Original Article

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How Sleep Quality Affects Postural Control?

Uyku Kalitesi Postural Kontrolü Nasıl Etkiler?

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ABSTRACT

Objective: We aimed to investigate how sleep quality affected postural control in medical and dental students.

Methods: One hundred twenty eight volunteer students with right hemispheric dominance participated in the study. Participants were divided into good and poor sleep quality groups based on their Pittsburgh Sleep Quality Index (PSQI) scores. A force platform was used for bipedal balance analysis. Participants were asked to remain upright and motionless on the platform and their body oscillations were recorded for 30 seconds in this position. Balance analysis was performed in two conditions, with eyes open and closed.

Results: There was no statistically significant difference between the demographics of the two groups. The PSQI medians of the good and poor sleep quality groups were 4 (minimum: 1, maximum: 4) and 7 (minimum: 5, maximum: 14), respectively. In the open-eye test, no significant difference was found between the two groups in any of the data. In the test performed with the eyes closed, the deviation of the center of pressure on the Y-axis and the force transferred to the anterior part of the foot on the left side were higher in the group with poor sleep quality. Parallel to this, the force transferred to the posterior part of the foot on the left side was also lower in the same group.

Conclusion: Sleep quality did not affect balance with eyes open, but negatively affected balance with eyes closed. The balance of force transferred to the non-dominant foot of the group with poor sleep quality was impaired.

Keywords: Balance analysis, sleep quality, postural control, Pittsburgh Sleep Quality Index

ÖZ

Amaç: Tıp ve diş hekimliği öğrencilerinde uyku kalitesinin postüral kontrolü nasıl etkilediğini araştırmayı amaçladık.

Yöntemler: Çalışmaya tamamı sağ el dominant olan 128 gönüllü öğrenci katıldı. Katılımcılar, Pittsburgh Uyku Kalitesi İndeksi (PUKİ) puanlarına göre iyi ve kötü uyku kalitesi olanlar olarak iki gruba ayrıldı. Bipedal denge analizi için kuvvet platformu kullanıldı. Katılımcılardan platform üstünde dik bir şekilde hareketsiz kalmaları istendi ve bu pozisyondayken 30 saniye boyunca vücut salınımları kaydedildi. Denge analizi gözler açık ve kapalı olacak şekilde iki koşulda yapıldı.

Bulgular: İki grubun demografik özellikleri arasında istatistiksel olarak anlamlı bir fark yoktu. Uyku kalitesi iyi olan ve kötü olan grupların PUKİ medyanları sırasıyla 4 (minimum: 1, maksimum: 4) ve 7 (minimum: 5, maksimum: 14) idi. Gözler açık yapılan teste, iki grup arasında verilerin hiçbirinde anlamlı fark bulunmadı. Gözler kapalı yapılan testte uyku kalitesi kötü olan grupta basınç merkezinin Y ekseni üzerindeki sapması ve sol tarafta ayağın ön bölümüne aktarılan kuvvet daha yüksekti. Buna paralel olarak sol tarafta ayağın arka bölümüne aktarılan kuvvet de aynı grupta daha düşüktü.

Sonuç: Gözler açıkken uyku kalitesi dengeyi etkilemezken, gözler kapalıyken olumsuz yönde etkiledi. Uyku kalitesi kötü olan grubun dominant olmayan ayağına aktarılan kuvvet dengesi bozuldu.

Anahtar Sözcükler: Denge analizi, uyku kalitesi, postural kontrol, Pittsburgh Uyku Kalitesi İndeksi

