# Investigation of the Relationship between Vestibular Disorders and Sleep Disturbance

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## Abstract

**Introduction**    Vestibular pathologies cause physical and psychological symptoms, as well as cognitive problems.

**Objective**    To evaluate the deterioration in sleep quality associated with vestibular pathologies.

**Methods**    The Dizziness Handicap Inventory (DHI), the Beck Depression Inventory (BDI), the Pittsburgh Sleep Quality Index (PSQI), and the Limits of Stability test (LOS) were applied to the participants.

**Results**    We included 25 patients with Meniere's disease (MD), 22 patients with benign paroxysmal positional vertigo (BPPV), 21 patients with unilateral peripheral vestibular loss (UPVL), 23 patients with vestibular migraine (VM), and 43 controls. The total PSQI scores of the controls were better than those of the MD ($p = 0.014$), VM ($p < 0.001$), BPPV ($p = 0.003$), and UPVL ($p = 0.001$) groups. The proportion of poor sleepers in the MD ($p = 0.005$), BPPV ($p = 0.018$), and UPVL ($p < 0.001$) groups was significantly higher than that of the controls. The highest total DHI score ($45.68 \pm 25.76$) was found among the MD group, and it was significantly higher than the scores of the BPPV ($p = 0.007$) and control ($p < 0.001$) groups. The highest BDI score was obtained in the VM group, and it was significantly higher than the scores of the BPPV ($p = 0.046$) and control ($p < 0.001$) groups. Moreover, the BDI scores of the MD ($p = 0.001$) and UPVL groups were also significantly worse than the score of the controls ($p = 0.001$).

**Conclusion**    The present study showed that presents with vestibular symptoms have physical and functional complaints, as well as increased psychosocial stress and decreased sleep quality. Evaluating multiple parameters of quality of life may contribute to a better understanding of vestibular physiology and symptoms, and may help establish a more effective therapeutic approach.

**Keywords**
► vestibular diseases
► sleep hygiene
► handicap

## Introduction

Vestibular inputs support postural reflexes and gaze fixation with the brainstem and cerebellar connections of the vestib-ular nuclei.[1] Cortical awareness of head–body movement, spatial perception, navigation, and representation, self-body perception, mental imagery, memory, attention, and social cognition functions are supported by the connections of the

vestibular nuclei to the parieto-insular vestibular cortex, the posterolateral thalamus, the hippocampus, the amygdala, and the hypothalamus.[2,3] Connections between the vestibular nuclei and the hypothalamus enable the vestibular inputs to be used both in the transition to sleep and in sleep/wakefulness regulation.[4]

Vestibular pathologies cause physical symptoms (such as dizziness, imbalance, nausea, vomiting, fatigue, and weakness), and psychological symptoms (such as depression, anxiety, and social isolation), as well as cognitive problems (such as forgetfulness, distraction, and impaired concentration).[5] In previous studies on vestibular diseases, insomnia was found to be the most common symptom after fatigue.[6] The possible reasons reported include anxiety caused by vestibular symptoms,[7] disruption in the circadian rhythm due to vestibular disease,[8] and the triggering of vertigo due to the position of the head during sleep.[9] In addition, in patients with chronic dizziness, a significant relationship among sleep disorders, poor quality of life, and depression has been reported.[10] The decrease in quality of life caused by vestibular diseases is higher among women.[7,10] The increasing knowledge about the central connections of the vestibular system raises the question of whether the decrease in sleep quality after vestibular pathology occurs secondary to the impaired vestibular functions or to the vestibular symptoms. The aim of the present study is to evaluate the relationships involving quality of life, depression, balance, and sleep quality in patients with vestibular disorders.

## Materials and Methods

The present cross-sectional, case-control study was conducted with ethical approval from the local Ethics in Clinical Research Committee (approval number: 2019/0132; date: March 27, 2019). We included patients from the Ear, Nose, and Throat (ENT) Department of our institution diagnosed according to the current internationally-accepted criteria as having benign paroxysmal positional vertigo (BPPV),[11] unilateral peripheral vestibular loss (UPVL),[12] Meniere's disease (MD),[13] and vestibular migraine (VM)[14] from January 2018 to March 2020. Cases of psychogenic or phobic postural vertigo, persistent postural perceptual dizziness, motion sickness, diagnoses of more than one vestibular pathology, and central pathologies with neurological findings were excluded from the study. The inclusion criteria were patients aged between 18 and 70 years, with dizziness or vertigo lasting for least 3 months,[10,15] with no history of chronic orthopedic diseases (of the spine or lower extremities) or neurological diseases, and no sleep disorders before the vestibular complaints.

