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Original article

Relationship of sleep quality and sleepiness state with antisaccade performance in healthy young individuals having no sleep deprivation

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Abstract. *Study Objectives:* It is a fact that sleep affects the function of many brain regions. Clinical and / or experimental sleep and sleep deprivation studies are not easy to implement, as they require both participants and researchers to spend long periods in the laboratory or clinic. Often, the clinician or researcher uses subjective methods to obtain information about the quality of sleep that patients or participants have. For this purpose, the Pittsburgh Sleep Quality Index (PSQI) and the Epworth Sleepiness Scale (ESS) are frequently used. In this study, it is aimed to present concrete neurobiological evidence by testing whether there is a correlation between the data obtained with these subjective methods, which are frequently used in the clinic and the saccadic eye movements of healthy and young individuals. *Methods:* Eye movements were recorded by using the electrooculographic method and PSQI and ESS scores were determined by questionnaire method from 48 healthy (31 male and 17 female) individuals between 18-25 years of age. *Results:* There was a positive correlation between the PSQI scores and antisaccade spatial errors, a negative correlation between ESS scores and maximum saccade velocities, and a positive correlation between ESS scores and the number of antisaccade directional errors. *Conclusion:* it may be considered that sleep quality and sleepiness state can effect the saccadic system antisaccade paradigm in young individuals who have not been diagnosed with any psychiatric, neurological, and systemic diseases before and who have not had acute sleep deprivation for at least the past three days.

Key Words: sleep quality, sleepiness, antisaccade

Introductıon

Low quality and non-relaxing sleep or insufficient sleep, in terms of time and the state of daytime sleepiness, decreases the quality of life. It leads up to occupational and traffic accidents and can cause material damages, injuries, and even deaths. Since the sleep duration that individuals need is long for laboratory studies and participants are reluctant to spend at least one night at a laboratory without having clinic needs, it becomes inevitable to use the subjective tests that the participants themselves grade the duration and quality of the sleep experiences they have. Therefore, subjective tests have often been used in clinic and scientific studies.

It has been reported in previous studies that sleep disorder causes attention decrease and affects many cognitive processes related to sensory perception negatively and memory while a good night's sleep has positive effects on cognitive performance (1). A recent study reports that some cognitive processes, especially attention and working memory, are associated with antisaccade performance (2). In many studies using neuroimaging methods, it is stated that visual spatial attention mechanism and wakefulness level are arranged by attention neural circuits in the frontoparietal cortex (3,4). Brain regions where dysfunction is reported in sleep deprivation to involve the superior colliculus, known to provide saccadic eye movements, dorsolateral prefrontal cortex, and frontal eye field (5,6).

The saccadic system is the neural integration that moves eyeballs rapidly to collect visual information from the environment as fast as possible. A visual stimulus formed in the periphery of the retina starts a visual grasp reflex and creates visually guided saccades by creating the eye movement that transfers this image to the fovea. However, the saccadic system does not always need a visual stimulus. It can produce memory-guided saccades by moving eyeballs again to a point previously fixed – even there is no visual target -. Moreover, it can create a reverse antisaccade by suppressing the visual grasp reflex started by a visual target formed in the periphery of the retina. Healthy working of the eye movements, which saccadic system can create voluntarily and stimulus independent and even by suppressing the effect of the stimulus, play a great role in directing eyeballs to the place requiring to be focused on at the right time and in avoiding potential dangers, as it is in driving. A factor that harms this system will make individuals defenseless against accidents in daily life or some high risk practices. Antisaccade paradigm can reveal golden findings since related brain fields have mostly been unveiled because producing an antisaccade includes the processes of suppressing visual grasp reflex firstly, then a vector calculation in the reverse side of the spatial position of this visual information (voluntary saccade planning), and lastly creating a voluntary saccade with the inhibition of the neurons providing fixation. Antisaccade failure in patients with frontal lobe lesion is a symptom revealed long ago (7). It is known that disruptions occur not only in structural brain damages but also in psychiatric diseases such as affective disorders, obsessive compulsive disorder, and schizophrenia (8). Therefore, it is thought that disruptions in the antisaccade paradigm can indicate structural or functional disruptions in related brain fields.