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Introduction

Sleep, which accounts for one-third of our lives, is an important physiological need and factor in daily performance and productivity (1). During sleep, consciousness is lost, and organic activities and voluntary muscle movements are reduced. This state is temporary and returns at regular intervals (2). During sleep, the body rests, renews, and prepares for an active life (3). Sleep quality is defined as the individual's satisfaction with sleep (4). After a good night's sleep, an individual feels fit and ready for the new day (3). Sleep quality includes quantitative aspects of sleep, such as sleep latency, duration, and the number of awakenings per night, as well as subjective aspects, such as depth of sleep and relaxation (5). Poor sleep quality, attention and memory deficits, emotional lability, hallucinations, and delusions may be observed. Accordingly, work life, social life, economic status, general health, and mental status may be affected (6). In studies that investigated the sleep quality of university students, sleep problems were common among first-year students (7) and young medical students (8). This situation negatively affects individuals' academic and physical performance (8-11). Some studies assess postural control to understand the physical effects of sleep disturbance (11-13). Postural control refers to the body's ability to maintain its position in space. It plays an important role in many activities of daily living, such as standing, moving, and reaching (11,14). The necessary information for maintaining balance in standing is obtained from the physiological system, which includes vestibular, proprioceptive, and visual elements, and the protection of balance is maintained by the coordinated work of the neuromuscular system (15,16). In their study on patients with Parkinson's disease, Gallea et al. (17) found that the pedunculopontine nucleus network was associated with postural control and sleep disturbances. They found that functional connectivity of the pedunculopontine nucleus and anterior cingulate cortex decreased in patients with sleep disturbances (17). How sleep quality affects these systems is not fully understood. Some studies stated a strong relationship between sleep disturbance and postural control (18). This relationship was linear, and it was suggested that poor sleep was related with poor postural control.

We need our ability to control posture in almost all activities of daily living (11). However, in the modern world, sleep problems, whether young or old, affect all groups (7,8,19). In particular, most young people, whom we consider healthy, suffer from sleep problems (20). In our study, we aimed to investigate the effect of sleep quality on postural control in medical and dental students by measuring balance with objective measurement tools. In addition, unlike the studies in the literature, we evaluated how the dominant side was affected by sleep quality in balance analysis.

Methods

The Ethics Committee approved this cross-sectional study for Scientific Research of the Faculty of Medicine of Trakya University under the Declaration of Helsinki (decision no: 06/04, date: 16.03.2020). The study was conducted in the Laboratory of Motion Analysis of the Faculty of Medicine of Trakya University University, Department of Anatomy. Subjects were divided into two groups: those with good sleep quality and those with poor sleep quality.

Participants

The number of volunteers to participate in the study was set at 64 for each group using the G*Power program (version: 3.1.9.7) (effect size: 0.5, alpha: 0.05, power: 0.8). Healthy volunteers (55 men, and 73 women) from medical and dental schools participated in our study. Those who had a medical condition that could affect balance or were taking medications that could affect sleep status and those who had left hemispheric dominance were excluded from the study. All participants were right-sided dominant. The study was explained in detail to the participants, and written informed consent was obtained from the volunteers under the Declaration of Helsinki.

Pittsburgh Sleep Quality Index

The Pittsburgh Sleep Quality Index (PSQI) is a scale developed by Buysse et al. (21) to assess sleep quality over one month. While 19 of the 24 questions on the scale are answered by the individual, 5 are answered by the person with whom they share the room, if any. The questions assess seven components: subjective sleep quality, latency, duration, habitual sleep efficiency, sleep disturbance, use of sleep medication, and time-of-day disturbance (12). If the participants' calculated score is ≥5, sleep quality is labeled poor, and if the score is <5, sleep quality is labeled good.

Study Protocol

Participant demographics were collected, and participants were asked to complete the PSQI form. If the participants' calculated score is ≥5, sleep quality is labeled poor, and if the score is <5, sleep quality is labeled good. Based on the PSQI score, two groups were formed: those with good sleep quality (35 women, 29 men) and those with poor sleep quality (38 women, 26 men). Postural control data were measured every morning between 08:00 and 10:00 for three weeks.

Balance Analysis

A force platform (Zebris©, FDM system type FDM 3.5) was used for the measurements. The force platform was 158 cm long, 60.5 cm wide, and 2.5 cm high. The sensor area of the platform was 149 cm long and 54.2 cm wide. The number of sensors on the platform was 11264, and the measurement width was between 1-120 N/cm^2. The computer program WinFDM (Zebris Medical GmbH, Isny, Germany) was used to convert the information obtained from this platform into digital data and transmit it to the computer environment. Each participant was shown individually what the subjects would do during the measurement. Participants assumed an upright position on the platform with both feet on the floor and arms at their sides. The distance between the feet was not interfered; it was left to the participant's free will. An image was placed about two meters away from the participants and at eye level. The measurements were performed in two ways. First, participants were kept still on the platform by looking at the image two meters away. The recordings were taken for 30 seconds. Second, participants had the same position, looked at the same image, and then closed their eyes. Recordings were made for 30 seconds after the eyes were closed. The data we obtained from the measurements were related to the movement of the center of pressure (COP), which expressed the point where the ground reaction force acted. The data we obtained with the force measurement system were as follows.

