KBB Uygulamaları 2025;13(3):153-161

Original Article / *Özgün Makale*

The effect of chronic sleep deprivation on postural sensory organization

Kronik uyku yoksunluğunun postüral duyusal organizasyon üzerindeki etkisi

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ABSTRACT

Objectives: This study aims to examine the effect of chronic sleep deprivation on postural sensory organization.

Patients and Methods: The study included 39 healthcare professionals (23 males, 16 females; mean age: 29.9±5.6 years; range, 26 to 32.5 years) who had worked at a hospital for at least one year and were assigned to either 16-h night shifts (n=20) or regular 8-h daytime shifts (n=19) between March 2022 and June 2022. Evaluations were performed at baseline and at the end of the study. Fatigue evaluations were made by a Visual Analog Scale. Postural sensory organization (somatosensory, visual, and vestibular) and stability limits were evaluated by computed dynamic posturography.

Results: There was no difference between groups in terms of prestudy fatigue, postural sensory organization, and stability limits (p>0.05). Poststudy fatigue values were higher in both groups compared to prestudy values (p<0.05). Anteroposterior and mediolateral somatosensory, visual, and vestibular values and stability limits test values were lower in the night-shift group (p<0.05). Poststudy anteroposterior somatosensory and vestibular test values were lower in the daytime group (p<0.05). The night-shift group had higher poststudy fatigue and lower postural sensory organization and stability limits values compared to the daytime group (p<0.05).

Conclusion: Although sleepiness and fatigue levels can be evaluated subjectively, such assessments may not reflect the true physiological state of the tired person.

Keywords: Chronic sleep deprivation, posturography, somatosensory, vestibular, visual.

ÖZ

Amaç: Bu çalışmada, kronik uyku yoksunluğunun postural duyusal organizasyon üzerindeki etkisi incelendi.

Hastalar ve Yöntemler: Çalışmaya Mart 2022 - Haziran 2022 tarihleri arasında en az bir yıldır hastanede 16 saatlik gece vardiyasında (n=20) ya da gündüz 8 saatlik çalışma düzeninde (n=19) çalışan 39 sağlık çalışanı (23 erkek, 16 kadın; ort. yaş: 29.9±5.6 yıl; dağılım, 26-32.5 years) yıl) dahil edildi. Değerlendirmeler çalışmanın başlangıcında ve sonunda yapıldı. Yorgunluk değerlendirmeleri Görsel Analog Skalası ile yapıldı. Postüral duyu organizasyonu (somatosensöriyel, vizüel ve vestibüler) ve stabilite limitleri bilgisayarlı dinamik postürografi ile değerlendirildi.

Bulgular: Çalışma öncesi gruplar arasında yorgunluk, postüral duyu organizasyonu ve stabilite limitleri açısından fark yoktu (p>0.05). Her iki grupta çalışma sonrası yorgunluk değeri çalışma öncesine kıyasla daha yüksekti (p<0.05). Gece vardiyalı çalışma grubunda çalışma sonrası anteroposterior ve mediolateral somatosensöriyel, vizüel ve vestibüler değerler ile stabilite limitleri test değerleri daha düşüktü (p<0.05). Gündüz çalışan grupta çalışma sonrası anteroposterior somatosensöriyel ve vestibüler test değerleri daha düşüktü (p<0.05). Gece vardiyalı çalışma grubu, çalışma sonunda sabit çalışma grubuna kıyasla daha yüksek yorgunluk, daha düşük postüral duyu organizasyonu ve stabilite limitleri değerlerine sahipti (p<0.05).

Sonuç: Uykusuzluk ve yorgunluk seviyeleri subjektif olarak değerlendirilebilmesine rağmen, bu tür değerlendirmeler yorgun kişinin gerçek fizyolojik durumunu yansıtmayabilir.

Anahtar sözcükler: Kronik uyku yoksunluğu, posturografi, somatosensör, vestibüler, vizüel.