The especially superior colliculus is an important center in the occurrence of saccadic eye movements. While fixation neurons in the rostral of the superior colliculus inhibit the movement neurons in their caudals, they are under inhibition of the neurons at the same time (9). Fixation neurons in the rostral of the superior colliculus inhibit movement neurons through omnipause neurons, and omnipause neuron activity decreases considerably in sleep deprivation (10). The superior colliculus is also under the control of some cortical fields. These fields are mainly dorsolateral prefrontal cortex (DLPF), frontal eye field in the premotor cortex (FEF), and supplementary eye field in the parietal cortex (SEF) (11). In addition, thalamus, putamen, and superior parietal cortex activities are high during antisaccade (12,13). Neuronal connections coming from the frontal cortex to the superior colliculus use sources from the neurons showing attention and mnemonic activity at the same time (14). One of the structures forming the last common pathway of the saccadic system subcortically is paramedian pontine reticular formation, and it plays role in coding saccade velocity. A dysfunction in the brainstem reticular formation is likely to affect the velocity of any kind of saccadic eye movements in this way (5).

Although it is difficult to assess the neurological effects of acute sleep deprivation, it is possible and there are many studies in the literature related to this issue. However, assessment of the low sleep quality that individuals are exposed without a change in their daily lives or the daytime sleepiness state that they experience, widely necessitates the practice of subjective tests. No study discussing whether these tests, which provide important information for physicians in clinic practices, are different in the voluntary eye movement in healthy young individuals having no neuropsychological complaint was found in the literature. In this study, it is aimed to investigate the relationships of PSQI scores, which is an indicator of the sleep quality of individuals, and ESS scores, which is the indicator of daytime sleepiness state with antisaccade parameters without creating sleep deprivation. Antisaccade paradigm has been discussed in this study for two reasons; 1) As the antisaccade-generating neuronal mechanism includes visual suppression, voluntary saccade planning, and the prosaccade mechanism, it may be more sensitive to negativities such as low sleep quality and sleepiness. 2) deterioration in antisaccades may make individuals more open to risks such as traffic or occupational accidents whether they are due to the failure in suppressing the visual stimulus or the failure in planning a voluntary saccade.

Materıals and Methods

Participants

A total of 48 volunteers aged between 18 - 25 (20.42 ± 1.99), 31 men and 17 women, participated in this study. Volunteers were selected from students studying at various faculties of Erciyes University. Those who had any neurological, psychiatric, chronic, and autoimmune disease history, had taken any medication with a neurological effect or alcohol in the past 48 hours or had been on a long journey that could disrupt their sleep patterns, had used a sedative, a tranquilizing or stimulating chemical in the past year, and smokers were not included in the study. None of the participants had brain/eye trauma or brain injury or surgery history. The participants were asked to have at least 6 hours of sleep for the last three nights until the study day. All measurements were made between 12: 00 - 14: 00 at the same time of the day to standardize the differences arising from the circadian rhythm.

The study was conducted in accordance with the Helsinki Declaration, the approval of each participant was obtained, and an informed voluntary consent form was filled in by each participant.

Eye Movements Recording

Binocular horizontal eye movements were recorded by the Biopac MP30 system electrooculography method. Records were made using disposable adhesive Ag / AgCl surface electrodes to the lateral canthus one for each eye and one to the center of the forehead, a total of three electrodes. To reduce the electrode impedances as much as possible, the oil or makeup in the electrode areas was cleaned with ethyl alcohol. During the test, the head was fixed using the chin stabilizer to prevent the participant from moving his head, and the participants with refractive errors were ensured to wear glasses. To create a visual stimulus, a computer-driven LED panel located 2 m from the participant was used. A total of five LEDs were used on the panel, one for the common point, four for the 10 degrees, and 20 degrees of eye movements on the left and right.

Calibration and Antisaccade Procedure

At the beginning of the test, each participant was asked to look at the LED lit, and starting with the LED in the middle, 10- and 20-degree LEDs to the right and left were lit five times, and the calibration records were taken. After the calibration, participants were asked to look at the reverse side of the LED lit, and each LED on the left was lit 20 times by waiting for a period between 1 and 3 seconds that the computer selected randomly, therefore each participant was ensured to create 80 antisaccades. When each LED lit, the previous LED was turned off simultaneously, and the gap and overlap paradigm was not performed. Antisaccades before and after 80ms stimulus delivery and after 500ms and the following antisaccades were not evaluated. Saccades occurring in the direction of the stimulus (even they have corrected afterward) were accepted as antisaccade direction errors. Antisaccade spatial error was calculated as the absolute difference of expected and occurring eye movement in degree.