We included 91 patients who agreed to participate and were diagnosed with BPPV ($n = 22$), MD ($n = 25$), UPVL ($n = 21$), VM ($n = 23$), and 43 controls. Written informed consent was obtained from the participants. The study protocol adhered to the principles of the Declaration of Helsinki. Patients who presented to the ENT clinic due to dizziness or imbalance, and those who showed signs vestibular pathology were submitted to an audiovestibular evaluation after the ENT examination. The study protocol was applied after the patients were diagnosed, when the MD and VM groups were in the non-attack period. The data regarding the UPVL and BPPV groups were recorded before the vestibular rehabilitation and/or repositioning maneuvers.

The Dizziness Handicap Inventory (DHI) was used to evaluate the physical, emotional, and functional effects of the vestibular disease. The Beck Depression Inventory (BDI) was used to evaluate the psychological status, and the Pittsburgh Sleep Quality Index (PSQI) was used to assess sleep quality. The participants filled out the questionnaires on paper with pencils while they were with the audiologist, which enabled them to ask about any items that they could not understand.

The PSQI is a self-assessment questionnaire frequently used in clinical and research settings to assess sleep quality.[16] It evaluates a person's sleep quality over the previous month. The questionnaire consists of 24 items, 19 of which are self-assessed, and 5 of which are evaluated by the patient's partner. The 19 self-assessment questions include 7 components: subjective sleep quality, time taken to fall asleep, sleeping time, sleep efficiency, sleep disturbances, hypnotics, and daytime dysfunction. The total score on the PSQI ranges from 0 to 21. Scores of items are based on a scale from 0 to 3, in which 3 reflects the negative extreme. The higher the total score, the worse the sleep quality. A total PSQI score > 5 is considered a sensitive and specific measure of poor sleep quality. The score is used to classify subjects being tested for sleep dysfunction as good sleepers (0 to 5 points) or poor sleepers (> 5 points).[16] The sensitivity and specificity of the PSQI in the diagnosis of sleep problems have been reported as 89.6% and 86.5% respectively.[17] The PSQI has been shown to have high validity and reliability among the Turkish population.[18]

The BDI is a 21-item self-assessment scale that numerically evaluates patients' depressive perceptions and measures symptoms that occur in the fields of vegetative, emotional, cognitive, and motivational depression.[19] The severity of the patient's depression is indicated by how high the total score is. It has been suggested that those who score $\geq 17$ on the BDI are part of an at-risk group. The value of the Cronbach $\alpha$ for the Turkish version of the BDI is of 0.80.[20]

The DHI is a multidimensional self-assessment scale that measures the levels of disability and handicap in three subdimensions: physical, emotional, and functional.[21] The score ranges from 0 to 100, and 100 indicates high levels of disability and handicap due to dizziness symptoms. A total DHI score of > 60 indicates serious dizziness and an increased risk of falling. Total scores between 0 and 30 and 31 and 60 indicate mild and moderate dizziness respectively. The analysis of the validity and reliability of the Turkish version of the DHI has already been performed.[22]

Postural stability can be defined as maintaining an upright posture against gravity and despite changes in environmental conditions. The limits of stability function expresses the limits of displacement of the center of gravity with feet on the ground and it is an important function to maintain daily activities. It has been determined that the limits of stability (LOS) function deviates from normal in peripheral vestibular pathologies.[23] To evaluate the balance of the patients with

vestibular pathologies, the LOS test was performed using static posturography (PhysioSensing, Sensing Future Technologies, Coimbra, Portugal). The subjects were instructed to stand barefoot on a force platform in a comfortable position, with their arms by their sides. Then, they were asked to shift their weight to move a cursor toward different targets displayed on a screen as quickly and accurately as possible. Eight circular targets were shown, and the participants were required to shift their weight toward each marked target and then return their weight to a central position before shifting their weight to the next target on the screen. The subjects were instructed not to raise their heels while performing the task. The composite scores of reaction time (CRT), movement velocity (CMV), endpoint excursion (CEE), maximum excursion (CME), and direction control (CDC) were analyzed. Healthy controls between the ages of 18 and 70 years who reported no vestibular, otologic, or neurologic complaints were selected from a group of university staff and volunteers with normal hearing and balance.