Received: December 15, 2024
Accepted: September 30, 2025
Published online: October 24 2025

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Doi: 10.5606/kbbu.2025.29981

Citation:
Yılmaz T, Baran E. The effect of chronic sleep deprivation on postural sensory organization. KBB Uygulamaları 2025;13(3):153-161. doi: 10.5606/kbbu.2025.29981.

Chronic sleep issues are common in some occupational groups (e.g., soldiers, police officers, and health workers), where the shift work system is applied. However, since this way of working is against the biological rhythm of the person, it can cause disruption in the sleep-wake cycle, and thus, may cause many mental and physical health problems.[1,2] When sleep quality deteriorates, besides attention/memory and mood disorders, normal working efficiency decreases and occupational safety may be endangered.[3]

In addition to the disruption of the circadian rhythm, sleep issues, and decreased sleep quality, symptoms normally associated with drunkenness such as loss of coordination and deterioration in reasoning and reaction time can be observed in shift workers.[4,5] Similarities between fatigue and drunkenness have been demonstrated in driving simulation studies. It has been found that those who drive after 17 to 19 h of wakefulness have worse driving performance than those with 0.05% blood alcohol level.[6]

Despite the high prevalence of shift work and sleep deprivation, few studies have examined balance-coordination problems caused by sleepiness. It has been reported that prolonged night sleep deprivation and monotonous and prolonged tasks slow down the reaction time[7] and impair postural stability[5,8] in healthy volunteer participants. Narciso et al.[3] found in 20 night workers that the 12-h night shift system and sleepiness had a negative impact on the postural and psychomotor vigilance performance. Since no control group working daytime hours was included in these studies, it was not possible to make a complete conclusion about the results. Therefore, the current study aimed to examine the fatigue level, postural sensory organization, and stability limits of health workers working 16-h night shifts and those working 8-h daytime shifts in a university hospital.

PATIENTS AND METHODS

This prospective study was conducted with 39 healthcare professionals (23 males, 16 females; mean age: 29.9±5.6 years; range, 26 to 32.5 years) at Necmettin Erbakan University Ear Nose Throat Clinic between March 2022 and June 2022. Sixty participants were initially assessed, and 21 were excluded for not meeting eligibility criteria (Figure 1). The inclusion criteria were as follows: being aged 20 to 45 years, being a healthcare worker (nurse, doctor, or health technician) in a hospital, working 16-h shifts at night (between 16:00 and 08:00) or 8 h daytime (between 09:00 and 17:00) for at least one year, being physically inactive,[9] having a body mass