- Confidence ellipse: An ellipse containing 95% of the points through which the COP passes during the measurement (Figure 1). The data for this ellipse is the length of the ellipse's minor axis, the length of the major axis, the angle between the long axis and the Y-axis, and the ellipse area (Figure 2).

- The data relating to the COP are the path length of the COP, the standard deviation (SD) on the X-axis, and the SD on the Y-axis (Figure 1).

- We have obtained the average load distribution of the forefoot and heel on the left and right sides and the data on the total load distribution of the left and right contact area in percent (Figure 1).

- Left/right side fore (%): The ratio of the total load on the left/right foot transferred to the forefoot (Figure 1)

- Left/right side back (%): The rate of load transferred to the heel of the left/right foot (Figure 1).

- Left/right side total (%): Percentage of total load transferred to the left/right foot (Figure 1).

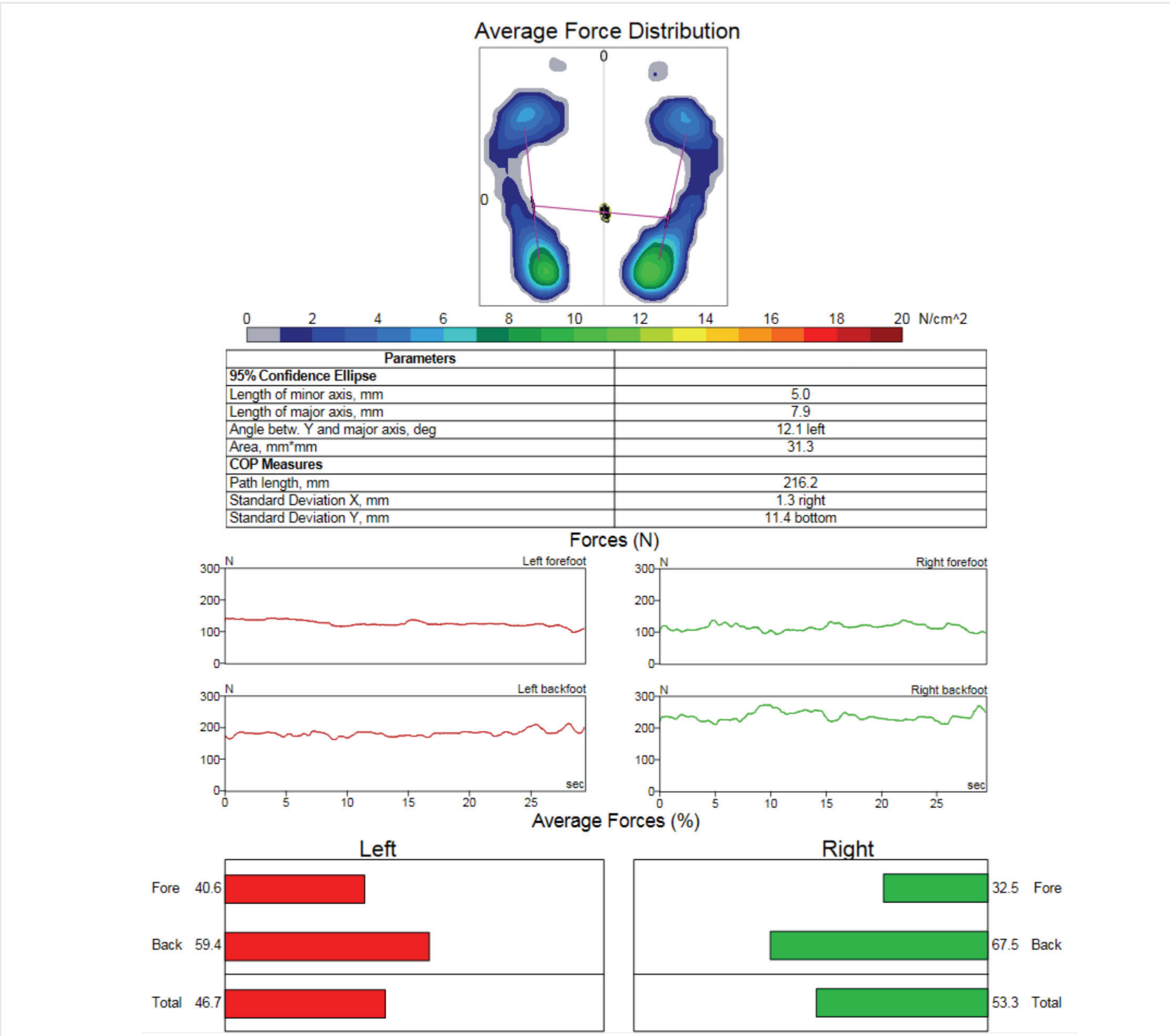

Figure 1. Data from balance analysis

Statistical Analysis

The SPSS 20.0 program (IBM SPSS software, USA) was used for statistical analysis. Results were expressed as mean ± SD, median, minimum, and maximum. The "Single Sample Kolmogorov-Smirnov Test" was used to check the conformity of the variables to the normal distribution. Comparison of weight distribution data on age, height, weight, and foot regions was performed using Student's t-test. As the data from COP did not conform to the normal distribution, the Mann-Whitney U test was used for comparisons between groups. P<0.05 was accepted as the threshold for statistical significance.

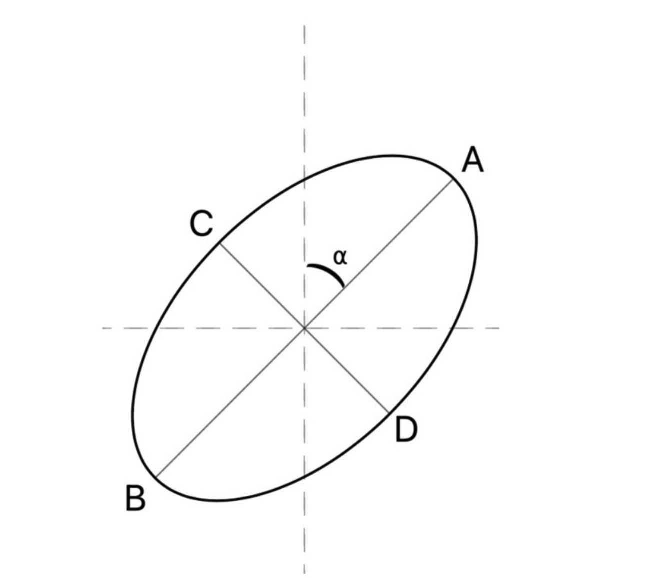

Figure 2. Confidence ellipse
A,B: Length of major axis
C,D: Length of minor axis
α: Angle between Y and major axis

Table 1. Demographic data of the participants