### Statistical Analysis
Effect sizes (phi coefficient) of chi-squared analyses performed in the present study were calculated using the Statistical Package for the Social Sciences (IBM SPSS Statistics for Windows, IBM Corp., Armonk, NY, United States) software, version 25.0. Based on these effect sizes, the statistical power ratios of the analyses were calculated using the Real Statistics Resource Pack.[24] In the analyses, the level of significance was accepted as 5%, the degree of freedom was accepted as 5 for the PSQI, 20 for daytime dysfunction, and 15 for the other 6 components. According to the results obtained, the effect sizes ranged from 0.32 to 0.58. Therefore, the effects discovered can be interpreted as "moderate association" and "relatively strong relationship"[25]. In addition, the statistical power ratios of the 7 Chi-squared analyses except 'sleeping time' component ranged from 0.92 to 1.00, well above the typically desired power level of 0.80. The power ratio of the Chi-squared analysis with which the sleeping time of the groups was compared was found close to that level ($\beta = 0.74$). The data that showed normal distribution were analyzed with the Shapiro–Wilk test. The mean and standard deviation values of the continuous data and the frequencies of the categoric data were calculated. The significance of the difference in the continuous data was analyzed using the Kruskal–Wallis test. After the nonparametric variation analyses, the pairwise comparisons were performed. The significance of the difference in the categoric data was analyzed using the Chi-squared test. The patients with scores higher than five on the PSQI were grouped as "poor sleepers," and those who scored lower than five, as "good sleepers." The significance of the difference in sleep quality between the groups was tested with the Chi-squared test. The data were also analyzed using the SmartPLS (SmartPLS GmbH, Oststeinbek, Germany) structural equation modeling (SEM) technique. The partial least squares structural equation model (PLS-SEM), which is a second-generation multivariate statistical method in the SmartPLS software, was applied to the nine variables included in the research model. All variables in the research model were included in the analysis to explain the

indirect and direct effects on sleep quality of the different diseases that cause dizziness. The model was run four times for four separate diseases, and used data from individuals with the relevant disease and a healthy control group in each trial. In all the models henceforth discussed in the present article, the heterotrait–monotrait (HTMT) ratio and the variance inflation factors (VIFs) are analyzed, and we have ensured that the models have no validity and collinearity issues. In the present study, the factors affecting the adaptation trends in the pathology were examined using the PLS-SEM. In this method, nonparametric resampling (bootstrap) is used to calculate the estimated standard error values, t statistics, and confidence intervals. It is recommended to resample five thousand times.[26] All models obtained during the present study were submitted to 5 thousand resamplings and 300 maximum iterations. The significance level was set as 0.05 in all analyses.

## Results
The demographic characteristics of the study and control groups are presented in ►**Table 1**. There was no significant difference between the controls and the study group in terms of mean age ($p > 0.05$). The mean age of the BPPV group was significantly higher than those of the VM ($p < 0.001$) and MD ($p < 0.01$) groups. The ratios of female and male subjects in each group were compared using the Chi-squared test, and no statistically significant difference was observed ($p = 0.402$).

The total score on the DHI and the BDI score are shown in ►**Table 1**. Accordingly, the highest total score on the DHI ($45.68 \pm 25.76$) was found in the MD group, and it was significantly higher than the scores of the BPPV ($p = 0.007$) and control ($p < 0.001$) groups. The highest BDI score was observed in the VM group, and it was significantly higher than those of the BPPV ($p = 0.046$) and control ($p < 0.001$) groups. Moreover, the BDI scores of the MD ($p < 0.001$) and UPVL ($p < 0.001$) groups were also significantly worse than those of the controls ($p < 0.001$). Since the PSQI is a likert-type scale, the total scores and subscores of the participants were compared using the Chi-squared test (►**Table 2**). The ratios of poor sleepers were compared among the groups. Accordingly, the proportions of poor sleepers in the MD ($p = 0.005$), BPPV ($p = 0.018$), and UPVL ($p < 0.001$) groups were significantly higher than among the controls.

The composite scores of the LOS test are presented in ►**Table 3**. There was a significant difference between the controls and the other groups, especially in forward movements. The CRT was significantly faster in the controls than in the MD group ($p = 0.026$). The CMV values of the controls were significantly higher than those of the MD ($p < 0.001$) and BPPV ($p = 0.003$) groups. The CME values of the controls were significantly higher than those of the MD ($p = 0.016$) group. No variables in any group differed significantly regarding gender ($p > 0.05$).