PSQI and ESS

Epworth Sleepiness Scale (ESS) has been developed to be able to assess how often individuals fall asleep at specific circumstances frequently experienced in daily life, and accordingly, to what extent they have the state of sleepiness. It is used to express the state of sleepiness as a numerical value (15). Individuals grade their daily experiences with this 8-question scale, and ESS total score is obtained in this way. A high score of ESS indicates a high state of daytime sleepiness (16).

Pittsburgh Sleep Quality Index (PSQI) has been designed as a valid, reliable, and standardized scale to assess the quality of sleep, and it has been used in clinic and scientific fields for a long time. using this scale, the sleep qualities of the participants can be expressed as index values. This 24-question test also ensures to assess 7 different components related to sleep quality (17).

The sleep qualities of the participants were assessed by using the PSQI Turkish version of which validity and reliability study had been performed. It is a subjective method that the participants themselves evaluate (18). The daytime sleepiness levels of the participants were assessed ESS Turkish version of which validity and reliability study had been performed (16).

Statistical Analysis

Statistical analyzes were done using SPSS 22.0 software. Pearson correlation analyses were performed to test the linear relationship between PSQI and ESS scores and antisaccade parameters, and the confidence limit was determined as 95%. All variables were tested for normality, which was assumed when skewness and kurtosis were between -1 and +1.

Results

The descriptive statistics of age, ESS, PSQI, and antisaccade parameters of the volunteers participating in the study were introduced in Table 1.

As a result of the linear correlation analysis performed with ESS, there was a negative and statistically significant relationship between 100 antisaccade mean velocity (r =0.472, p<0.01) (see Figure 1), there was a negative and statistically significant relationship between the 100 antisaccade maximum velocity (r=0.303, p<0.05), and 200 antisaccade maximum velocity (r=0.329, p<0.05) (see Figure 2 and Table 2).

There was a positive and statistically significant relationship between total antisaccade direction error and ESS (r=0.315, p<0.05) (see Figure 3 and Table 2).

As a result of the linear correlation analysis performed with PSQI scores, it was determined that there was a moderate and positive correlation only between the total PSQI scores of the participants and 20-degree antisaccade absolute spatial error (r=0.454, p<0.05) (see Figure 4 and Table 3).

The strongest correlation between total PSQI scores and subcomponents was found as "subjective sleep quality" (r=0.739, p<0.01) and "daytime dysfunction" (r=0.769, p<0.01). There was no correlation between PSQI and ESS scores (r=0.055, p>0.05).

Discussion and Conclusion

Previous studies conducted by creating sleep deprivation revealed that sleep deprivation had a

Table 1. Descriptive statistics of the results.

	Mean±SD	Unit
Females/Males	17/31	
Age	20,42±1,99	years
ESS Score	6,58±3,44	
PSQI Score	3,71±2,04	
Antisaccade Direction Error	13,90±8,29	
10° Antisaccade Spatial Error	1,98±1,62	°
20° Antisaccade Spatial Error	3,19±2,08	°
10° Antisaccade Latency	225,57±24,94	msec
20° Antisaccade Latency	214,57±24,88	msec
10° Antisaccade Mean Velocity	190,08±40,16	° / sec
20° Antisaccade Mean Velocity	226,58±28,38	° / sec
10° Antisaccade Maximum Velocity	343,95±66,14	° / sec
20° Antisaccade Maximum Velocity	346,47±80,75	° / sec
N	48	

ESS: Epworth Sleepiness Scale, PSQI: Pittsburg Sleep Quality Index

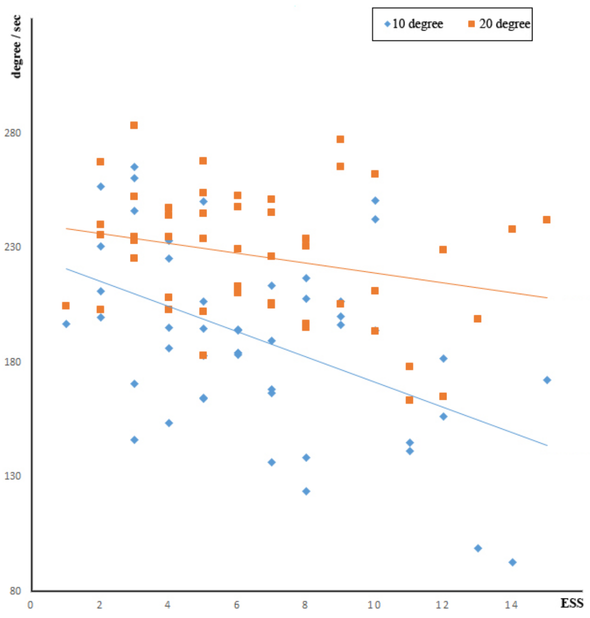

Figure 1. The relationship between Epworth Sleepiness Scale (ESS) scores and antisaccade mean velocity