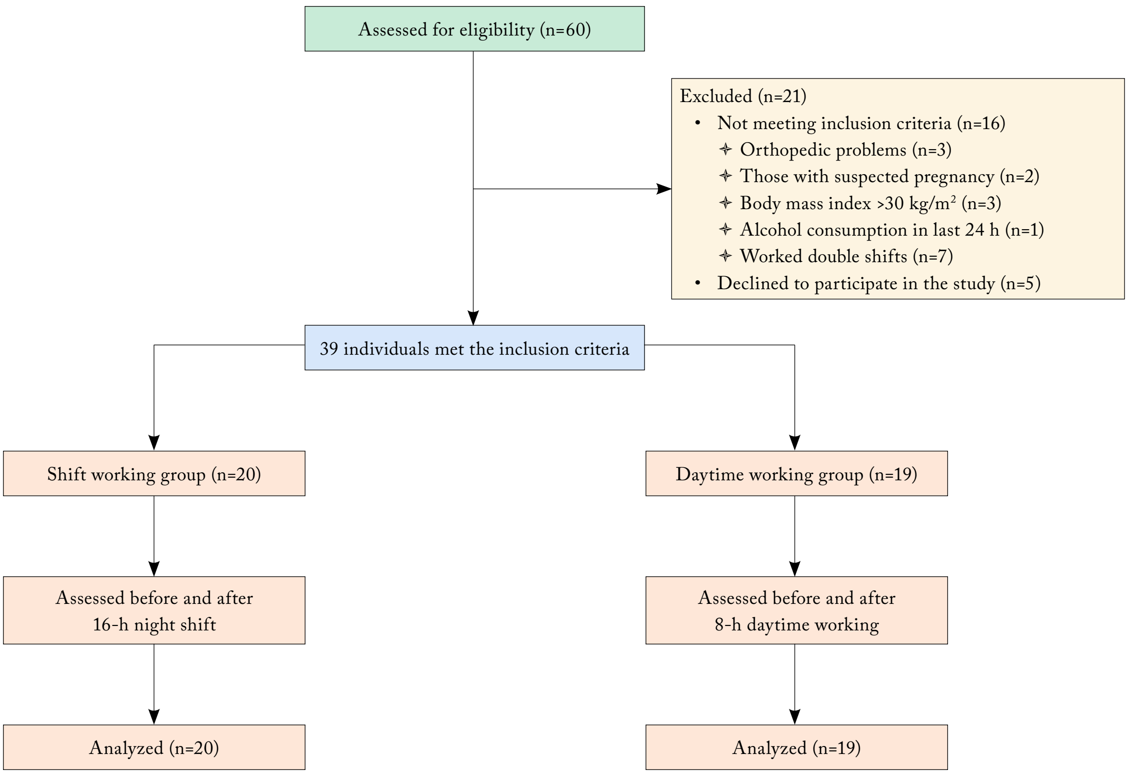

Figure 1. Flow chart of the participants.

index (BMI) <30 kg/m^2, not performing activities that would cause fatigue before the study, and volunteering to participate in the study. Those working double shifts (intermittently involved in both day and night shifts); those who sleep during the shift; those who drink alcohol at least 24 h before the measurements; those with hearing, visual impairments, neurological, orthopedic, rheumatologic, mental, or any systemic chronic diseases; those who were pregnant or suspected of pregnancy; and those who had any pain or discomfort during the assessments were excluded from the study. Written informed consent was obtained from all participants. The study protocol was approved by the Necmettin Erbakan University Noninvasive Ethics Committee (Date: 04.03.2022, No: 2022/3689). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Evaluations were made before the health workers daily shift (day or night) and after they finished their shift. Those working shifts for 16 h at night were included in the night-shift group (n=20), and those working 8 h daytime were included in the daytime group (n=19). Detailed demographic, physical, and medical information of the participants were recorded.

A 10-cm Visual Analog Scale (VAS) was used to evaluate participants' fatigue levels, with 0 indicating no fatigue and 10 indicating extreme fatigue.[10] Participants were asked to mark the point on the scale corresponding the level they felt closest to their prestudy and poststudy fatigue levels.

The Synapsys Posturography System (Synapsis, Marseille, France) was used for computerized dynamic posturography. In this study, sensory organization tests and the limits of stability test were performed. All posturography tests were performed in a quiet room (Figure 2).[11] Sensory organization tests are the gold standard test for postural control, and they evaluate the function and integration of somatosensory, visual, and vestibular senses in relation with balance.[12,13] These tests were used to identify abnormalities in the somatosensory, visual, or vestibular systems that affect postural control and to compare the location of these systems on postural control. The system consisted of a platform, a video projector, and a computer. Combinations of fixed platform/foam, eyes open/closed, and fixed visual surround/oscillating visual surround variables were used to modify sensory conditions. Tests under each different sensory condition consisted of 20-sec periods, and each test was performed twice. Sensory organization test values from somatosensory, visual, and vestibular systems were automatically analyzed by the system and converted to numerical values between "0" and "100." Higher scores indicated better postural control. The scores obtained from the somatosensory, visual, and vestibular systems provided information about the participants' ability to stay in balance using these sensory systems.[11,14]