	Good	Poor	p-value
Age (year)	20.75±1.24	20.71±0.75	0.864
Weight (kg)	65.4±13.2	66.98±15.1	0.542
Length (cm)	169.12±8.22	171.9±8.96	0.070

Independent samples t-test was used

Results

There was no statistically significant difference between the demographics of the two groups (p>0.05) (Table 1). The PSQI medians of the good and poor sleep quality groups were 4 (minimum: 1, maximum: 4) and 7 (minimum: 5, maximum: 14), respectively.

The open-eye balance analysis found no difference between the two groups in the confidence ellipse and COP shift data. In the analysis with eyes closed, the deviation of the COP Y-axis was higher in the group with poor sleep quality (Table 2).

In the test with eyes open, no difference was found between the two groups in the pressure distribution on the foot regions. In contrast, a significant difference was found in the data for the left anterior and left posterior sides in the test performed with eyes closed. The data for the left anterior side was higher in the group with poor sleep quality than in the group with good sleep quality, and the data for the left posterior side were lower (Table 3).

Discussion

The PSQI is a commonly used and easy-to-use assessment method for evaluating sleep quality. We assessed participants' sleep quality using this index and examined its effects on postural balance. We hypothesized that poor sleep quality might negatively affect postural control. As a result of the study, we found that sleep quality did not affect balance when the eyes were open. However, when the eyes were closed, the oscillation of the COP in the anteroposterior direction was negatively affected. Poor sleep quality increased the oscillation of the COP on the Y-axis. Data on the distribution of plantar strain were also similar. There was no difference between the two groups when

