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Validation of the Karolinska Sleepiness Scale in Korean

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Background and Purpose The Karolinska Sleepiness Scale (KSS) is widely used for assessing current level of sleepiness, but it has not been validated in South Korea. This study aimed to validate the KSS using the Stanford Sleepiness Scale (SSS), polysomnography (PSG), and electroencephalography (EEG).

Methods The sample consisted of 27 adult participants in this study aged 40.5±7.7 years (mean±standard deviation) and included 22 males. They completed questionnaires and underwent EEG recording and overnight PSG. The KSS was completed from 18:00 to 24:00 every 2 hours and following PSG (at 07:00). KSS scores changed over time and in particular increased with the time since waking, with the score peaking at 24:00.

Results Convergent validity of the KSS was verified by performing a Spearman correlation analysis between the KSS and SSS (r=0.742, p<0.01). Concurrent validity of the KSS was verified by performing a Spearman correlation analysis between the KSS administered before sleep and the sleep onset latency measured using PSG (r=-0.456, p<0.05). Alpha waves were measured 5 minutes before administering the KSS, and the KSS scores were compared with these alpha waves. There were no significant correlations observed between the KSS scores and alpha waves measured in the left occipital area (O1), left frontal area (F3), or left central area (C3). In addition, Spearman correlation analyses of the difference between KSS scores and alpha waves measured at O1, F3, and C3 produced no significant results.

Conclusions This study verified the convergent validity and concurrent validity of the KSS, and confirmed the capabilities of this scale in assessing sleepiness changes over time.

Keywords Karolinska Sleepiness Scale; validation study; sleepiness.

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INTRODUCTION

While there is no clear agreement on the definition of sleepiness, the most commonly accepted definition is the state of being susceptible to falling asleep, or sleep propensity.[1-3] Excessive daytime sleepiness[4] is a symptom of disorders described as the persistence of overwhelming sleepiness, which occurs in inappropriate situations, interferes with the ability to perform the activities of daily living, and can even threaten health and safety. Sleepiness is not only a common physiological phenomenon but can also be a symptom of sleep disorders.

Currently, the best way to measure sleepiness is through physiological measures such as the Multiple Sleep Latency Test, the Maintenance of Wakefulness Test, and the Alpha Attenuation Test (AAT). However, these physiological tools are invasive, time-consuming, and expensive, making them difficult to use in clinical settings.[5] Self-report questionnaires are an alternative tool type used in clinical practice and research settings to assess sleepiness.[6,7]

Self-report questionnaires that measure sleepiness can be broadly categorized into those measuring trait-related sleepiness and state-related sleepiness.[8] The most widely used questionnaire for assessing trait-related sleepiness is the Epworth Sleepiness Scale, which rates sleepiness on a 4-point Likert scale in eight different situations.[9] State-related sleepiness questionnaires include the Stanford Sleepiness Scale (SSS), the Visual Analogue Scale for Sleepiness (VAS), and the Karolinska Sleepiness Scale (KSS). Although the SSS is widely used, the descriptions of each anchor have been questioned, and it has also been criticized for measuring other factors besides sleepiness.[10] The VAS is a single-item measure that is utilized by the subject to indicate their current level of sleepiness on a 100-mm straight line that has labels at each end describing opposing extremes of sleepiness.[11] The VAS has been criticized for a lack of specific explanations and anchors, which can lead to ambiguity in the measurement concept.[11,12]

The overall aim of this study was to validate the KSS, which was developed to measure the current level of sleepiness. The state of sleepiness identified by the KSS provides behavioral criteria related to sleepiness that are easy for anyone to recognize. The KSS has been validated using various objective measurements, has high reliability and validity,[13-15] and is known to be sensitive to changes in sleepiness.[13,16] The specific aims of this KSS validation study were as follows: 1) determine the sensitivity of the KSS by repeatedly applying this scale and comparing the scores over time, 2) characterize the convergent validity and concurrent validity of the KSS using both self-report measures (SSS) and objective measures (polysomnography [PSG]), and 3) quantify the correlation between KSS scores and alpha waves as measured by electroencephalography (EEG) for 5 minutes immediately before applying the KSS. First, we predicted that KSS scores would vary over time since sleepiness changes. We repeatedly applied the KSS every 2 hours and compared the obtained scores over time. Second, we assumed that KSS scores would be correlated with scores on the SSS, which is a self-report questionnaire of sleepiness, and sleep onset latency (SOL), a physiological indicator of sleepiness as measured by PSG. Third, we measured the correlation between KSS scores and alpha waves measured by EEG 5 minutes before completing the KSS.