The limits of stability test, a measurement tool of dynamic postural control, was used to assess the participant's ability to control their center of gravity on the support surface. During the test, the platform was stationary, and the eyes of the participants were open. During the test, the participants were asked to move the center of pressure as much as possible by moving forward, backward, right, or left by only moving from the ankle joint, without lifting their feet, without stepping, and without falling. Participants were instructed not to twist their trunk or make arm movements to maintain balance during the test. Three pressure sensors on the floor of the device detected the pressure centers. A diagram of the scanned areas was created by the displacement of the center of pressure on the platform, and this area was automatically calculated by the system as the limits of the stability value.[11,15]

Figure 2. Postural sensory organization and starting position on the posturography device in the limits of stability test.

Statistical analysis

Statistical analyses were performed with the IBM SPSS version 22.0 software (IBM Corp., Armonk, NY, USA). The conformity of the data to the normal distribution was determined using visual and analytical methods. Nonnormally distributed data were presented with median and interquartile range. Categorical data were given as numbers and percentages. The Mann-Whitney U test was used to compare the groups in terms of age, BMI, fatigue, postural sensory organization, and limits of stability test values. The chi-square test was used to compare the groups in terms of the data presented as ratios (e.g., sex). The Wilcoxon signed-rank test was used to compare the values of fatigue, postural sensory organization, and limits of stability before and after the study in each group. A p-value <0.05 was considered statistically significant.

A power analysis was performed using the G*Power version 3.1 software (Heinrich-Heine Universität Düsseldorf, Düsseldorf, Germany). The post hoc power analysis (n=39) of the Mann-Whitney U test for poststudy anteroposterior somatosensory values between the groups achieved a power of 95%, with an effect size of 0.54 and a significance level of <0.001.

RESULTS

The mean BMI was 24.0±2.9 kg/m^2. The groups had a similar distribution in terms of age, BMI, and sex (p>0.05; Table 1).

When the groups were compared in terms of prestudy fatigue, postural sensory organization, and limits of stability test values, there was no statistically significant difference between the groups (p>0.05; Table 2). When each group was compared in terms of fatigue, postural sensory organization, and limits of stability test data before and after the study, statistically significant differences were observed (p<0.05; Table 3). Poststudy fatigue values were higher in the night-shift group compared to prestudy values (p<0.001). In the night-shift group, poststudy

Table 1
Demographic and physical characteristics of the participants

	Shift group (n=20)				Daytime group (n=19)					
	n	%	Median	IQR	n	%	Median	IQR	Z	*p*
Age (year)			30.0	28.0-31.7			29.0	26.0-32.5	–1.526	0.134
Body mass index (kg/m^2)			23.4	22.5-26.2			23.6	21.6-25.0	–0.338	0.749
Sex									χ^2=1	0.576
Female	8	40			8	42.1				
Male	12	60			11	57.9				

IQR: Interquartile range; Z: Mann-Whitney U test value; χ^2: Chi-Square test value.

Table 2
Intergroup comparison of baseline fatigue and posturography data

	Shift group (n=20)		Daytime group (n=19)			
	Median	IQR	Median	IQR	Z	*p*
Fatigue (cm)	1.5	0.8-2.2	1.5	0.6-2.2	–0.366	0.728
Posturography values						
AP somatosensory	99.0	95.0-100.0	100.0	98.0-100.0	–0.809	0.478
AP visual	90.5	81.0-99.0	91.0	85.0-95.0	–0.367	0.728
AP vestibular	75.0	66.0-81.7	81.0	78.0-84.0	–1.936	0.054
ML somatosensory	99.5	98.0-100.0	99.0	94.0-100.0	–0.798	0.461
ML visual	89.0	82.0-95.0	92.0	91.0-96.0	–1.385	0.175
ML vestibular	80.0	74.0-82.0	83.0	79.0-86.0	–1.271	0.214
LOS	26.0	20.0-32.0	29.0	23.0-34.0	–0.706	0.496

IQR: Interquartile range; AP: Anteroposterior; ML: Mediolateral; LOS: Limits of stability; Z: Mann-Whitney U test value.

anteroposterior somatosensory, visual, and vestibular test values were lower than prestudy values (p<0.001, p<0.001, p=0.002, respectively). In the night-shift group, poststudy mediolateral somatosensory, visual, and vestibular test values were lower than prestudy values (p=0.006, p<0.001, p<0.001, respectively).

