Sleep Breath (2014) 18:731–739
DOI 10.1007/s11325-013-0935-z

ORIGINAL ARTICLE

Measuring subjective sleepiness at work in hospital nurses: validation of a modified delivery format of the Karolinska Sleepiness Scale

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Received: 29 May 2013 / Revised: 27 November 2013 / Accepted: 31 December 2013 / Published online: 29 January 2014

Abstract
Introduction Sleepiness during the work shift is common and can be hazardous to workers and, in the case of nurses, to patients under their care. Thus, measuring sleepiness in occupational studies is an important component of workplace health and safety. The Karolinska Sleepiness Scale (KSS) is usually used as a momentary assessment of a respondent's state of sleepiness; however, end-of-shift measurement is sometimes preferred based on the study setting. We assessed the predictive validity of the KSS as an end-of-shift recall measurement, asking for "average" sleepiness over the shift and "highest" level of sleepiness during the shift.
Method Hospital registered nurses (N=40) working 12-h shifts completed an end-of-shift diary over 4 weeks that included the National Aeronautical and Space Administration Task Load Index (NASA-TLX) work intensity items and the KSS (498 shifts over 4 weeks). Vigilant attention was assessed by measuring reaction time, lapses, and anticipations using a 10-min performance vigilance task (PVT) at the end of the shift. The Horne-Ostberg Questionnaire, Epworth Sleepiness Scale, General Sleep Disturbance Scale, and Cleveland Sleep Habits Questionnaire were also collected at baseline to assess factors that could be associated with higher sleepiness. We hypothesized that higher KSS scores would correlate with vigilant attention parameters reflective of sleepiness (slower reaction times and more lapses and anticipations on a performance vigilance task) and also with those factors known to produce higher sleepiness. These factors included the following: (1) working night shifts, especially for those with "morningness" trait; (2) working sequential night shifts; (3) having low physical and mental work demands and low time pressure; (4) having concomitant organic sleep disorders; and (5) having greater "trait" sleepiness (Epworth Sleepiness Scale). Linear mixed models and generalized linear mixed models were used to test associations that could assess the predictive validity of this format of administering the KSS.
Results Greater sleepiness, as measured by higher KSS scores, was found on shifts with nurses working night shift, the third sequential night compared to the first, those with sleep disorder symptoms (especially insomnia), and in nurses with trait sleepiness on the Epworth scale. Less sleepiness (lower KSS scores) was seen in shifts with a high level of time pressure and in nurses with a biologic predisposition to be more alert in the morning (morningness trait) who worked the day shift.
Conclusion We found partial support for using the Karolinska Sleepiness Scale in the recalled format based on our multiple tests of predictive validity.

There have been no conference presentations of these data.

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Keywords Work schedule tolerance · Occupational fatigue · Sleepiness · Karolinska Sleepiness Scale · Nurse schedule

Introduction

Sleepiness during the work shift is a state that is common to both day and night shift workers [1]. Determinants of sleepiness are well known—individuals are sleepier during the middle of the night and midafternoon due to their internal circadian clock and sleepier the longer they have been awake such that after about 16–18 h of wakefulness, the standard two-process model predicts that there is strong pressure to sleep [2, 3]. There are additional factors that can also affect sleepiness levels, such as a chronic sleep debt from inadequate time devoted to sleep or from a sleep disorder [4]. Caffeine and other alerting substances reduce sleepiness, and sedating medications increase sleepiness [5, 6]. An individual's level of sleepiness is also strongly influenced by genetic polymorphisms; thus, sleepiness behaves somewhat as a trait [7]. This is seen as a biologic predisposition to be more alert in the morning (morningness) or evening (eveningness), and also the individual's level of sleepiness in response to sleep deprivation [7, 8].