METHODS

Participants

The sample consisted of 27 adult participants who consented to being included the study and were aged 30−66 years. Inclusion and exclusion criteria were applied using a screening questionnaire and brief interview at the hospital. The inclusion criterion was the intermediate type of circadian rhythm according to the Morningness-Eveningness Questionnaire (MEQ). Sleep indicators estimated by PSG may differ among MEQ types,[17,18] and so we included a normal sleep-wake cycle classified as the intermediate type only. The exclusion criteria were as follows: shift worker, pregnant female, impaired cognitive ability (assessed by the communication ability during the screening interview), severe clinically uncontrolled medical diseases, ophthalmic diseases, or a past or current history of taking sleep medications.

Procedures

The KSS was independently translated and back-translated by a clinical psychologist and a sleep specialist who were fluent in both English and Korean. An independent sleep specialist then verified the content validity. This study was conducted at a Samsung Medical Center in Seoul, South Korea, where EEG and PSG were available, and informed consent was obtained from the participants before the study.

Before conducting PSG, participants completed a questionnaire and EEG was performed. Specifically, for PSG, all participants arrived at the hospital by 16:00. Participants completed the questionnaires, were connected to electrodes for PSG, and then had dinner and a rest. The participants completed the KSS every 2 hours, and EEG was performed from 18:00 to 24:00 (Fig. 1). Participants were required to stay awake during this investigation period.

Alpha waves were measured by EEG at 5 minutes before applying the KSS at 20:00, 22:00, and 24:00. The relationship between KSS scores and alpha waves was analyzed by calculating within-individual means. Difference scores (d values) for KSS scores and alpha waves were measured at 20:00 and 22:00 and at 22:00 and 24:00, respectively, and were also analyzed by calculating within-individual means.

At 24:00 the participants completed the KSS, and then PSG was performed while sleeping until the waking time of 07:00. The participants then completed the KSS again, and the PSG electrodes were removed. All participants completed the KSS six times. The study received ethical approval from the Institutional Review Board of Sungshin Women's University (SSWUIRB-2021-065).

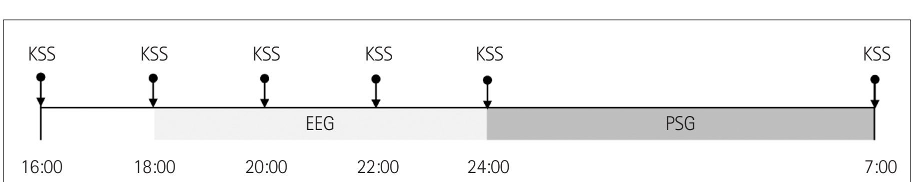

Fig. 1. Research protocol (n=27). EEG, electroencephalography; KSS, Karolinska Sleepiness Scale; PSG, polysomnography.

Measures

Self-report questionnaires

Demographic information

Participants answered questions about their demographic characteristics, including their age, sex, marital status, education, occupation, shift types, and health-related habits.

Morningness-Eveningness Questionnaire

The MEQ developed by Horne and Ostberg in 1976[19] and validated by Park and Seo in 1996[20] was used to examine the circadian rhythm of participants. The MEQ comprises 19 items: 5 on a 5-point Likert scale and 14 on a 4-point Likert scale. The total score ranges from 16 to 68, with scores of 16−41 classified as evening type, 42−58 as intermediate type, and 59−68 as morning type.