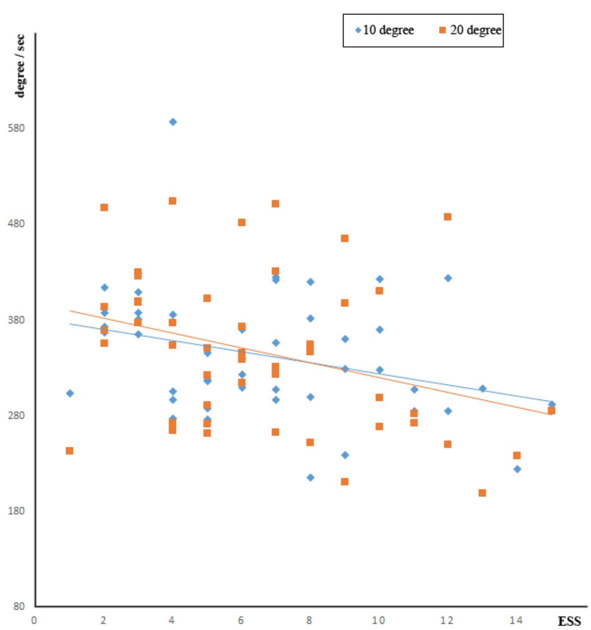

Figure 2. The relationship between Epworth Sleepiness Scale (ESS) scores and antisaccade maximum velocity

Table 2. Correlations of ESS scores with antisaccade parameters.

	df	F	r
Direction Error	1,46	5.071	*0.315
10° Spatial Error	1,46	0.672	0.118
20° Spatial Error	1,46	1.318	0.167
10° Latency	1,46	0.617	0.114
20° Latency	1,46	1.503	0.179
10° Mean Velocity	1,46	13.184	*0.472
20° Mean Velocity	1,46	3.359	0.261
10° Max Velocity	1,46	4.666	*0.303
20° Max Velocity	1,46	5.558	*0.329

ESS: Epworth Sleepiness Scale, df: Degree of Freedom, *: Statistically significant correlation (P<0,05), r: Pearson correlation coefficient.

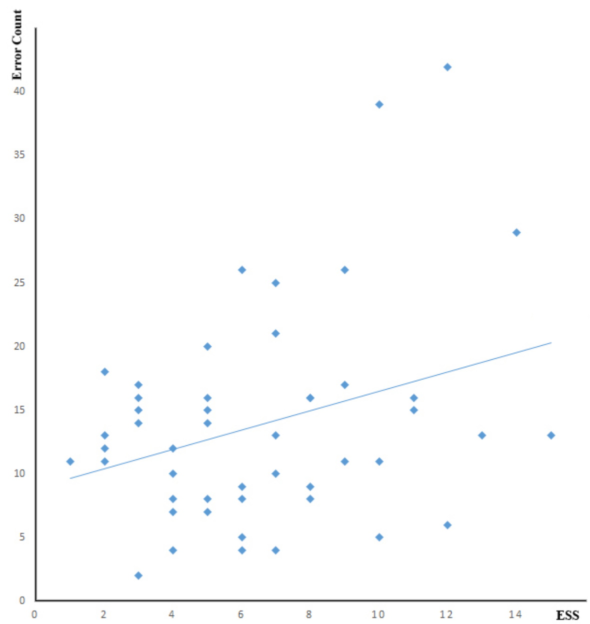

Figure 3. The relationship between Epworth Sleepiness Scale (ESS) scores and antisaccade direction error count

significant effect on the saccadic system (5,19,20). In this study, the sleepiness states and sleep qualities of young individuals who had slept at least 6 hours regularly for three days before the study day without creating sleep deprivation were determined through subjective methods, and the correlations between these parameters and antisaccade performances were investigated. It was seen that PSQI scores did not have a significant relationship with antisaccade mean velocity, latency, and direction error. Although it is a common finding that antisaccade mean velocity is affected by