### PLS Path Modeling for Ménière Disease
One of the methods suggested to assess the discriminant validity (the degree to which a test or measure diverges from

**Table 1** Demographics of the study and control groups

|  |  | Meniere's disease | Vestibular migraine | Benign paroxysmal positional vertigo | Unilateral peripheral vestibular loss | Controls |
|---|---|---|---|---|---|---|
| N |  | 25 | 23 | 22 | 21 | 43 |
| Age (years) |  | $47.24 \pm 9.63$ | $44.34 \pm 7.58$ | $57.68 \pm 7.47$ | $54.81 \pm 11.58$ | $50.48 \pm 7.57$ |
| Gender | Male: n (%) | 8 (32) | 4 (17.4) | 7 (31.8) | 10 (47.6) | 15 (34.8) |
|  | Female: n (%) | 17 (68) | 19 (82.6) | 15 (68.2) | 11 (52.4) | 28 (65.2) |
| Comorbidities: % |  | 37.5 | 56.52 | 59.1 | 58 | 34.8 |
| Psychiatric comorbidities: % |  | – | 21.73 | – | – | 6.97 |
| Beck Depression Inventory: total score |  | $13.88 \pm 6.41$ | $16.08 \pm 10.84$ | $9.72 \pm 7.42$ | $13.19 \pm 6.43$ | $4.44 \pm 5.19$ |
| Dizziness Handicap Inventory: total score |  | $45.68 \pm 25.76$ | $39.47 \pm 21.61$ | $29.63 \pm 23.67$ | $37.14 \pm 20.11$ | $1.12 \pm 0.42$ |

**Table 2** Results of the Chi-squared test regarding the Pittsburgh Sleep Quality Index scores and subscores

|  | Controls-Meniere's disease | DF | Controls-vestibular migraine | DF | Controls-benign paroxysmal positional vertigo | DF | Controls-unilateral peripheral vestibular loss | DF | Effect size (phi coefficient) |
|---|---|---|---|---|---|---|---|---|---|
| Pittsburgh Sleep Quality Index | 0.014 | 7 | < 0.001 | 13 | 0.003 | 11 | 0.001 | 12 | 0.325 |
| Sleep quality - component 1 | 0.016 | 2 | 0.117 | 3 | 0.001 | 3 | 0.043 | 3 | 0.496 |
| Time to fall sleep - component 2 | < 0.001 | 3 | 0.002 | 3 | < 0.001 | 3 | 0.001 | 3 | 0.581 |
| Sleeping time - component 3 | 0.044 | 3 | 0.276 | 3 | 0.238 | 3 | 0.404 | 2 | 0.322 |
| Sleep efficiency - component 4 | < 0.001 | 2 | 0.002 | 3 | 0.021 | 2 | < 0.001 | 2 | 0.518 |
| Sleep disturbance - component 5 | 0.002 | 3 | 0.011 | 3 | 0.053 | 3 | < 0.001 | 3 | 0.517 |
| Hypnotics - component 6 | 0.263 | 1 | 0.089 | 2 | 0.001 | 3 | 0.039 | 2 | 0.492 |
| Daytime dysfunction - component 7 | 0.004 | 3 | 0.008 | 3 | 0.018 | 3 | < 0.001 | 4 | 0.581 |

Abbreviation: DF, degree of freedom.

another measure whose underlying construct is conceptually unrelated to it) of a PLS-SEM model is the evaluation of the HTMT ratio. If the HTMT ratios of the variables are below 0.90, the discriminant validity is ensured.[27] In the present study, the HTMT values were between 0.00 and 0.84. Therefore, it can be said that the model provides the discriminant validity. However, all VIFs were below 10. Accordingly, there was no multiple linear connection problem in the model.[28] Therefore, the path coefficients were examined in the second step, and are presented in ►**Table 4**. We observed a statistically significant and positive relationship between the diagnosis of MD and BDI, CRT, and DHI variables. However, a statistically significant and negative relationship was found between MD and the CEE, CME, CMV, and PSQI variables. There was no statistically significant relationship between the diagnosis of MD and the CDC variable ($p > 0.05$). When the relationships of the mediator variables with the PSQI variable were examined, positive relationships only with the BDI, CRT, and DHI variables were observed. We found that the other four static balance variables, except the CRT, were not significantly correlated with the PSQI ($p > 0.05$). The total and specific indirect effects are shown in ►**Table 5**, which shows that the total indirect effect of the diagnosis of MD on the PSQI scores was statistically significant ($p = 0.01$), and this effect was positive. When the reasons for this significant indirect effect were examined, we found that the partial mediator variables are the BDI and DHI. Thus, in MD patients, BDI and DHI scores increase, as well as the PSQI score through these variables. When the two coefficients were examined, we observed that the indirect effect (0.483) on the DHI variable was greater than on the BDI variable (0.356). The adjusted $R^2$ value of the model was found to be 0.661 for the PSQI score. Accordingly, the model can explain 66.1% of the changes in the sleep quality of MD patients.