Karolinska Sleepiness Scale

The KSS was developed by Akerstedt and Gillberg[13] to measure subjective sleepiness, and evaluates the current level of sleepiness using a 9-point scale: 1=extremely wide awake; 2=very wide awake; 3=wide awake; 4=relatively wide awake; 5=not awake, but not sleepy either; 6=signs of sleepiness; 7=sleepy, but not trying to stay awake; 8=sleepy, but trying to stay awake; and 9=very sleepy, and fighting to stay awake. A higher KSS score indicates a higher current level of sleepiness.

Stanford Sleepiness Scale

The single-item SSS was developed by Hoddes et al.[21] to measure subjective sleepiness, and evaluates the current level of sleepiness using a 7-point scale: 1=feeling active, vital, alert, or wide awake; 2=functioning at a high level, but not at peak, but still able to concentrate; 3=awake but relaxed, responsive, but not at full alertness; 4=a little foggy; 5=foggy, beginning to lose interest in remaining awake, and slowed down; 6=sleepy, preferring to be lying down, fighting sleep, and woozy; and 7=almost in reverie, sleep onset soon, and having lost the struggle to remain awake. A higher SSS score indicates a higher current level of sleepiness.

Objective measures

Polysomnography

PSG was conducted to measure sleep-related variables, including SOL and other physiological indicators of sleepiness. PSG was performed using the Embla N7000 device (Medcare-Embla, Reykjavik, Iceland) with six EEG recording electrodes (C3-A2, C4-A1, F3-A2, F4-A1, O3-A2, and O2-A1), four electrooculography electrodes, and one chin electromyography electrode to measure the stage of sleep and alert frequency. Also, thoracic and abdominal movements were monitored using two plethysmography belts, and nasal and oral airflows were measured using a nasal pressure transducer and thermistor. In addition, oxygen saturation was measured using pulse oximetry on the index finger, and abnormal breathing or movements during sleep were monitored using synchronized video monitoring. Finally, two bilateral anterior tibialis electromyography electrodes were attached to measure leg movements, while body-position sensors, electrocardiography, and video recording were recorded to identify behavioral or posture disturbances during sleep. PSG data were scored in accordance with the method reported by the American Academy of Sleep Medicine. From these measures, the duration of each sleep stage, latency to reach each sleep stage, total sleep time, sleep efficiency, oxygen desaturation index, apnea hypopnea index (AHI), and arousal index were collected.

Electroencephalography

At the start of the study, six EEG electrodes were attached at C3, C4, F3, F4, O1, and O2 according to the international 10−20 system.[22] Resting-state EEG was performed in the eye-open condition, and 5 minutes of data were used before applying the KSS. The EEG signals were sampled at 200 Hz and digitally filtered using a band-pass filter (0.3−30 Hz). The raw data were re-referenced to the average reference.

The records were inspected visually, with 2-s epochs containing artifacts removed before further analysis. The power spectrum was calculated using the fast Fourier transform for every 2-s epoch of artifact-free EEG data. The power densities were calculated in the delta (0.5−3.9 Hz), theta (4−7.9 Hz), alpha (8−13.9 Hz), and beta (14−30 Hz) frequency bands. MATLAB (version R2021b, The MathWorks, Natick, MA, USA) was used for the EEG analysis, and the EEGLAB toolbox was used for preprocessing and spectrum analysis.[23]

Statistical analyses

All statistical analyses were conducted using SPSS (version 21.0, IBM Corp., Armonk, NY, USA). First, descriptive statistics and frequency analysis were used to analyze the demographic characteristics and produce mean±standard deviation values of the measured variables. Second, repeated-measures analysis of variance (ANOVA) was conducted to examine the changes in KSS scores over time. Third, convergent validity of the KSS was confirmed by performing a Spearman correlation analysis between the KSS and SSS scores at the same time point. Fourth, concurrent validity of the KSS was confirmed by performing a Spearman correlation analysis between the KSS score obtained before bedtime and the

SOL calculated through PSG. Fifth, the relationship between KSS scores and alpha waves was examined by performing a Spearman correlation analysis between the KSS score measured during EEG recordings and alpha waves calculated from EEG. Sixth, the relationship between the KSS scores and alpha waves was examined by performing a Spearman correlation analysis between difference score of the KSS from three time points and difference score of alpha waves from the same three time points.