Individuals with high levels of sleepiness have brief intrusions of sleep patterns on EEG while awake ("microsleep"), which impair neurocognitive functioning [9]. For this reason alone, sleepiness at work can be hazardous to workers and, in the case of nurses and other health care workers, to patients under their care. Measuring sleepiness in occupational studies is an important component of workplace health and safety [9–12]. Although physiologic measures of sleepiness are quite good, these are often impractical for research in occupational settings such as hospitals. The Karolinska Sleepiness Scale (KSS) is a subjective measure of sleepiness that has been validated with electroencephalography and provides an adequate substitute for direct physiologic measurement [13, 14]. It is usually used as an assessment of a respondent's state of sleepiness "in the moment." In our previous study of registered nurses working 12-h shifts, Geiger-Brown et al. [15] found that nurses are often not able to respond to response cues at the time that they are given; for example, when they are engaged in certain tasks such as administering blood, giving medications, admitting a patient to the ward, in a 1:1 session about a psychosocial issue, working with a patient in an isolation room, or assisting in surgery, the nurse will not stop to record their sleepiness level and often will forget to record it later. Thus, in the current study of nurses' sleepiness at work, we chose to use the KSS as an end-of-shift recalled measurement, asking for "average" sleepiness over the shift and "highest" level of sleepiness during the shift. The purpose of this paper is to examine the predictive validity of the KSS as used in this format in hospital nurses working 12-h shifts.

In this report, we assess the strength of the relationship of the KSS as a measure of sleepiness with several known factors that are expected to produce higher sleepiness. Our primary hypothesis was that the KSS would correlate with objectively measured vigilant attention, a behavioral variable reflective of sleepiness (assessed using reaction times, lapses, and anticipations from the psychomotor vigilance task), as well as those factors known to produce higher sleepiness. These factors included the following: (1) working night shifts, especially for those with "morningness" trait; (2) working sequential night shifts; (3) having low physical and mental work demands and low time pressure; (4) having symptoms suggestive of an organic sleep disorders; and (5) having greater "trait" sleepiness (Epworth Sleepiness Scale).

Methods

The study was approved by the University of Maryland School of Medicine institutional review board and by the institutional review board at the Children's National Medical Center. All participants signed an informed consent. Data for this analysis are from pre-intervention (4-week baseline) measures from the FRAME (Fatigue Risk, Alertness Management Effectiveness, Centers for Disease Control/National Institute for Occupational Safety and Health R21OH009979) study, an ongoing longitudinal pilot study of nurses to assess the effectiveness of several fatigue reduction interventions.

Sample and data collection

Registered nurses working full time in an acute care hospital volunteered for the study. All nurses in the study worked 12-h shifts, with shift start times of 7 a.m. and 7 p.m., plus 30 min added to the 12-h shift for handovers. There were no exclusion criteria as these data were collected as part of an effectiveness trial. Participating nurses kept a work diary for 4 weeks, completed at the end of each shift, recording the work intensity during the shift (National Aeronautical and Space Administration Task Load Index (NASA-TLX)) as well as average and highest level of sleepiness during the shift using the KSS [16]. Over a month's time, each nurse reported data for an average of 12 shifts. Baseline instruments included the modified Horne-Ostberg Scale to assess circadian chronotype, the General Sleep Disturbance Scale and the Cleveland Sleep Habits Scale to describe symptoms of sleep disorders, and the Epworth Sleepiness Scale to assess trait sleepiness [17–20].

Measures

Sleepiness

Sleepiness as a state function was measured by the single-item KSS. Scores range from 1 (extremely alert) to 9 (extremely sleepy, fighting sleep), with 7–9 representing a high level of sleepiness. This cut point was established by assessing physiologic changes in electroencephalogram (alpha and theta power density) and electrooculogram studies (slow rolling eye movements) during conditions of overnight wakefulness [13]. The KSS has shown validity as a measure of sleepiness when compared with electroencephalographic and performance vigilance measures [13, 14].

Trait sleepiness was measured using the Epworth Sleepiness Scale [20]. Eight items measure the likelihood of dozing in a variety of situations (e.g., as a passenger in a car and watching TV). Items used a 0 (would never doze) to 3 (high chance of dozing) scale, with summed score ranging from 0 to 24. Scores >9 were considered to be clinically relevant sleepiness.

Vigilant attention

Vigilant attention was measured using a performance vigilance task monitor (PVT-192, Ambulatory Monitoring, Inc., hereafter PVT) which uses a simple neurobehavioral response to a visual stimulus at random stimulus intervals over a 10-min testing period. It is widely used in studies of sleep deprivation and is sensitive to the effects of sleep loss [21]. There are numerous parameters available for this test of attention. For this study, mean reaction time, lapses (responses greater than 500 ms), and anticipations (false starts, i.e., responses when no stimulus was presented) were used.