**Table 3** Composite scores of the Limits of Stability test

| Parameters of the Limits of Stability test | Meniere's disease | Vestibular migraine | Benign paroxysmal positional vertigo | Unilateral peripheral vestibular loss | Controls | Kruskal-Wallis $p$-values | DF |
|---|---|---|---|---|---|---|---|
| Composite reaction time (s) | 0.91 ± 0.41 | 0.81 ± 0.25 | 0.88 ± 0.35 | 0.67 ± 0.31 | 0.62 ± 0.21 | **0.005** | 4 |
| Composite movement velocity (°/s) | 2.07 ± 0.84 | 2.83 ± 0.94 | 2.16 ± 0.89 | 2.48 ± 0.56 | 3.32 ± 1.02 | **< 0.001** | 4 |
| Composite endpoint excursion (%) | 53.17 ± 15.12 | 59.62 ± 14.97 | 55.56 ± 13.31 | 56.86 ± 10.98 | 62.74 ± 11.38 | 0.082 | 4 |
| Composite maximum excursion (%) | 73.81 ± 16.53 | 84.17 ± 13.89 | 73.65 ± 21.54 | 80.43 ± 15.28 | 86.86 ± 12.38 | **0.012** | 4 |
| Composite directional control (%) | 48.85 ± 24.75 | 60.72 ± 11.77 | 53.41 ± 18.87 | 54.17 ± 15.65 | 57.86 ± 11.74 | 0.561 | 4 |

## PLS Path Modeling for Vestibular Migraine

The HTMT values were between 0.01 and 0.83. Therefore, it can be said that the model provides discriminant validity. However, all VIFs were below 10; therefore, there was no multilinear connection problem in the model. As so, the path coefficients were examined in the second step, and are presented in ►**Table 4**. We found a statistically significant and positive relationship between the diagnosis of VM and the BDI, CRT, and DHI variables. However, a statistically significant and negative relationship was found between VM and the CMV variable. There was no statistically significant relationship between the diagnosis of VM and the CDC, CEE, CME and PSQI variables ($p > 0.05$). When the relationships of the mediator variables with the PSQI variable were examined, we only found a positive relationship with the BDI variable. No significant relationship was found regarding any of the other variables and the PSQI ($p > 0.05$). Therefore, the indirect effect analysis is only possible for BDI. ►**Table 5** shows that the total indirect effect of the diagnosis of VM on the PSQI score was not statistically significant. However, when the specific indirect effects were considered, we found that the BDI was a mediator variable. Accordingly, VM increases the BDI score of the patients and increases the PSQI score through the BDI. Since the direct effect of VM diagnosis on the PSQI was not significant (►**Table 5**), it can be said that BDI scores affect the PSQI scores indirectly in this group. The adjusted $R^2$ value of the model was found to be 0.429 for the PSQI score. Accordingly, the model can explain 42.9% of the changes in the sleep quality of migraine patients.

## PLS Path Modeling for BPPV Disease

The HTMT values were between 0.07–0.85. Thus, it can be said that the model provides the discriminant validity. However, all VIFs were below 10; therefore, there was no multilinear connection problem in the model. As so, the path coefficients were examined in the second step, and they are presented in ►**Table 4**. We found a statistically significant and positive relationship between the BPPV diagnosis and the BDI, CRT, and DHI variables. However, a statistically significant and negative relationship was found between the BPPV diagnosis and the CME and CMV variables. There was no statistically significant relationship between the diagnosis of BPPV and the of CDC, CEE, and PSQI variables ($p > 0.05$). When the relationships of the mediator variables with the PSQI variable were examined, we found a positive relationship only with the BDI and DHI variables. We observed that five static balance variables were not significantly associated with the PSQI ($p > 0.05$). Accordingly, indirect effect analyses are only possible for BDI and DHI scores. ►**Table 5** shows that the total indirect effect of the diagnosis of BPPV on the PSQI scores was statistically significant ($p = 0.01$). When the reasons for this significant total indirect effect were examined, we found that the partial mediating variables were the BDI and DHI. Thus, in BPPV patients, BDI and DHI scores increase, as well as the PSQI scores through these scores. When two path coefficients were examined, we found that the indirect effect (0.525) on the DHI variable was greater than on the BDI variable (0.302). The adjusted $R^2$ value of the model was found to be 0.661 for the