RESULTS

Demographic information

The participants were aged 40.5±7.7 years and included 22 males. Descriptive statistics are presented in Table 1. The AHI was 17.6±20.4/hour, and 16 (59.3%) of the participants had an AHI of >5/hour.

Table 1. Demographic characteristics and sleep indices (*n*=27)

Variable	Value
Age (yr)	40.52±7.68
Sex	
Male	22 (81.5)
Female	5 (18.5)
Education	
High school	1 (3.7)
College/university	14 (51.9)
Graduate	11 (40.7)
No answer	1 (3.7)
Physiological tool	
PSG	
SOL (minutes)	5.52±4.60
TST (minutes)	317.15±36.04
SE (%)	89.59±9.42
ODI (per hour)	13.24±15.55
AHI (per hour)	17.57±20.43
Mild	7 (25.9)
Moderate	2 (7.4)
Severe	7 (25.9)
AI (per hour)	19.90±11.21
Self-report measures	
KSS score	3.30±1.41
SSS score	2.26±0.53
Sleep variables	
KSS score, before sleep	7.15±1.70
SOL (minutes)	5.52±4.60

Data are mean±standard deviation or *n* (%) values.
AHI, apnea hypopnea index; AI, arousal index; KSS, Karolinska Sleepiness Scale; ODI, oxygen desaturation index; PSG, polysomnography; SE, sleep efficiency; SOL, sleep onset latency; SSS, Stanford Sleepiness Scale; TST, total sleep time.

Changes in KSS scores over time

The KSS scores for the different time points are presented in Fig. 2. These scores increased with the time since waking, peaked at 24:00, and were lower after waking (07:00) than before sleep (24:00) (p<0.001). The Greenhouse-Geisser ε was applied in the repeated-measures ANOVA because the test of sphericity (W=0.23, χ^2=35.11, p<0.01) was violated. The KSS score differed significantly with the measurement time point [F(5,130)=29.54, p<0.001, η^2=0.53], being higher at 20:00 than at 18:00 (p<0.001), and higher at 24:00 than at 22:00 (p<0.05). However, the difference between the scores measured at 16:00 and 18:00 and at 20:00 and 22:00 was not significant (p=0.465 and 0.294, respectively). The results of specific analyses are presented in Table 2 and Fig. 2.

Correlation of the KSS and SSS

The Spearman correlation analyses revealed a significant positive correlation between the KSS and SSS scores measured at the same time point (16:00) (r=0.742, p<0.01).

Concurrent validity of the KSS

The Spearman correlations between KSS scores administered before sleep (24:00) and SOL measured using PSG were de-

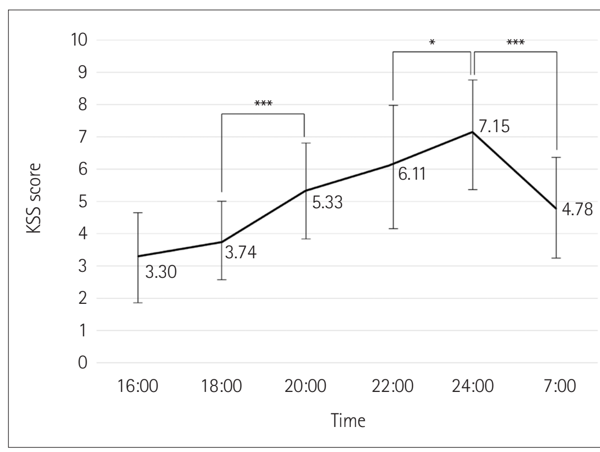

Fig. 2. Changes in KSS scores over time (*n*=27). *p<0.05; ***p<0.001. KSS, Karolinska Sleepiness Scale.

