Research Article / Araştırma Makalesi
doi: 10.18678/dtfd.1648494

Duzce Med J, 2025;27(2):194-200
Düzce Tıp Fak Derg, 2025;27(2):194-200

Evaluation of Neck Proprioception, Vestibular Function, and Cervical Muscle Thickness in Patients with Cervical Spinal Stenosis: A Cross-Sectional Study

Servikal Spinal Stenozlu Hastalarda Boyun Propriosepsiyonu, Vestibüler Fonksiyon ve Servikal Kas Kalınlığının Değerlendirilmesi: Kesitsel Bir Çalışma

Hakan KINA[1]
0000-0002-9741-7720
Bülent BOZYİĞİT[2]
0000-0001-5038-2260
Emre SÖYLEMEZ[3]
0000-0002-7554-3048
Musa GÜNEŞ[4]
0000-0001-8532-2575
Nevin KÖREMEZLİ KESKİN[5]
0000-0002-3169-9083
Tuğçe GÜREL SÖYLEMEZ[6]
0000-0002-9867-8842
Aydın Sinan APAYDIN[7]
0000-0002-2916-9550

[1]Department of Neurosurgery, İstinye University Faculty of Medicine, İstanbul, Türkiye

[2]Department of Neurosurgery, Private Gözde İzmir Hospital, İzmir, Türkiye

[3]Department of Audiology, Karabük University Vocational School of Health Services, Karabük, Türkiye

[4]Department of Physiotherapy and Rehabilitation, Karabük University Faculty of Health Sciences, Karabük, Türkiye

[5]Department of Radiology, Karabük University Faculty of Medicine, Karabük, Türkiye

[6]Department of Audiology, Karabük Training and Research Hospital, Karabük, Türkiye

[7]Department of Neurosurgery, Faculty of Medicine, Karabük University, Karabük, Türkiye

Corresponding Author
Sorumlu Yazar
Hakan KINA
kinahakan@gmail.com

Received / Geliş Tarihi : 01.03.2025
Accepted / Kabul Tarihi : 05.07.2025
Available Online /
Çevrimiçi Yayın Tarihi : 04.08.2025

ABSTRACT

Aim: This study aimed to examine the relationship between spinal canal diameter and cervical proprioception, vestibular function, and neck muscle thickness in patients with cervical spinal stenosis (CSS), compared with healthy controls.
Material and Methods: This cross-sectional study included 23 patients diagnosed with CSS through radiological and clinical examination, and 23 healthy individuals as a control group. The severity of CSS was determined by measuring the cross-sectional area (CSA) of the thecal sac. Proprioception was evaluated using the cervical joint position error test (CJPET), balance with static posturography on a foam surface, and dizziness with the dizziness handicap inventory (DHI). Cervical vestibular function was assessed using cervical vestibular evoked myogenic potential (cVEMP) and subjective visual vertical (SVV) tests. The CSA of the sternocleidomastoid, longus capitis, and longus colli muscles was also measured.
Results: The CSS group showed significantly greater CJPET deviation (p=0.032), foam surface balance scores with eyes open and closed (p=0.034 and 0.015, respectively), and DHI scores (p<0.001) compared to the control group. No significant differences were found in right ear cVEMP amplitude (p=0.222), P1 latency (p=0.781), N1 latency (p=0.945), and in left ear amplitude (p=0.916), P1 latency (p=0.156), and N1 latency (p=0.558). Similarly, no significant difference was observed in SVV values (p=0.862).
Conclusion: CSS patients demonstrate increased dizziness and impaired balance and proprioception, independent of stenosis severity. These findings suggest that sensorimotor interventions may be beneficial for improving balance and proprioceptive function in CSS.
Keywords: Cervical spinal stenosis; dizziness; proprioception; balance.

ÖZ

Amaç: Bu çalışmanın amacı, servikal spinal stenoz (cervical spinal stenosis, CSS) hastalarında spinal kanal çapı ile servikal propriosepsiyon, vestibüler fonksiyon ve boyun kası kalınlığı arasındaki ilişkiyi, sağlıklı kontrollerle karşılaştırarak incelemektir.
Gereç ve Yöntemler: Bu kesitsel çalışmaya, radyolojik ve klinik muayene ile CSS tanısı konulan 23 hasta ve kontrol grubu olarak 23 sağlıklı birey dahil edilmiştir. CSS şiddeti, tekal kese kesitsel alanı (cross-sectional area, CSA) ölçülerek değerlendirilmiştir. Propriosepsiyon, servikal eklem pozisyon hata testi (cervical joint position error test, CJPET), denge foam yüzey üzerinde statik posturografi ile ve baş dönmesi dizziness handicap inventory (DHI) ile değerlendirilmiştir. Servikal vestibüler fonksiyon, servikal vestibüler uyarılmış miyojenik potansiyel (cervical vestibular evoked myogenic potential, cVEMP) ve subjektif görsel dikeylik (subjective visual vertical, SVV) testleriyle incelenmiştir. Ayrıca, sternokleidomastoid, longus capitis ve longus colli kaslarının CSA değerleri de ölçülmüştür.
Bulgular: CSS grubunda, kontrol grubuna kıyasla anlamlı derecede daha yüksek CJPET sapması (p=0,032), gözler açık ve kapalı foam yüzey denge skorları (sırasıyla p=0,034 ve p=0,015) ve DHI skoru (p<0,001) bulunmuştur. Sağ kulak cVEMP genliği (p=0,222), P1 latansı (p=0,781), N1 latansı (p=0,945) açısından ve sol kulak cVEMP genliği (p=0,916), P1 latansı (p=0,156) ve N1 latansı (p=0,558) açısından anlamlı bir fark saptanmamıştır. Benzer şekilde, SVV değerleri açısından da anlamlı bir fark görülmemiştir (p=0,862).
Sonuç: CSS hastalarında, stenoz şiddetinden bağımsız olarak artmış baş dönmesi ile birlikte denge ve propriosepsiyon bozukluğu gözlenmiştir. Bu bulgular, CSS'de denge ve proprioseptif fonksiyonların iyileştirilmesinde sensörimotor müdahalelerin faydalı olabileceğini düşündürmektedir.
Anahtar kelimeler: Servikal spinal stenoz; baş dönmesi; propriosepsiyon; denge.