Work intensity

Work intensity was measured using six items from the NASA-TLX, measuring the subjective dimensions of mental demands, physical demands, temporal demands, effortfulness, own satisfaction with job performance, and frustration during work [16]. Each dimension named the demand then asked a question to prompt the participant to consider how this demand would be experienced on the job, using a 10-point visual analogue scale with anchors of “low” to “high.” Items included (1) mental demands (How much mental activity (e.g., thinking, deciding, calculating, remembering, looking, and searching) was required to perform your job?), (2) physical demands (How much physical activity (e.g., pushing, pulling, turning, lifting, and activating) was required to perform your job?), (3) temporal demands (How much time pressure did you feel due to the rate or pace of your job?), (4) effort (How hard did you have to work (mentally and physically) to accomplish your level of performance?), (5) performance (How satisfied were you with your performance at your job today?), and (6) frustration (How insecure, discouraged, irritated, stressed, and annoyed versus secure, gratified, content, relaxed, and complacent did you feel during your shift today?).

Chronotype

The biological predisposition toward alertness during the morning or evening was measured using a modified version of the Horne-Ostberg Questionnaire [17]. This five-item scale measuring the morningness-eveningness trait is reduced from the original 1976 Horne-Ostberg Morningness-Eveningness Questionnaire [8]. Scores classified respondents into morning, neither, or evening chronotype.

Sleep disorder symptoms

Insomnia symptoms were measured using the General Sleep Disturbance Scale [18]. This 21-item scale assessed sleep difficulties in the past week (eight-point Likert scale for 0–7 days) including insomnia symptoms, daytime consequences of poor sleep, napping, and use of substances and medications to aid sleep. Scores >3 suggested a risk for a sleep disturbance. The scale was validated in a population of registered nurses similar demographically to those in the present study. For this study, insomnia was indicated when nurses had three or more days in the past week of having difficulty getting to sleep, waking during the sleep period, or waking up too early at the end of a sleep period.

Symptoms suggestive of sleep disordered breathing were measured using the Cleveland Sleep Habits Questionnaire [19]. This questionnaire contains 10 items from the Berlin Questionnaire which is validated for screening patients for sleep apnea in a primary care setting. Three categories of signs and symptoms are assessed: snoring history and witnessed episodes of apnea, tiredness and sleepiness during wake time, and a history of high blood pressure and/or body mass index (BMI) >30 kg/m^2. Nurses were considered at high risk of sleep apnea if two of the three categories were positive. The Cleveland questionnaire also contained evaluation of restless leg syndrome (RLS) [19]. RLS was a positive screen if the nurse indicated “in the evening I get strange crawling sensations in my legs along with an urge to move them” on three or more days per week.

A composite indicator variable for any sleep disorder was created based on the reported symptoms of insomnia (GSDS), sleep apnea, and/or RLS (Cleveland).

Statistical analysis

Demographic and response variables were described based on the level of measurement. Means and standard deviations were calculated for continuous variables and proportion for categorical variables. KSS scores were used as a continuous variable (1–9) for analyses where the mean of average or highest level of sleepiness was employed. The KSS score was also dichotomized to reflect a comparison between those with high sleepiness (7–9) versus low sleepiness (0–6). Group comparisons of KSS scores were calculated for differences by shift, trait, consecutive night shifts for three nights in a row, and presence of sleep disorder symptoms. Prior to model fitting, the distribution of outcome variables was checked and the PVT mean reaction time was log-transformed to meet the model assumption. Linear mixed models (LMMs) or generalized linear mixed models (GLMMs) were used when appropriate to compare the differences of sleepiness scales with regard to each of the predictors, accounting for nonindependence of measures within subjects. A random intercept of individual nurse was included in each model to account for the intraclass correlation between the repeated measures (sleepiness scores during each shift over the shifts) within the individual nurse. To explore the association between shift and sleepiness scales, a series of mixed models of each sleepiness scale were fit separately. The mixed models were then fit including shift and trait along with interaction between shift and trait in the model. When the interaction was significant, shift-stratified models were estimated. Similarly, bivariate LMMs were used to assess the association between sleepiness scales and sequential night shifts, sleep disorder, and work intensity separately. In addition, effects of each predictor on neurobehavioral performance (mean reaction time, number of lapses, and number fault starts) were assessed via LMMs and GLMMs. The GLMMs were fit for number of lapses and number of anticipations by negative binomial distribution and log link due to the overdispersed Poisson distribution of the data. The log-transformed LMM models were used to estimate the association between mean reaction time and each predictor.