Table 2. Changes in KSS scores over time (*n*=27)

	Mean±SD	F	Bonferroni
16:00 (1)	3.30±0.27	29.54***	5>3=4=6>1; 5>3=4>2
18:00 (2)	3.74±0.23		
20:00 (3)	5.33±0.28		
22:00 (4)	6.11±0.36		
24:00 (5)	7.15±0.33		
07:00 (6)	4.78±0.30		

***p<0.001.
KSS, Karolinska Sleepiness Scale; SD, standard deviation.

Table 3. Correlations between KSS scores and alpha waves (n=27)

	KSS	α (O1)	α (F3)	α (C3)
KSS	1			
α (O1)	0.371	1		
α (F3)	0.294	0.766**	1	
α (C3)	0.141	0.709**	0.656**	1
Mean±SD	6.20±1.35	5.95±3.12	5.36±2.85	2.62±1.67

**p<0.01.
α, alpha wave; C3, left central area; F3, left frontal area; KSS, Karolinska Sleepiness Scale; O1, left occipital area; SD, standard deviation.

Table 4. Correlations between difference scores for KSS scores and alpha waves (n=26)

	d (KSS)	d (O1α)	d (F3α)	d (C3α)
d (KSS)	1			
d (O1α)	0.224	1		
d (F3α)	0.209	0.755**	1	
d (C3α)	0.056	0.517**	0.580**	1
Mean±SD	0.91±1.01	-0.11±1.16	-0.29±1.43	-0.24±0.92

**p<0.01.
α, alpha wave; C3, left central area; d, difference score; F3, left frontal area; KSS, Karolinska Sleepiness Scale; O1, left occipital area; SD, standard deviation.

termined. The results indicated a significant negative correlation between KSS scores and SOL, with higher levels of sleepiness being negatively associated with shorter time to fall asleep (r=-0.456, p<0.05).

Correlation between KSS scores and alpha waves

Alpha waves were measured by EEG, yielding 78 EEG data files after excluding 3 data files that were affected by errors in the EEG measurements. Correlations between KSS scores and alpha waves measured in the left occipital area (O1), left frontal area (F3), and left central area (C3) were not significant (p=0.057, 0.137, and 0.484, respectively) (Table 3).

Spearman correlation analyses were conducted between the difference scores for KSS scores and alpha waves (Table 4). No significant correlation was observed between the difference scores for KSS scores and alpha waves measured at O1, F3, and C3 (p=0.271, 0.307, and 0.785, respectively).

DISCUSSION

This study examined the validity of the Korean version of the KSS in adults aged 30−66 years. Although the KSS is the only tool to measure sleepiness that has been validated by demonstrating its association with physiological indicators, this validation had not been in South Korea. This study aimed to validate the Korean version of the KSS by demonstrating its association with objective measures (PSG and EEG) and self-report measure (SSS). The main findings indicate that KSS scores increased significantly over time with increasing sleep pressure and propensity for sleepiness. There were also strong correlations with already established subjective (e.g., SSS) and objective (e.g., SOL from PSG) indicators. However, we did not find any associations with alpha waves.

Psychometric properties of the KSS

We found that KSS scores increased with the time since waking, with significant differences in KSS scores measured between 18:00 and 20:00, between 22:00 and 24:00, and between 24:00 and 07:00. This is consistent with previous studies showing that levels of sleepiness increased with the time since waking and decreased after sleep.[24,25] In addition, studies of the typical pattern of sleepiness have found that the level of sleepiness is relatively high in the morning, then decreases before increasing again during the evening, to reach its highest level before sleep.[26-28] The same pattern of sleepiness was found in a large-scale study using the KSS.[29] Despite the relatively small sample in the present study, the results were consistent with those obtained in the previous studies. It is meaningful that the KSS is a sensitive tool for measuring changes in sleepiness.