Table 3
Intragroup comparison of fatigue and posturography data before and after the study

	Shift group (n=20)		Daytime group (n=19)			
	Median	IQR	Median	IQR	Z	*p*
Shift group						
Fatigue (cm)	1.5	0.8-2.2	6.5	4.5-8.5	–3.920	<0.001*
Posturography values						
AP somatosensory	99.0	95.0-100.0	85.0	81.0-93.2	–3.903	<0.001*
AP visual	90.5	81.0-99.0	75.5	74.0-81.0	–3.540	<0.001*
AP vestibular	75.0	66.0-81.7	59.0	49.0-70.0	–3.032	0.002*
ML somatosensory	99.5	98.0-100.0	96.5	91.0-97.0	–2.740	0.006*
ML visual	89.0	82.0-95.0	77.5	64.0-73.0	–3.745	<0.001*
ML vestibular	80.0	74.0-82.0	73.0	64.0-73.0	–3.824	<0.001*
LOS	26.0	20.0-32.0	19.5	15.0-22.0	–3.954	<0.001*
Daytime group						
Fatigue (cm)	1.5	0.6-2.2	4.9	4.3-5.6	–3.825	<0.001*
Posturography values						
AP somatosensory	100.0	98.0-100.0	97.0	93.0-99.0	–2.214	0.027*
AP visual	91.0	85.0-95.0	90.0	84.0-95.0	–0.871	0.383
AP vestibular	81.0	78.0-84.0	68.0	62.0-86.0	–2.018	0.044*
ML somatosensory	99.0	94.0-100.0	99.0	96.0-100.0	–1.355	0.176
ML visual	92.0	91.0-96.0	88.0	85.0-94.0	–1.553	0.12
ML vestibular	83.0	79.0-86.0	78.0	70.0-86.0	–1.169	0.243
LOS	29.0	23.0-34.0	28.0	20.0-33.0	–1.639	0.101

IQR: Interquartile range; AP: Anteroposterior; ML: Mediolateral; LOS: Limits of stability; Z: Wilcoxon Signed Ranks test value.

Table 4
Intergroup comparison of post-study fatigue and posturography data

	Shift group (n=20)		Daytime group (n=19)			
	Median	IQR	Median	IQR	Z	*p*
Fatigue (cm)	6.5	4.5-8.5	4.9	4.3-5.6	–2.152	0.03*
Posturography values						
AP somatosensory	85.0	81.0-93.2	97.0	93.0-99.0	–4.061	<0.001*
AP visual	75.5	74.0-81.0	90.0	84.0-95.0	–4.204	<0.001*
AP vestibular	59.0	49.0-70.0	68.0	62.0-86.0	–2.141	0.033*
ML somatosensory	96.5	91.0-97.0	99.0	96.0-100.0	–3.415	<0.001*
ML visual	77.5	64.0-73.0	88.0	85.0-94.0	–4.183	<0.001*
ML vestibular	73.0	64.0-73.0	78.0	70.0-86.0	–2.497	0.013*
LOS	19.5	15.0-22.0	28.0	20.0-33.0	–3.047	0.002*

IQR: Interquartile range; AP: Anteroposterior; ML: Mediolateral; LOS: Limits of stability; Z: Mann-Whitney U test value.

In the night-shift group, poststudy limits of stability test values were lower than prestudy values ($p<0.001$). Poststudy fatigue values were higher in the daytime group compared to the prestudy values ($p<0.001$). Poststudy anteroposterior somatosensory and vestibular test values were lower in the daytime group compared to prestudy values ($p=0.027$, $p=0.044$, respectively). There was no significant difference between prestudy and poststudy anteroposterior visual, mediolateral somatosensory, visual, and vestibular test values and limits of stability test values ($p>0.05$; Table 3).