Results

Table 1 shows the demographic characteristics of the sample. A total of 53 nurses consented and participated in the baseline surveys, and 40 of them filled in the work and sleep diaries over 4 weeks (494 shifts). No statistical differences were found among demographic characteristics of nurses who filled work diaries and those who did not. Only the reports from the 40 nurses who filled in work diaries were included in the current study. This sample of nurses was younger than the average age of US registered nurses, with 28 being the median age of this sample compared to 46 for all US RNs [22]. Nurses were similar in racial and ethnic characteristics to the US population of RNs. However, more nurses in this sample had bachelor’s degrees or higher than in the USA where only 34 % of nurses have at least a bachelor’s degree. Nearly 500 shifts are represented in this study. All nurses in the study were eligible to rotate shifts by terms of their employment.

Sleepiness, chronotype, and sleep disorder symptoms

Table 2 shows the self-reported sleepiness of the nurses during the shift. Although mean KSS scores were in an acceptable range, 21.3 % of shifts were worked by nurses who reported an average level of sleepiness over the shift that fell into the high range (KSS 7–9); similarly, 44.3 % of shifts were worked by nurses reporting that their highest level of sleepiness during the shift was in this high range. One third had Epworth Sleepiness Scale scores that were exceeding the threshold for high level of trait sleepiness (>9). As to chronotype, there were fewer morningness trait nurses than eveningness trait; however, the night shift was oversampled so this cannot be generalized to the population. More than half (57.5 %) of nurses reported symptoms of insomnia, and two thirds (67.5 %) reported symptoms of at least one sleep disorder, with a smaller percentage having symptoms of sleep apnea (17.5 %) and restless leg syndrome (12.5 %). Only a few nurses had symptoms of more than one disorder.

Prior to the hypothesis testing, the intraclass correlation coefficient (ICC) was calculated on each KSS outcome in null models (i.e., without predictor). The ICC was 0.41 (95 % CI (0.29, 0.53)) for average sleepiness scores and 0.48 (95 % CI (0.36, 0.60)) for highest level of sleepiness scores, both of which are considered to be large intraclass correlation coefficients [23, 24].

Table 1 Characteristics of the sample, full-time hospital nurses working 12-h shifts (*n*=40)

Variable	*n* (%)
Age, mean (SD), range	30.9 (7.9), 22–52
Race	
White	30 (79.0)
African American	4 (10.5)
Asian	1 (2.6)
More than one race	3 (7.9)
Ethnicity	
Hispanic	2 (6.3)
Non-Hispanic	30 (93.7)
Marital status	
Married	11 (27.5)
Unmarried	29 (72.5)
Highest degree	
AD	2 (5.0)
BS	33 (82.5)
MS	4 (10.0)
Other	1 (2.5)
Years in current job, mean (SD), range	3.7 (5.4), 0–25.8
Shift in this study	
Day shift	6 (15.0)
Night shift	10 (25.0)
Rotating(both)	24 (60.0)
BMI (kg/m^2), mean (SD), range	25.2 (5.6), 19.3–40.4
Normal(BMI<25 kg/m^2)	28 (70.0)
Overweight (BMI 25–29.9 kg/m^2)	5 (12.5)
Obese (BMI≥30 kg/m^2)	7 (17.5)

Values represent *n* (%) unless indicated otherwise. Numbers are not necessarily summed up to total sample due to missing data

Table 2 Sleepiness, chronotype, and sleep disorder symptoms among hospital nurses working 12-h shifts