Additionally, the KSS demonstrated adequate validity relative to using a well-established subjective measure: the SSS. The KSS and SSS are often considered the gold standards for assessing sleepiness.[30] However, previous KSS validation studies have not examined both scales, and few studies have examined the relationship between KSS and SSS scores. Our study results showed that KSS and SSS scores are correlated, which is consistent with the few previous findings.[30]

There was also a strong correlation between the KSS score and SOL measured by PSG. In this study, KSS scores and SOL were negatively correlated, which is consistent with a previous study.[31] SOL is the sleep indicator produced by PSG that has been used to indicate sleepiness.[32] Objective sleepiness is defined as how quickly a person can fall asleep when they are provided with an adequate opportunity for sleep, which can be captured by the sleep latency. SOL is considered an objective measure of sleepiness, since it has been shown to be correlated with brain waves associated with sleepiness, such as alpha and delta waves,[32] and also with subjective sleepiness.[33,34] Previous KSS validation studies have determined the validity of the KSS by correlating KSS scores with physiological indicators such as EEG and the psychomotor vigilance task,[13-15] but few studies have performed PSG.[31] The present study is meaningful due to it yielding an estimate of the correlation between KSS scores and physiological indicators measured by PSG.

KSS scores and alpha-wave attenuation

Finally, an exploratory examination found no significant correlation between KSS scores and alpha waves, nor between d values of the KSS and alpha waves at the time of measurement. Waves in the alpha EEG frequency band are predominantly present in relaxed states and are associated with sleepiness. Specifically, relationships between increased alpha waves with eyes open, decreased alpha waves with eyes closed, and increased sleepiness have been demonstrated.[16,35-39]

However, alpha waves can be reduced in some situations, notably during exposure to visual, auditory, and somatosensory (senses other than the eyes and ears) stimuli and when performing complex tasks. This phenomenon is known as "alpha blocking."[40-42] In addition, it has been found that alpha waves tend to be lower during the presentation of audiovisual stimuli than in a no-stimulus condition.[43-47] Previous KSS validation studies have demonstrated a correlation between sleepiness and alpha waves using standardized tests such as the AAT and the Karolinska drowsiness test (KDT).[13-15] In contrast, EEG measurements were made while watching TV in the present study, and it is likely that the associated visual and auditory stimuli caused "alpha blocking" and decreased alpha waves. Therefore, the design of this study might have been responsible for no association being found between alpha waves and KSS scores, and so carefully interpretation of the results is necessary.

Limitations

The limitations of this study and suggestions for future research include the following: First, the generalizability of the present results is restricted by the small number of participants. It is therefore necessary to further validate the results in larger numbers of participants in follow-up studies.

Second, most (81.5%, n=22) of the participants in this study were male, which further restricts the generalizability of the results, and so future studies should also include larger female samples.

Third, the KSS scores were collected through six repeated measurements in this study. This is smaller than the 12–25 repeated measurements performed in previous studies,[14,15] and the number of KSS scores responded to by each participant did not vary, which restricted the ability to identify the physiological characteristics of KSS scores. It is therefore necessary to demonstrate differences in sleep-related indicators based on KSS scores through larger numbers of repeated measurements (as in previous studies) to verify concurrent validity and further identify the physiological characteristics of each score.

Finally, most previous studies that have validated the KSS used the AAT and KDT to demonstrate the relevance of alpha waves. However, EEG was performed in this study in a situation where external stimuli were present, such as watching TV. Therefore, it is necessary to use a standardized method such as the AAT to confirm the relationship between KSS scores and alpha waves in future studies.

The KSS has an advantage over other sleepiness questionnaires in that it is a validated scale that has been demonstrated to be relevant to physiological indicators. However, this scale had not been validated in South Korea. We confirmed high convergent validity between the KSS and the SSS that measures sleepiness. In addition, this study has demonstrated the concurrent validity of the KSS by correlating its scores with PSG measurements. We analyzed the changes in KSS scores over time, and found that they increased with the time since waking. These results demonstrate that the KSS is a valid tool for measuring sleepiness and is useful for sensitively evaluating changes in sleepiness.

Because the KSS can rapidly measure the current level of sleepiness with a single question, it has been used in various contexts such as shift work,[48-51] driving ability,[52] jet lag,[53] driving performance,[52] and attention and performance,[54-56] and is widely used in research and clinical settings. Our validation of the Korean version of the KSS will allow it to be used not only in clinical settings but also in various other settings where sleepiness measurements are required.

Availability of Data and Material

The datasets generated or analyzed during the study are not publicly available due to patient confidentiality but are available from the corresponding author on reasonable request.

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Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

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