When the groups were compared in terms of poststudy fatigue, postural sensory organization, and limits of stability test values, there was a statistically significant difference between the groups ($p<0.05$; Table 4). Poststudy fatigue values were higher in the night-shift group compared to daytime group ($p=0.03$). Poststudy anteroposterior somatosensory, visual, and vestibular test values were lower in the night-shift group compared to the daytime group ($p<0.001$, $p<0.001$, $p=0.033$, respectively). Poststudy mediolateral somatosensory, visual, and vestibular test values were lower in the night-shift group compared to the daytime group ($p<0.001$, $p<0.001$, $p=0.013$, respectively). Poststudy limits of stability test values were lower in the night-shift group compared to the daytime group ($p=0.002$).

DISCUSSION

This study examined the fatigue level, postural sensory organization, and stability limits in healthcare workers working 16-h night shifts or 8-h daytime shifts in a university hospital. Poststudy somatosensory, visual, and vestibular test values were lower in the night-shift group compared to the daytime group. While the poststudy limits of stability test values were lower in the night-shift group compared to the daytime group, their poststudy fatigue values were higher. Studies have shown that sleepiness causes deterioration in the integration of vestibular, visual, and somatosensory data, and therefore, sways increase in the upright position. Increases in upright sways have been associated with some vestibular and visual mechanisms. It has been interpreted that body sways may increase due to the decrease in the adaptation ability of the individual against the optical shift that occurs following sways occurring in the upright position due to sleeplessness.[16] Sways begin as a result of the decrease in the components of the balance system of sleep loss; consequently, sensory receptors are activated to restore the balance, leading to muscle activity that further increases sway.[17]

In a study investigating the effect of sleepiness on postural control with repeated tests at different times, it was stated that sleepiness had a progressively greater impact on the postural system with increasing hours of sleep deprivation.[18] Contrary to this study, in a study in which postural control was evaluated at 24 and 36 h of sleep deprivation, it was determined that while the deterioration of postural stability of sleep deprivation was significant compared to the baseline, further sleepiness did not affect the results.[3] Similarly, in a study examining the effect of sleepiness on postural control at 24 and 36 h, it was stated that while postural control was significantly affected at 24 h, the effect was lower after 36 h.[8] However, it should be noted that postural control may change similarly at certain times of the day due to the circadian rhythm.[19] One of the limitations of our study was that we made the measurements at different times in the comparison between the two groups. In night-shift workers, the first measurement was made at 16:00, and the second measurement was made at 8:00. In daytime workers, the first measurement was made at 8:00, and the second measurement was made at 17:00. Due to the different working hours of the two groups, we think that the results may have been affected by the circadian rhythm in the evaluation we made at different hours.

There are studies evaluating the effects of sleepiness on performance capacity and postural control.[20-23] Although sleepiness and fatigue levels can be evaluated subjectively, such an assessment may not reflect the objective physiological state of the tired person because the answers of the person can be affected by personal factors such as education level, sociocultural level, and experiences.[24] In a study in which the postural balance was evaluated in two different situations (eyes open and eyes closed) on a stable surface, the authors stated that postural sway increased with sleepiness, but the changes in the eyes open state were statistically significant, while the changes in the eyes closed state were not statistically significant.[18] Contrary to this study, many studies have reported that postural sway in sleepiness and fatigue increases significantly, particularly in eyes closed test situations.[20-23] Contrary to the study of Fabbri et al.,[18] the difference observed in our study with eyes closed was consistent with those reported in other studies.