**Table 4** Partial Least Squares Path Modeling and Coefficients

| Meniere's disease | Original sample (O) | Sample mean (M) | Standard deviation | t | *p*-value |
|---|---|---|---|---|---|
| BDI → PSQI | 0.563 | 0.580 | 0.116 | 4.843 | 0.000* |
| CRT → PSQI | 0.249 | 0.249 | 0.111 | 2.254 | 0.024* |
| DHI → PSQI | 0.588 | 0.622 | 0.168 | 3.502 | 0.000* |
| DIAGNOSIS → BDI | 0.632 | 0.629 | 0.079 | 8.047 | 0.000* |
| DIAGNOSIS → CEE | -0.271 | -0.270 | 0.120 | 2.265 | 0.024* |
| DIAGNOSIS → CME | -0.351 | -0.351 | 0.117 | 3.013 | 0.003* |
| DIAGNOSIS → CMV | -0.538 | -0.536 | 0.075 | 7.197 | 0.000* |
| DIAGNOSIS → CRT | 0.424 | 0.420 | 0.099 | 4.270 | 0.000* |
| DIAGNOSIS → DHI | 0.822 | 0.823 | 0.042 | 19.719 | 0.000* |
| DIAGNOSIS → PSQI | -0.386 | -0.427 | 0.192 | 2.009 | 0.045* |
| **Vestibular migraine** | | | | | |
| BDI → PSQI | 0.657 | 0.677 | 0.166 | 3.961 | 0.000* |
| DIAGNOSIS → BDI | 0.595 | 0.596 | 0.075 | 7.965 | 0.000* |
| DIAGNOSIS → CMV | -0.233 | -0.234 | 0.110 | 2.110 | 0.035* |
| DIAGNOSIS → CRT | 0.370 | 0.364 | 0.094 | 3.918 | 0.000* |
| DIAGNOSIS → DHI | 0.833 | 0.837 | 0.036 | 23.261 | 0.000* |
| **Benign paroxysmal positional vertigo** | | | | | |
| BDI → PSQI | 0.603 | 0.606 | 0.144 | 4.199 | 0.000* |
| DHI → PSQI | 0.620 | 0.619 | 0.278 | 2.228 | 0.026* |
| DIAGNOSIS → BDI | 0.501 | 0.498 | 0.095 | 5.283 | 0.000* |
| DIAGNOSIS → CME | -0.306 | -0.300 | 0.139 | 2.200 | 0.028* |
| DIAGNOSIS → CMV | -0.469 | -0.467 | 0.090 | 5.188 | 0.000* |
| DIAGNOSIS → CRT | 0.416 | 0.410 | 0.116 | 3.589 | 0.000* |
| DIAGNOSIS → DHI | 0.847 | 0.852 | 0.046 | 18.583 | 0.000* |
| **Unilateral peripheral vestibular loss** | | | | | |
| BDI → PSQI | 0.536 | 0.538 | 0.125 | 4.282 | 0.000* |
| CEE → PSQI | -0.484 | -0.460 | 0.186 | 2.597 | 0.009* |
| CME → PSQI | 0.575 | 0.547 | 0.204 | 2.821 | 0.005* |
| DHI → PSQI | 0.496 | 0.474 | 0.208 | 2.381 | 0.017* |
| DIAGNOSIS → BDI | 0.588 | 0.588 | 0.076 | 7.693 | 0.000* |
| DIAGNOSIS → CMV | -0.405 | -0.403 | 0.082 | 4.922 | 0.000* |
| DIAGNOSIS → DHI | 0.855 | 0.859 | 0.033 | 25.593 | 0.000* |

Abbreviations: BDI, Beck Depression Inventory (total score); CEE, composite endpoint excursion; CME, composite maximum excursion; CMV, composite movement velocity; CRT, composite reaction time; DHI, Dizziness Handicap Inventory (total score); PSQI, Pittsburgh Sleep Quality Index (total score).
Note: *Statistically significant.

PSQI score. Accordingly, the model can explain 66.1% of the changes in the sleep quality of BPPV patients.

### PLS Path Modeling for UPVL Disease
The HTMT values were between 0.02–0.88. Therefore, it can be said that the model provides the divergence validity. However, all VIFs were below 10; therefore, there was no multilinear connection problem in the model. As so, the path coefficients were examined in the second step, and they are presented in ►**Table 4**. We found a statistically significant

and positive relationship between the UPVL diagnosis and the BDI and DHI variables. However, a statistically significant and negative relationship was found between the diagnosis of UPVL and the CMV variable. There was no statistically significant relationship between the diagnosis of UPVL and the CDC, CEE, CME, and PSQI variables ($p > 0.05$). When the relationships of the mediator variables with the PSQI variable were examined, we found a positive relationship with the BDI, CME, and DHI variables. The CEE variable affects the PSQI score negatively. We observed that none of the other

