men and women experiencing the same intensity of a symptom getting different scores on a questionnaire measuring that symptom, thereby creating the illusion of gender differences that are not there or conversely obfuscating gender differences that exist. The ESS, for example, contains items that men and women tend to answer differently. Boyes and colleagues¹²⁶ found that men scored higher on items 3 (inactive in a public place), 6 (sitting and talking to someone), 7 (sitting quietly after lunch), and 8 (in a car while stopped for a few minutes in traffic), whereas women scored higher on items 1 (sitting and reading), 4 (as a passenger in a car for an hour without break), and 5 (lying down to rest in the afternoon).

Gender or sex might not only affect how we measure sleep-related phenomena, but it might also act in more complex ways to affect the results of our measurements, especially in clinical settings. In addition to potential physiologic differences between sexes that can affect diagnostic and research outcomes, it is possible that women and men can differ in how they perceive and report their symptoms, likelihood to seek medical care, and filling in questionnaires and strategies used on cognitive tests.^{45,51,56,68,143,144} These factors

could in turn be affected by norms, differences in expectations between women and men, life situation, and personality. The first assessment of a patient is typically not through a formal measurement but a clinical assessment based on history taking and a physical examination. If clinicians have preconceptions that make them less likely to suspect, for instance OSA in a woman, not for actual clinical reasons but the patient might not fit into the OSA stereotype of a middle-aged, overweight, sleepy man, they may be less likely to refer the patient to further examination.^{145–147} Taking narcolepsy as an additional example, both men and women can be affected, but there is a substantial sex difference in time from symptom onset to diagnosis.¹⁴⁸ Won and colleagues mark that even though men and women present with similar symptoms of narcolepsy, 85% of men were likely to be diagnosed within 16 years, whereas 85% of women were likely to be diagnosed within 28 years from symptoms onset⁴⁵; this is concerning and might influence disease progression and quality of life. In order to take preventive measures, it is important to consider possible causes behind this pattern, which also brings us to the core of this review: are there sex differences in sleep-related functions, and are our diagnostic and research tools sufficiently developed to take these sex and gender differences into account?

Most methods and instruments in this review have not been substantially tested for sex or gender differences, and only few studies had the primary aim to investigate sex differences; this is problematic, as potential sex differences might have been missed, thus risking that standard values are misleading, diagnoses missed or delayed, and results from scientific studies could be distorted. In combination with referral selection bias, affected by the clinician’s preconceptions and knowledge, methodological tools not sensitive enough to detect potential sex or gender differences could possibly be contributing to delay diagnoses in women for certain sleep disorders.

FUTURE DIRECTIONS

Although differences between women and men have been shown for subjective and objective sleep measures, there is still a lack of studies in women, and in addition, few studies have been aimed and designed specifically for looking at sex differences in sleep measurements. Therefore, it is of importance that future studies have a greater focus on potential sex differences.

In addition to what we have covered in this review, there is a great need for future studies to

further examine the effect of the menstrual cycle and hormonal contraceptives on sleep and sleep-related functions and related methods.¹⁴⁹ Today, menstrual cycle status and hormonal contraceptive use is taken into account differently between studies but most often not at all.

Not only the measurements themselves but also how we talk and write about differences between women and men are important. As scientists and health professionals, we need to be aware of the importance of phrasing for setting standards. Do we refer to men’s symptoms as typical, whereas women’s symptoms are atypical because they are less studied?

It is also common that the terms “gender” and “sex” are used as equivalents, and there seems to be some confusion regarding when the one or the other are more appropriate to use; this is outside of the scope of this review but something we suggest that journals should have guidelines for and writers and reviewers be aware of. To conclude, words matter.

SUMMARY

In sum, although it is likely that there are differences in sleep between women and men, which has also been shown in large meta-analyses, few studies to date are specifically designed to study sex or gender differences of sleep variables, and measurements are not sufficiently validated with respect to sex differences. These types of studies are needed if we are to fully understand sleep and sleep disorders in women and men. Future studies need to focus on sex and gender differences and the interaction with age, along with possible effects of sex hormones across the life-span. We urge researchers, policy makers, and clinicians to reflect on the consequences of not studying sex differences and to take steps to increase equality in research, method development, guidelines, and health care.

CLINICS CARE POINTS

- Both objective and subjective measures of sleep and sleep-related variables show differences between women and men in some aspects.
- Most methods and instruments assessing sleep have not been substantially tested for sex or gender differences, and only few studies have had the primary aim to investigate sex differences.

- There are to date no guidelines as to whether or not scoring (or set up) should be performed differently in women and men, and studies to assess whether different approaches should be applied are needed.
- Future studies need to be specifically designed to study sex or gender differences of sleep variables and focus on sex and gender differences and the interaction with age, along with possible effects of sex hormones across the life-span.

DISCLOSURE

J. Theorell-Haglöw and M. Ulander have nothing to disclose. F. Rångtell is the founder of Slumra of Sweden in which she gives payed lectures and scientific consultancy within the sleep field. F. Rångtell has acted as scientific advisor or content writer for several organizations and sleep-related companies, including Sleep Cycle and The Nap lab. None of FR's collaborations had any insight into or influence on the work related to this article.

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