Table 2. Confidence ellipse data generated by the displacement of the COP

	Eyes open			Eyes closed		
	Good sleep quality (n=64)	Poor sleep quality (n=64)		Good sleep quality (n=64)	Poor sleep quality (n=64)	
	Median (min-max)	Median (min-max)	p-value	Median (min-max)	Median (min-max)	p-value
Length of minor axis, mm	5.7 (2.8-17.7)	5.5 (1.9-11)	0.395	5 (2-13.9)	5 (1.5-12.4)	0.592
Length of major axis, mm	11.8 (4.3-46.9)	11.05 (5.9-48.5)	0.327	11.6 (5.8-25.7)	9.7 (5-53.4)	0.196
Angle between Y and major axis, deg	16.35 (0.1-89.5)	11.9 (0.1-86.3)	0.145	9.3 (0-85.3)	8.55 (0.1-75.1)	0.422
Area mm^2	52.4 (10.5-375.2)	46.8 (8.9-262.8)	0.356	45 (11.9-22.5)	37.15 (8.4-520.20)	0.318
Path length, mm	224.5 (145.2-425.6)	220.25 (125-411.9)	0.286	244.35 (139-454.8)	237.95 (146.7-392.7)	0.311
Standard Deviation X, mm	6.75 (0.3-29.8)	8.75 (0.1-32.2)	0.259	7.75 (0-33.2)	8.85 (0.5-32.7)	0.378
Standard Deviation Y, mm	7.1 (0.1-40.3)	6.6 (40.1-0.2)	0.556	5.15 (0.2-23.3)	7.65 (0-29.8)	**0.042***

Mann-Whitney U test was used. *Signifcant diferences (p<0.05) between the two groups, min: Minimum, max: Maximum

Table 3. Load distribution data on right and left side

	Eyes open			Eyes closed		
	Good sleep quality (n=64)	Poor sleep quality (n=64)	p-value	Good sleep quality (n=64)	Poor sleep quality (n=64)	p-value
Left side fore %	41.74±11.4	44.86±10.55	0.112	42.33±11.09	46.29±9.64	0.033*
Left side back %	58.26±11.4	55.14±10.55	0.112	57.67±11.09	53.71±9.64	0.033*
Left side total %	51.24±4.4	50.33±5.52	0.314	51.17±5.39	50.24±5.27	0.327
Right side fore %	43.32±12.1	44.88±9.88	0.428	45.46±10.68	45.45±10.01	0.995
Right side back %	56.68±12.1	55.12±9.88	0.406	54.54±10.6	54.55±10.19	0.995
Right side total %	48.76±4.4	49.67±5.52	0.314	48.83±5.39	49.76±5.27	0.325

Independent samples t-test was used. *Signifcant diferences (p<0.05) between two groups

the eyes were open. However, there were differences in the load ratios distributed on the anterior and posterior part of the foot on the left side when the eyes were closed. We observed that the load on the anterior part of the foot increased in the group with poor sleep quality. In ideal equilibrium, the total load distribution on the right and left sides is 50% (22). When the same side is in the load distribution of the foot, 2/3 of the load is transferred to the dorsum of the foot and 1/3 to the forefoot (22). We hypothesize that worsening this distribution ratio also increases the anterior-posterior displacement of the COP. Therefore these ratios are higher in the group with poor sleep quality. In addition, because all participants had right hemisphericdominance, we found that the non-dominant side was more affected.

Some studies investigate sleep deprivation's effects on the central nervous system (23,24). It has been observed that deactivation of the cortico-thalamic network after 24 hours of sleep deprivation alters the attentional system and functions of the prefrontal cortex (23). Sleep deprivation has been found to reduce glucose metabolism in the temporal lobes, basal ganglia, white matter, and cerebellum (24). Thomas et al. (25,26) examined the rate of glucose metabolism in brain regions during sleep deprivation. They examined participants for 72 hours at 24-hour intervals and found that the metabolic rate in the thalamus, prefrontal cortex, and posterior parietal cortex decreased at the end of the 24 hours. As the duration of sleep deprivation increased, different regions were added. At the end of 72 hours, they observed that the metabolic rate decreased in the thalamus, prefrontal cortex, posterior parietal cortex, dorsal thalamus, and medial visual cortex regions. In contrast, the metabolic rate increased in the lateral superior occipital cortex, lingual and fusiform gyrus, anterior cerebellum, and primary and supplementary motor cortex. They stated that the decrease in metabolic rate in the prefrontal-thalamic network was the reason for the decrease in alertness and cognitive performance and that the brain was involuntarily driven to the onset of sleep. They explained that the increase in metabolism in the visual and motor areas indicated that the brain struggled to stay awake. In addition, the postural control system cannot use visual input with maximum efficiency during sleep deprivation (27). Postural control is more impaired during poor sleep quality when visual input is removed (11). These changes in the central nervous system associated with sleep disruption also negatively affect postural control (27).