**Table 5** Specific and Total Indirect Effects

| Meniere's disease | | | | | |
|---|---|---|---|---|---|
| Total indirect effects | Original sample (O) | Sample mean (M) | Standard deviation | t | *p*-value |
| DIAGNOSIS → PSQI | 0.838 | 0.881 | 0.181 | 4.641 | 0.000* |
| Specific indirect effects | | | | | |
| DIAGNOSIS → BDI → PSQI | 0.356 | 0.364 | 0.080 | 4.462 | 0.000* |
| DIAGNOSIS → DHI → PSQI | 0.483 | 0.516 | 0.141 | 3.434 | 0.001* |
| Vestibular migraine | | | | | |
| Total indirect effects | | | | | |
| DIAGNOSIS → PSQI | 0.290 | 0.272 | 0.222 | 1.306 | 0.192 |
| Specific indirect effects | | | | | |
| DIAGNOSIS → BDI → PSQI | 0.391 | 0.400 | 0.111 | 3.513 | 0.000* |
| Benign paroxysmal positional vertigo | | | | | |
| Total indirect effects | | | | | |
| DIAGNOSIS → PSQI | 0.764 | 0.768 | 0.254 | 3.009 | 0.003* |
| Specific indirect effects | | | | | |
| DIAGNOSIS → BDI → PSQI | 0.302 | 0.302 | 0.092 | 3.284 | 0.001* |
| DIAGNOSIS → DHI → PSQI | 0.525 | 0.525 | 0.245 | 2.143 | 0.032* |
| Unilateral peripheral vestibular loss | | | | | |
| Total indirect effects | | | | | |
| DIAGNOSIS → PSQI | 0.686 | 0.670 | 0.206 | 3.333 | 0.001* |
| Specific indirect effects | | | | | |
| DIAGNOSIS → BDI → PSQI | 0.315 | 0.319 | 0.083 | 3.801 | 0.000* |
| DIAGNOSIS → DHI → PSQI | 0.424 | 0.403 | 0.187 | 2.260 | 0.024* |

Abbreviations: BDI, Beck Depression Inventory (total score); DHI, Dizziness Handicap Inventory (total score); PSQI, Pittsburgh Sleep Quality Index (total score).
Note: *Statistically significant.

three static balance variables had a significant relationship with the PSQI ($p > 0.05$). Therefore, indirect effect analyses are only possible for BDI and DHI scores. ►**Table 5** shows that the total indirect effect of the UPVL diagnosis on the PSQI scores was statistically significant ($p = 0.01$), and this effect was positive. When the reasons for this significant total indirect effect were examined, we found that the partial mediating variables are the BDI and DHI. Thus, in UPVL patients, BDI and DHI scores increase, as well as the PSQI scores through these scores. When two path coefficients were examined, we found that the indirect effect on the DHI variable (0.424) was greater than on the BDI variable (0.315). The adjusted $R^2$ value of the model was found to be 0.605 for the PSQI score. Thus, the model can explain 60.5% of the changes in the sleep quality of UPVL patients.

## Discussion

Dizziness, imbalance, and related symptoms are complaints that can be hardly described and expressed by patients with vestibular disorders. While Patients may not be able to correlate cognitive, emotional, and/or sleep quality changes

with the vestibular disease. The present study evaluated how the sleep quality of patients with different vestibular pathologies was affected by other parameters. According to the findings, the PSQI score was affected by the DHI (60.5%) score in the MD (66.1%), BPPV (66.1%), and UPVL groups, and by the BDI (42.9%) score in the VM group. A significant relationship between the parameters of the LOS test and the PSQI score was found in the MD and UPVL groups.

There are few studies[29–31] evaluating sleep quality in diseases of the vestibular system. Kim et al. (2018) evaluated the relationship between sleep and quality of life in patients with BPPV, MD, vestibular neuritis, VM, and psychogenic vertigo using the PSQI, the insomnia severity index, and the DHI. They found that sleep quality and quality of life were significantly affected in a negative manner in patients with vestibular diseases. The correlation between sleep disturbance and the DHI was found to be highest in VM patients.[31] In the present study, the highest score on the DHI was obtained by the MD group, and the worst quality of sleep was found among the UPVL group. In the MD, BPPV, and UPVL groups, the indirect effect of the DHI scores on the PSQI scores was greater than of the BDI scores, but in the VM group, the indirect effect of BDI scores on the PSQI was greater than DHI scores.

The emotional impacts of vestibular complaints of patients may be an important trigger for vestibular symptoms. In both cases, the patients are at risk of experiencing a decrease in their ability to cope with the vestibular disease and in their self-reliance. This may lead to an increase in their fear of falling asleep. Determining the interdependence between otoneurological and psychiatric symptoms is particularly important in the prognosis of dizziness.[5] In this study, the highest BDI score was found in the VM group, and the lowest, in the BPPV group.