Variable	*n* (%)
KSS average sleepiness during shift[a]	
Continuous, mean (SD)	4.5 (2.0)
≥7	105 (21.3)
KSS highest level sleepiness during shift[a]	
Continuous, mean (SD)	5.5 (2.2)
≥7	219 (44.3)
Epworth Sleepiness Scale[b]	
Continuous, mean (SD)	8.8 (3.8)
>9	13 (32.5)
Morning/evening type[b]	
Morning type	6 (15.0)
Neither morning nor evening type	16 (40.0)
Evening type	18 (45.0)
Symptoms of sleep disorder[b]	27 (67.5)
Insomnia	23 (57.5)
Sleep apnea	7 (17.5)
Restless leg syndrome	5 (12.5)
Number of sleep disorders, by nurse[b]	
0	13 (32.5)
1	20 (50.0)
2	6 (15.0)
3	1 (2.5)

Values represent *n* (%) unless indicated otherwise

[a] Measured by shift

[b] Measured by nurse

Hypothesis testing

Tables 3 and 4 show the association of KSS scores with factors known to produce sleepiness; these tests were used to provide support for the validity of the KSS as used in this format. We hypothesized that higher sleepiness scores would be associated with poorer vigilant attention on the PVT and that sleepiness would be higher with work-related factors that were expected to produce sleepiness.

Vigilant attention, as measured by PVT lapses and anticipation responses, showed no significant association with KSS scores; however, mean reaction times were slower (566 ms) for a KSS score of 9 (extreme sleepiness and fighting sleep) compared to reaction time means ranging from 275 to 326 ms for KSS scores of 1–8 in nurses who reported their highest level of sleepiness during the shift (t=2.37; p=0.05). Thus, partial support for the validity of administering the KSS in this format was shown using this behavioral measure of vigilant attention.

We found that nurses working on the night shift were sleepier than those working the day shift, both in average sleepiness and highest sleepiness during the shift. But, sleepiness during the night shift was similar in nurses irrespective of circadian trait (morningness, eveningness, or neither) (Fig. 1). A trait-stratified analysis showed that nurses with a morningness trait reported less sleepiness on the day shift compared to those with eveningness trait. Nurses who worked at least three night shifts in a row had higher sleepiness on the third night compared to the first. For work demands (NASA-TLX scale), the association with the KSS was mixed. Nurses who reported higher time pressure during the shift based on the temporal demand item of the NASA-TLX also reported lower KSS scores; however, physical and mental demand intensities were not associated with KSS scores. Therefore, several factors known to be associated with higher sleepiness were associated with higher KSS scores, showing partial support for validity of this administration format.

Symptoms of sleep disorders were highly prevalent among nurses (Table 2), and nurses with these symptoms had three times the odds of reporting a KSS score of 7–9 for average or highest level of sleepiness during the shift, with insomnia being a major contributor. There was no association between nurses' Epworth Sleepiness Scale scores and their average sleepiness during the shift. However, when highest level of sleepiness during the shift was examined, nurses with elevated Epworth scores were also significantly sleepier with nearly four times the odds of reporting a KSS score of 7–9. These finding provided additional support for the validity of the KSS in this administration format.

Discussion

We believe that this format for the administration of the KSS is partially supported by the hypothesis tested in this pilot study. Nurses with a KSS score of 9 when reporting highest level of sleepiness over the shift had longer reaction times than those with lower levels of sleepiness. Higher sleepiness was found on shifts with nurses working night shift, on the third sequential night compared to the first, among those with sleep disorder symptoms (especially insomnia), and for those with trait sleepiness on the Epworth scale. Lower sleepiness was seen in shifts with a high level of time pressure and for nurses with morningness trait who worked the day shift.