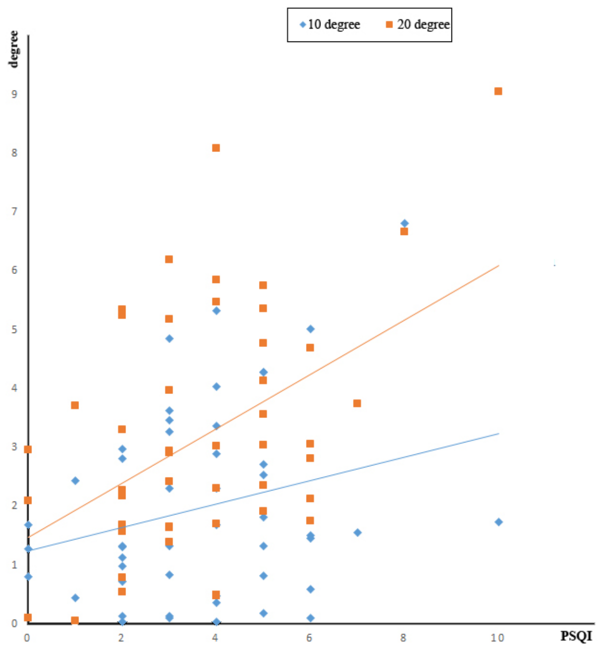

Figure 4. The relationship between Pittsburg Sleep Quality Index (PSQI) scores and absolute antisaccade spatial error

Table 3. Correlations of PSQI scores with antisaccade parameters.

	df	F	r
Direction Error	1,46	2.111	0.210
10° Spatial Error	1,46	3.073	0.251
20° Spatial Error	1,46	11.936	*0.454
10° Latency	1,46	2.219	0.214
20° Latency	1,46	0.814	0.130
10° Mean Velocity	1,46	1.886	0.197
20° Mean Velocity	1,46	0.589	0.114
10° Max Velocity	1,46	1.276	0.164
20° Max Velocity	1,46	1.518	0.179

PSQI: Pittsburg Sleep Quality Index, df: Degree of Freedom, *: Statistically significant correlation (P<0,05), r: Pearson correlation coefficient

sleep deprivation (5,20), the effect of sleep deprivation on latency is conflictive. It was also reported in previous studies that antisaccade direction error and spatial error were affected by sleep deprivation (21). Since the total PSQI score is the compound of the seven sub-components related to sleep quality, it cannot be expected to provide information about sleep deprivation directly. This can be the possible reason that our findings do not have a statistical correlation with total PSQI scores. On the other hand, it is an interesting finding in this study that although there is a significant relationship between total PSQI scores and antisaccade spatial error, there is no significant relationship between them and antisaccade direction error number (reflexive saccade). Two main components of the antisaccade mechanism are the inhibition of the reflexive response to visual stimulus and programming a voluntary saccade in the opposite direction (22). This situation suggests that the effect represented by PSQI scores may not on the mechanism of suppressing visual stimulus, but on the mechanism of antisaccade programming. The more interesting finding in this study is that the correlation between antisaccade spatial error and PSQI scores are significant in 20 degree but not significant in 10 degree of antisaccades. The regions responsible for the occurrence of antisaccades at the cortical level are DLPF, FEF, and SEF (11). Inputs from these three centers are needed for antisaccades to be coded in prefrontal working memory (11). These regions, which are often reported to be affected by acute sleep deprivation (5,6), may also be affected by sleep quality, which can be expressed by the PSQI total score. The decrease in the accuracy in antisaccades with wider amplitude is thought to arise from the decrease in the working memory performance of the prefrontal region. On the other hand, studies indicating that antisaccade accuracy is not affected in sleep deprivation (5).

The fact that the PSQI scores did not show any correlation with the remaining antisaccade parameters may have resulted from the limited range of PSQI scores since the volunteers who participated in our study were healthy individuals. Note that since total PSQI scores showed strong relation to “subjective sleep quality” and “daytime dysfunction” subcomponents, these subcomponents could be largely responsible for relationships between PSQI scores and antisaccade spatial error.