Postural control affects not only sleep deprivation but also sleep quality (11). Furtado et al. (11) observed that poor sleep quality negatively affected postural control, similar to sleep deprivation, which was exacerbated when the eyes were closed. They used the activity average of the least active 5-hour period daily to identify groups. The reason for this was that they argued that increased sleep movements shortened the duration of the adequate rapid eye movement sleep phase, which in turn affected postural control. They showed that at this stage, adequate regulation of muscle tone was warranted as the reason (11). The grouping method in this study differed from ours because we determined sleep quality using only PSQI scores. Nevertheless, our results were similar. We found that postural control was negatively affected in those with poor sleep quality when the eyes were closed.

There is a relationship between sleep quality and the maintenance of postural balance (12). Lack of effective sleep negatively affects postural control (28). In a study that examined postural control during a dual-task cognitive task, a positive correlation was found between sleep quality and postural control (29). Another study also found a low correlation between the two parameters and a moderate correlation when the test was performed with eyes open and closed. For this reason, the researchers recommended that the severity of the correlation should be considered before accepting the hypothesis in such studies (30). However, Saraiva et al. (31) found in their study that postural control was independent of sleep quality and that sleep quality did not affect balance.

Ensuring postural control is multifaceted, and mechanisms that integrate neural inputs are used for this purpose (12). These physiological systems include vestibular, proprioceptive, and visual elements (15,16). Studies showed that sleep deprivation caused changes in some parts of the central nervous system (23-26). However, the mechanism by which these changes affected postural control was not fully elucidated. However, these studies were related to sleep deprivation, and we did not find studies on whether sleep quality caused similar changes. Nevertheless, some studies showed poor sleep quality negatively affected postural control (12,28-30). In addition, the assessment of balance in the current studies usually evaluated the movements of the COP and did not examine the differences between the dominant and non-dominant sides in weight shifting. Our study observed that the load distribution on the non-dominant side was impaired when the eyes were closed.

Study Limitations

There are some limitations in our study. First, we assessed sleep quality using only one subjective method, the PSQI. We did not track participants' sleep habits using an objective method such as the ActiGraph. Second, we assessed the proportion of load distributed to the dominant and non-dominant sides of the participants. However, we did not separately assess the postural control of each limb by performing a balanced analysis on one leg.

Conclusion

We performed a two-leg static balance analysis with eyes open. We closed on participants divided into two groups for good and poor sleep quality based on PSQI scores. We found no effects of sleep quality on postural control for the open-eye test. In the closed-eye test, we found that the shift of COP on the Y-axis was higher in the participants with poor sleep quality. Since all participants had right hemispheric dominance, we could compare the percentage of force distribution on the dominant and non-dominant sides. The group with poor sleep quality had higher values for the left front, and correspondingly lower values for the left back. Normally, 2/3 of the load is transferred to the dorsum of the foot and 1/3 to the front of the foot. We observed that this harmony was impaired on the left side (non-dominant side) of the group with poor sleep quality. We think this deteriorated rate affects the SD of the Y data of the group with poor sleep quality and therefore is higher.

Ethics

Ethics Committee Approval: The Ethics Committee approved this cross-sectional study for Scientific Research of the Faculty of Medicine of Trakya University under the Declaration of Helsinki (decision no: 06/04, date: 16.03.2020).

Informed Consent: The study was explained in detail to the participants, and written informed consent was obtained from the volunteers under the Declaration of Helsinki.

Authorship Contributions

Surgical and Medical Practices: M.K., Concept: M.K., M.P., Design: M.K., M.P., D.D.A., Data Collection or Processing: M.K., M.P., E.U., M.S., D.D.A., Analysis or Interpretation: M.K., E.U., Literature Search: M.K., M.P., E.U., M.S., Writing: M.K., M.P., E.U., M.S., D.D.A.

Conflict of Interest: No conflict of interest was declared by the authors.

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