We did have discordant findings. The hypothesis that morningness trait nurses would have more sleepiness during night work was not supported; however, we did find an interaction effect of shift by chronotype that demonstrated less sleepiness for morningness nurses working the day shift. We explain the failure to support this hypothesis by the high level of circadian sleep pressure during night shift work in all chronotypes. We also did not find differences in sleepiness between the first and second night shifts; however, these differences did appear by the third night. We believe that a high level of cumulative sleep debt shown in our previous

Table 3 Distribution and association estimates between average sleepiness over the shift (KSS) and each predictor in a sample of nurses working 12-h shifts

	Total shifts	Average sleepiness (continuous)		Average sleepiness (score≥7)	
	n (%)	Mean (SD)	*b* (95 % CI)[a]	*n* (%)[b]	OR (95 % CI)[a]
Shift					
Day shift	253 (51.2)	4.1 (1.8)	Ref	37 (14.6)	Ref
Night shift	241 (48.8)	4.9 (2.0)	1.2 (0.9, 1.6)***	68 (28.2)	3.5 (1.9, 6.5)***
Night shift only					
Morning trait[c]	31 (12.9)	4.6 (2.2)	Ref	8 (25.8)	Ref
Neither type trait[c]	98 (40.7)	4.9 (2.0)	−0.02 (−1.8, 1.7)	26 (26.5)	1.0 (0.2, 6.5)
Evening trait[c]	112 (46.4)	5.0 (2.1)	0.03 (−1.8, 1.8)	34 (30.4)	1.1 (0.2, 7.0)
Day shift only					
Morning trait[c]	44 (17.4)	3.3 (1.3)	Ref	2 (4.6)	Ref
Neither type trait[c]	94 (37.2)	3.6 (1.8)	0.6 (−0.8, 2.1)	10 (10.6)	2.6 (0.4, 18.7)
Evening trait[c]	115 (45.4)	4.7 (1.7)	1.6 (0.4, 2.9)*	25 (21.7)	5.4 (0.9, 34.0)
Sequential night shifts					
First night shifts	68 (51.5)	4.7 (2.0)	Ref	16 (23.5)	Ref
Second night shifts	47 (35.6)	5.0 (2.0)	0.3 (−0.2, 0.7)	11 (23.4)	0.99 (0.3, 2.9)
Third night shifts	17 (12.9)	5.1 (2.2)	0.9 (0.2, 1.6)*	7 (41.2)	5.4 (1.3, 22.5)*
Sleep disorder					
No disorder	162 (32.8)	3.9 (2.0)	Ref	20 (12.4)	Ref
Any sleep disorder	332 (67.2)	4.8 (1.9)	0.9 (−0.02, 1.8)	85 (25.6)	2.8 (1.0, 7.4)*
Insomnia					
No	214 (43.3)	4.1 (2.0)	Ref	34 (15.9)	Ref
Yes	280 (56.7)	4.8 (1.9)	0.8 (−0.08, 1.6)	71 (25.4)	2.1 (0.8, 5.2)
Sleep apnea					
No	404 (81.8)	4.3 (2.0)	Ref	83 (20.5)	Ref
Yes	90 (18.2)	5.1 (1.8)	0.7 (−0.4, 1.8)	22 (24.4)	1.4 (0.4, 4.5)
RLS					
No	429 (86.8)	4.4 (1.9)	Ref	81 (18.9)	Ref
Yes	65 (13.2)	5.1 (2.1)	0.6 (−0.7, 1.9)	24 (36.9)	2.5 (0.7, 9.3)
Epworth Sleepiness Scale					
Continuous			0.1 (0.02, 0.2)*		1.1 (1.0, 1.3)*
ESS≤9	337 (68.2)	4.2 (1.9)	Ref	58 (17.2)	Ref
ESS>9	157 (31.8)	5.0 (2.0)	0.8 (−0.1, 1.7)	47 (29.9)	2.2 (0.9, 5.7)
Work intensity	Mean (SD)				
Mental demand	6.3 (2.1)		−0.02 (−0.1, 0.06)		1.0 (0.9, 1.1)
Physical demand	5.1 (2.4)		−0.04 (−0.1, 0.03)		1.0 (0.9, 1.1)
Temporal demand	5.7 (2.4)		−0.08 (−0.15, −0.02)*		0.9 (0.8, 1.1)
Effort	5.9 (2.2)		−0.03 (−0.1, 0.05)		1.0 (0.9, 1.2)
Performance	7.0 (1.8)		−0.07 (−0.2, 0.03)		0.9 (0.7, 1.0)*
Frustration	4.5 (2.6)		−0.02 (−0.08, 0.04)		1.0 (0.9, 1.2)

*$p<0.05$; **$p<0.01$; ***$p<0.001$

[a] LMMs or GLMMs were fit for each of the predictors separately with a random intercept included to account for intraclass correlation of repeated measures of each nurse

[b] Row percentage to represent proportion of KSS ≥7 that is contained within each level of row variables

[c] Definitely and moderate morning type were combined as morning type, and definitely and moderate evening type were combined as evening type

study of 12-h shift nurses would account for increased sleepiness by the third night [15].