It is seen that antisaccade parameters had a correlation with ESS scores more than PSQI scores. No correlation was found between ESS scores and 100 and 200 antisaccade latencies. Although studies reporting that antisaccade latency changed with sleep deprivation (21,23) there are also studies stating the opposite (5,24).

In this study, gap and overlap paradigms were not performed while creating antisaccade. Therefore, the latency of the antisaccades created in this study includes both suppressing visual grasp reflex and voluntary saccade programming processes. That is to say that the amount of time these two processes require appears not to be affected by sleep quality or sleepiness state. Inconsistent results in terms of the relationship between antisaccade latency and sleep deprivation in the literature need to be confirmed by studies with more participants.

Although a negative relationship was found between ESS scores and 100 antisaccade mean velocity, no significant relationship was found between 200 antisaccade mean velocity. However, for both angles, the negative correlation between maximum velocity and ESS was significant. The disappearance of the correlation between the mean saccade velocity and ESS score with the increase in the amplitude of the antisaccade is an unexpected finding, and it seems very difficult to make a satisfactory explanation for its reason. In 20-degree antisaccades, the occurrence of negative correlation between maximum velocity and ESS and the absence of correlation with mean velocity may indicate that saccade acceleration is affected by ESS. It is previously reported that saccade acceleration might be affected by sleep deprivation (25). The decrease in antisaccadic maximum velocity in sleep deprivation and low wakefulness level is a case supported by prevalent literature findings (5,25,26). In addition, findings are available stating maximum saccade velocity does not change in sleep deprivation (6). It suggests that the fact that the correlation between PSQI scores and antisaccade maximum velocity not being significant may arise from a possible sleepiness state created by acute sleep deprivation and it may not be affected by the longtime decrease in sleep quality. The correlation between maximum saccadic velocity and ESS scores (also, the correlation with 10-degree mean velocity) may arise from the role of the brainstem reticular formation, which is known to have a great role in arranging wakefulness, in coding saccade velocity (5).

It is reported that the cognitive performance that is low in the morning increases towards noon but starts to decrease after lunch (27). Therefore, all measurements were made between 12: 00-14: 00 and before lunch to minimize the effects of the circadian rhythm on the findings obtained from the study. Since the participants were asked to sleep at least 6 hours at the last three nights before the study to eliminate the effects of possible acute sleep deprivation, it can be stated that the findings in this study were affected by ESS and PSQI scores as much as possible.

ESS is a scale providing subjective information about daytime sleepiness state (15) and PSQI provides subjective information about sleep quality (17). Although daytime sleepiness level and sleep quality seem to be related concepts, it is reported that they are not affected by each other (28). The effect of sleep deprivation on cognitive processes has been discussed in several studies (1); consistent and inconsistent a lot of findings have been obtained. The saccadic system and especially antisaccade paradigm are under the control of cortical regions such as the dorsolateral and ventrolateral prefrontal cortex, which is also responsible for visual-spatial attention, supplementary visual field, frontal visual field, and anterior cingulate cortex (11,13,29). These cortical fields are among those reported to be affected by sleep deprivation (6,20). Russo et. al. (2003) states in their study, which they created 3-week partial sleep deprivation, that structural deteriorations could occur in these brain fields (20). Especially increase in antisaccade error number and latency prolongation may indicate function disorders in the parietal cortex (12). It is known that superior colliculus and brainstem reticular formations of the parietal visual field in the posterior parietal cortex and frontal visual field in the premotor cortex project to the fields related to the saccade (30). The reticular formation controlling the level of wakefulness may also be effective on the saccadic system as well as the possible dysfunction expected in the cortical areas with sleep deprivation may be effective. This suggests that the region responsible for saccadic maximum velocity changes correlated with ESS in our findings may be lower than the cortical level, further studies are needed to evaluate brainstem level functioning.

Limitations of the Study

Since the volunteers who participated in the study were healthy young individuals, ESS and PSQI scores were in a limited range. Supporting these findings in further studies to include individuals having higher ESS and PSQI scores is necessary to generalize. It should be remembered that the attention and cognitive levels of the participants were not measured in the study and that individual differences might have an impact on the results. Whether the participants had a psychiatric or neurological disease was evaluated not by a specialist examination, but by the medical history of the participants. The participants were all from different faculties, and when their different exam programs and different study habits are taken into consideration, their answers to ESS and PSQI may be periodic.

Conflicts of interest: The author declares that there is no conflict of interest in this manuscript.

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