In a study examining the effect of 24-h total sleep loss on oculomotor reactions in healthy young males, sleepiness affected saccade latencies and smooth pursuit gains but not the accuracy of the saccades.[25] In the study of Batuk et al.,[26] in which they applied postography to adults with acute sleep deprivation for

24 h, a significant decrease was observed in visual, somatosensory, and vestibular scores. In another study in which the effects of short-term sleepiness on vestibulo-ocular reflex (VOR) were evaluated according to the vestibular evoked myogenic potentials (VEMP) test results, ocular VEMP testing was associated with VOR, and cervical VEMP testing was associated with VSR.[27] The study concluded that the VOR mechanism was affected, while the VSR mechanism was not affected. Albathi and Agrawal[28] conducted a study in 20,950 patients with vestibular system-related vertigo complaints, and reported that 30% of the patients had abnormal sleep durations.

It has been stated that visual processing skills are also affected by total sleep loss. The human vision system processes visual information incredibly fast, allowing us to recognize visible objects for as little as 20 msec.[29] It has been stated that the activation of the lateral occipital regions of the interparietal sulcus and extrastriate cortex decreases in the case of sleepiness. Therefore, a reduction in the number of functional cortical circuits available for processing visual information was observed after total sleep loss. Furthermore, after total sleep loss, decreases in many important visual functions have been reported, such as, processing rapidly changing visual information, processing peripheral visual information, visual selectivity, suppression of distracting visual information, and visual short-term memory.[29-32]

One way to examine the somatosensory system in postural control is to stimulate the somatosensory afferent pathways by vibration given to the leg muscles,[33-36] which results in increased activation of muscle spindle afferents.[37] Information about stretching is sent to the central nervous system. Increased activity from the muscle spindles results in an illusion of proprioceptive movement, and tonic stretch reflexes appear.[38] To restore the balance, sensory receptors are activated and create muscle activity, and sways increase due to this muscle activity.[17] There are also studies in which total sleep loss is examined over the median nerve of the somatosensory system. In a study examining the effects on median nerve somatosensory early and medium latency evoked potentials after one night of sleep deprivation, it was stated that sleep deprivation caused changes in excitatory and inhibitory cortical activity.[39]

In a study conducted with athlete university students, they found that the limits of stability values increased with the decrease in the level of fatigue and the values of limits of stability were the lowest when they were most tired.[40] In our study, while the end-of-work fatigue level was higher in both groups, the limits of stability values were lower. In addition, the fatigue level was higher and the limits of stability value was lower in the night-shift group compared to the daytime group.

This study had some limitations. Firstly, although the study aimed to investigate the effects of chronic sleep deprivation on postural sensory organization, the actual sleep duration and quality of the participants were not objectively measured through validated tools such as actigraphy or polysomnography. Consequently, the assumption of sleep deprivation was based solely on shift duration rather than individual sleep data, which may have influenced the internal validity of the findings. Secondly, the timing of the pre- and post-assessments differed between the shift-working and daytime-working groups. Specifically, the measurements in the shift group were conducted at 16:00 and 08:00, while the measurements in the daytime group were performed at 08:00 and 17:00. This discrepancy introduces a potential confounding effect due to circadian rhythm variations, as postural control may naturally fluctuate over the course of the day.

In conclusion, in the assessment of sensory organization components, the posturography device is applicable in estimating the effects of sleepiness and fatigue secondary to sleepiness in shift workers. Although sleepiness and fatigue levels can be evaluated subjectively, such assessments may not reflect the real physiological state of the tired person, as the answers of the individual can be affected by personal factors, such as education level, sociocultural level, and occupation. Therefore, reliable and practical measurement tools and concrete strategies should be adopted to prevent or reduce sleepiness during and after a night-shift. We believe that a series of measures should be taken by considering the visual, vestibular, and somatosensory systems to prevent work and traffic accidents caused by sleepiness and long shifts, particularly in healthcare workers.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Idea/concept, design, writing the article, critical review: T.Y., E.B.; Control/supervision, analysis and/or interpretation: E.B.; Data collection and/or processing, literature review: T.Y.

Conflict of Interest: The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding: The authors received no financial support for the research and/or authorship of this article.

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