We have been unable to locate other papers that use the KSS as a recalled measure. Our experience of conducting

Table 4 Association estimates between highest level of sleepiness during the shift (KSS) and each predictor in a sample of nurses working 12-h shifts

	Highest level Sleepiness (continuous)		Highest level Sleepiness (score≥7)	
	Mean (SD)	*b* (95 % CI)[a]	*n* (%)[b]	OR (95 % CI)[a]
Shift				
Day shift	5.2 (2.1)	Ref	87 (34.4)	Ref
Night shift	6.0 (2.3)	1.4 (1.0, 1.7)***	132 (54.8)	5.5 (3.0, 10.2)***
Night shift only				
Morning trait[c]	6.0 (2.7)	Ref	20 (64.5)	Ref
Neither type trait[c]	6.0 (2.3)	−0.4 (−2.4, 1.7)	56 (57.1)	0.5 (0.05, 5.4)
Evening trait[c]	5.9 (2.2)	−0.3 (−2.3, 1.7)	56 (50.0)	0.5 (0.05, 4.7)
Day shift only				
Morning trait[c]	4.6 (1.6)	Ref	5 (11.4)	Ref
Neither type trait[c]	4.7 (2.3)	0.4 (−1.5, 2.3)	27 (28.7)	3.6 (0.4, 34.7)
Evening trait[c]	5.8 (1.9)	1.6 (−0.06, 3.2)	55 (47.8)	10.5 (1.2, 92.8)*
Sequential night shifts				
First night shifts	5.8 (2.3)	Ref	33 (48.5)	Ref
Second night shifts	6.1 (2.1)	0.2 (−0.3, 0.7)	23 (48.9)	0.9 (0.4, 2.3)
Third night shifts	6.2 (2.3)	0.9 (0.06, 1.6)*	9 (52.9)	1.8 (0.5, 6.6)
Sleep disorder				
No disorder	4.7 (2.3)	Ref	48 (29.6)	Ref
Any sleep disorder	6.0 (2.1)	1.3 (0.2, 2.3)*	171 (51.5)	3.4 (1.2, 10.2)*
Insomnia				
No	4.8 (2.4)	Ref	68 (31.8)	Ref
Yes	6.1 (1.9)	1.3 (0.4, 2.3)**	151 (53.9)	3.3 (1.1, 9.2)*
Sleep apnea				
No	5.3 (2.2)	Ref	169 (41.8)	Ref
Yes	6.5 (2.0)	1.1 (−0.2, 2.4)	50 (55.6)	2.0 (0.5, 7.9)
RLS				
No	5.5 (2.2)	Ref	182 (42.4)	Ref
Yes	6.0 (2.4)	0.5 (−1.1, 2.1)	37 (56.9)	2.1 (0.4, 10.9)
Epworth Sleepiness Scale				
Continuous		0.2 (0.02, 0.3)*		1.2 (1.0, 1.3)*
ESS≤9	5.2 (2.3)	Ref	122 (36.2)	Ref
ESS>9	6.3 (1.9)	1.2 (0.1, 2.2)*	97 (61.8)	3.7 (1.3, 110)*
Work intensity				
Mental demand		−0.03 (−0.1, 0.05)		1.0 (0.9, 1.1)
Physical demand		−0.06 (−0.1, 0.01)		0.9 (0.8, 1.0)
Temporal demand		−0.1 (−0.2, −0.06)***		0.9 (0.8, 1.0)**
Effort		−0.07 (−0.2, 0.006)		1.0 (0.9, 1.1)
Performance		−0.06 (−0.2, 0.04)		0.9 (0.8, 1.1)
Frustration		−0.03 (−0.09, 0.04)		1.0 (0.9, 1.1)