Dizziness is a symptom that has the potential to alter patients' sleeping habits. The presence of sleep disturbance in patients with chronic dizziness can exacerbate the symptoms and increase the dizziness. In patients with vestibular pathologies with impaired sleep quality, a decrease in quality of life and an increase in emotional problems have been reported.[7] Patients with chronic dizziness report a variety of symptoms, with insomnia being the most reported symptom after fatigue.[6] Konomi et al.[32] reported that the PSQI score was higher in the psychogenic dizziness and autonomic imbalance groups in their study. In the present study, the rate of "good sleepers" was significantly higher among the controls compared with all case groups.

Sleep disturbance can cause various psychiatric and physical health problems. Poor sleep quality has also been recognized as a risk factor for anxiety and major depressive disorder. The severity of dizziness and sleep-related problems are closely related, and both are associated with poor quality of life and emotional stress.[7,17,32] Sugaya et al.[15] reported that the presence of sleep disturbance in patients with chronic dizziness was associated with severe anxiety and depression, and a decrease in health-related quality of life; furthermore, subjective handicaps associated with dizziness were evident in female patients with concomitant sleep disorders. In the present study, no significant differences were observed regarding gender in any of the evaluation parameters.

It has been reported that ∼ 40% of MD patients suffer from poor sleep.[33] Nakayama et al.[34] reported that MD patients showed shorter durations of deep sleep and higher scores in the easy wake index compared with healthy individuals. In the present study, the ratio of poor sleep was of 60% in the MD group, and the total score on the PSQI of MD patients ranked fourth after the UPVL, BPPV, and VM groups.

Poor sleep quality is often reported by BPPV patients, and it adversely affects their quality of life. The average age of BPPV patients tends to be higher than that of patients with other vestibular diseases, and the effect of age on sleep should also be taken into consideration.[35–37] In the present study, the average age of the BPPV group was higher than that of the other groups. Head positions during sleep have been shown to be associated with BPPV, and a higher recurrence rate has been observed in patients who sleep on the pathological side after undergoing the repositioning maneuver.[38,39] It has been reported that sleep disturbance may be related to the pathophysiology and recurrence of BPPV.[40] The quality of sleep in patients with BPPV recurrence has been reported to be significantly lower than that of patients without recurrence.[9] In the present study, there were no recurrent cases of BPPV; however, the group

with the poorest sleep quality and the highest use of hypnotics was the BPPV group.

In the present study, the indirect effect of the DHI variable on the PSQI was greater than the indirect effect of the BDI variable on the MD, BPPV, and UPVL groups. However, VM increased the BDI score of the patients and thereby increased their PSQI score. These findings support the possibility that impairments in sleep quality, especially in cases in which the symmetrical vestibular input is eliminated or impaired, may be caused not only by the emotional involvement secondary to vestibular disease, but also by the central connections of the vestibular system.

The present study has some limitations. The first limitation is the heterogeneity of the vestibular patients due to the nature of the diseases. While MD is fluctuant and episodic, UPVL is often compensated. In the case of BPPV, it can be cured by repositioning maneuvers or by itself, while VM is also episodic. Although some characteristics of these diseases are different, the common point is the impairment of the vestibular input. In order not to ignore the differences between the diseases, we compared the findings among the groups. Longitudinal studies with larger samples may eliminate this limitation. The second limitation study is the lack of polysomnographic evaluation of the participants. This has been planned for the next investigation. In future studies, we plan to compare the sleep quality of vestibular patients with other chronic symptoms (rheumatologic pain, headache, laryngopharyngeal reflux etc.), The study group was composed of patients who agreed to participate in the study; the author did not use randomization or methods to reduce the selection bias. Therefore, the third limitation of the present study is sample selection bias.

## Conclusion

Vestibular pathologies that cause dizziness and imbalance decrease the self-reliance of patients in the management of their daily living activities. The present study showed that patients with vestibular symptoms have physical and functional complaints, as well as increased psychosocial stress and decreased sleep quality. Evaluating multiple parameters of quality of life may contribute to a better understanding of vestibular physiology and symptoms, and may help establish a more effective therapeutic approach. During the treatment phase, vestibular functional tests, as well as other evaluations (emotional, cognitive, quality of life, and sleep) are particularly important for the multidimensional approach to the patient. They provide the clinician with the opportunity to evaluate parameters that patients cannot simulate in clinical conditions.

Conflict of Interests
The authors have no conflict of interests to declare.

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