*$p<0.05$; **$p<0.01$; ***$p<0.001$

[a] LMMs or GLMMs were fit for each of the predictors separately with a random intercept included to account for intraclass correlation of repeated measures of each nurse

[b] Row percentage to represent proportion of KSS ≥7 that is contained within each level of row variables

[c] Definitely and moderate morning type were combined as morning type, and definitely and moderate evening type were combined as evening type

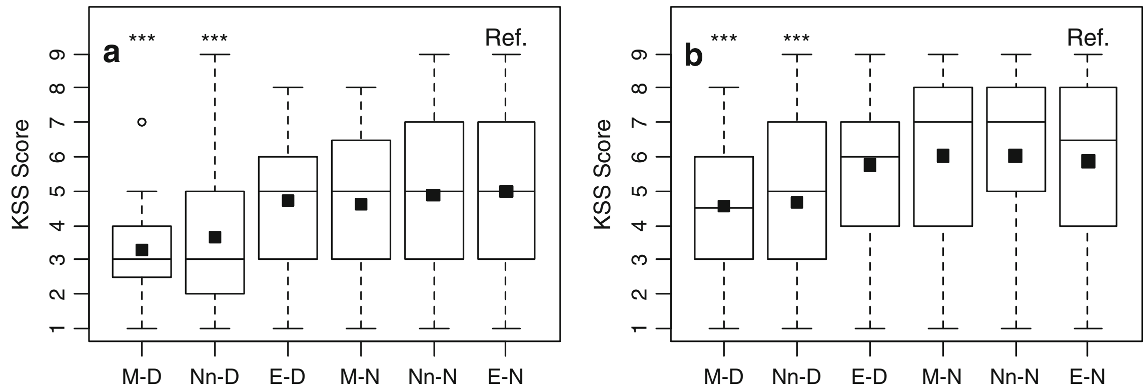

Fig. 1 Boxplots of KSS scores by combination of shift and trait. Boxplot contains 25th and 75th percentiles, with *central line* as median, *small solid box* as mean, and circle as outlier. *Whiskers* are min and max excluding the outliers. *M* morningness trait, *Nn* neither morningness nor eveningness trait, *E* eveningness trait, *D* working day shift, *N* working night shift. Panel (**a**) shows the average sleepiness during shift; Panel (**b**) shows the highest level of sleepiness during shift. Differences between the asterisk group and the group of eveningness trait working night shift (reference group): *$p<0.0.5$; **$p<0.01$; ***$p<0.001$

studies of sleepiness and fatigue in busy hospital settings suggests that having the ability to use the KSS as a recalled measure may be valuable in other occupational settings where ecological momentary assessment is not practical as a sampling strategy. It appears that recall of average versus highest sleepiness are not identical and that nurses can differentiate between these two forms of recalled sleepiness. Additional validation studies in other occupational settings will be needed to provide additional support for this approach.

The paper's strengths and weaknesses should be taken into account when considering these findings. This sample of nurses worked only 12-h shifts, and the sleep patterns for other shift durations may vary, so the validity of recalled KSS may not generalize to other shift lengths. This sample of nurses is younger and more educated than the US nursing population, although the biasing effect of this on the predictive validity of the KSS is unknown. Although this is a fairly small sample of nurses, it encompasses a large number of shifts, and the within-subject variability is accounted for in the analysis. Strengths include having the same start times for all day shifts and night shifts, so that circadian influences on sleepiness were standardized based on this shift worked. Also, nurses reported on multiple shifts over the 4-week data collection period so that within-subject variability could be effectively modeled. The KSS scores were collected in an actual work setting on a variety of differently paced nursing units. This study use both self-reported and behavioral assessments to predict the KSS, thus avoiding monomethod bias. Based on these findings, we believe that the validity of using the KSS as a recalled measure over the duration of a work shift is partially supported and that it can be useful in occupational settings where momentary assessment of sleepiness is not feasible due to the participant's inability to respond in the moment to a scoring cue.

Acknowledgments We thank the National Institute for Occupational Safety and Health for funding this study and Ms. Emily Redding for study coordination.

Funding CDC/NIOSH R21OH009979-01.

Conflict of interest The authors declare that they have no conflicts of interest to report.

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