INTRODUCTION

Spinal disorders rank among the most frequently encountered medical conditions today. Although the sagittal diameter of the spinal canal varies from person to person, it generally provides enough space for spinal nerves to function properly. However, factors such as aging can contribute to discopathy and spondylosis, leading to a reduction in the cervical spinal canal's width (1). While some individuals may have congenital stenoses, the majority of cases result from progressive intervertebral disc degeneration. This degenerative process is characterized by the gradual breakdown and sequestration of discs, the development of bony outgrowths extending into the vertebral canal, thickening of the ligamentum flavum, and facet joint hypertrophy (1,2). In certain cases, spinal cord compression remains asymptomatic for a period but may become clinically evident over time. Symptomatic individuals may present with neck pain, hand numbness, fine motor difficulties, and gait disturbances associated with radiculopathy and/or myelopathy. Dizziness is a broad term encompassing sensations such as vertigo, lightheadedness, and presyncope. Most instances of dizziness or vertigo arise due to vestibular or central nervous system disorders, including cerebellar infarctions, all of which can be identified through various diagnostic tests. However, in certain cases, pinpointing the exact cause of dizziness proves challenging. Cervicogenic dizziness, which is linked to cervical spine abnormalities and remains poorly understood in terms of pathophysiology, is particularly difficult to diagnose (3). There is ongoing debate regarding whether cervicogenic dizziness should be classified as an independent condition; however, some researchers consider it one of the most frequently observed dizziness subtypes (4). The proprioceptive system plays a crucial role in maintaining balance and functions alongside the vestibular and visual systems. Proprioceptors located within the zygapophyseal joints, particularly in the upper cervical spine, are highly developed and essential for balance regulation (3). Disruptions in proprioceptive input due to cervical spinal stenosis (CSS) may lead to abnormal signal transmission to the vestibular nuclei. This results in sensory mismatches between cervical and vestibular inputs, which could contribute to cervicogenic dizziness (3,5). Consequently, CSS may impair balance functions by disrupting sensory organization (6). Additionally, the sternocleidomastoid (SCM) muscle in the neck has a connection to the saccule, a peripheral sensory organ, through the medial vestibulospinal (vestibulocollic) tract. This reflex mechanism assists in coordinating head and eye movements in response to changes in head position (7). CSS affects not only spinal structures, such as discs and ligaments, but also the musculature in the cervical region. As a result, it can lead to abnormal vestibulocollic stimulation. Consequently, the integrated balance mechanisms governed by the visual, proprioceptive, and vestibular systems may become dysfunctional in CSS (8). Furthermore, the correlation between stenosis severity and clinical symptoms remains unclear in the existing literature. While previous studies have predominantly focused on lumbar spinal stenosis (LSS), some findings indicate a potential association between pain intensity and radiological characteristics in lumbar cases (9). However, such a relationship has not been definitively established for CSS. A comprehensive literature review revealed no studies specifically investigating the interplay between cervical proprioception, vestibular function, spinal canal diameter, and cervical muscle size in CSS patients. The objective of this study was to evaluate cervical proprioception and vestibular function in individuals with CSS. Additionally, it aimed to explore possible correlations between these parameters and both the spinal canal diameter and cervical muscle thickness.

MATERIAL AND METHODS

This research was carried out with patients who visited the neurosurgery clinic from January to April 2024 and received a diagnosis of CSS. Patients aged between 18 and 65 years who had a spinal sagittal diameter of less than 12 mm on magnetic resonance imaging (MRI)—indicating the presence of cervical central stenosis (whether relative or absolute)—and who exhibited symptoms such as neck pain and numbness in the arms and hands were included. The exclusion criteria were: traumatic neck injuries, true vertigo, hearing impairment (defined as a pure tone average >25 dB), any neurological or systemic conditions, visual impairment, spinal malignancies, foraminal and lateral recess stenosis, any cervical surgery performed in the past 12 months, and musculoskeletal conditions that affect balance. Sample size calculations based on a pilot study involving proprioception using the G*Power v.3.1.9 program indicated that at least 23 participants per group were required (α=0.05, d=0.853, β=0.20). A specialist neurosurgeon conducted comprehensive medical interviews, and 23 patients who were diagnosed with CSS based on both clinical evaluations and radiological results were selected for the study. Additionally, a control group consisting of 23 healthy individuals, matched for age and gender, was included for comparison. All participants provided written and verbal consent. This study was approved by the ethics committee of the Karabük University (05.12.2023-2023/1521).

The duration of neck pain symptoms was recorded for each participant. The cross-sectional area (CSA) of the spinal stenosis was measured by a radiologist from the MRI scans, and the CSA of the SCM, longus capitis (L Cap), and longus colli (L Colli) muscles at the level of the thyroid cartilage was assessed using ultrasonography (USG). Additionally, otoscopic examination and pure tone audiometry were performed, and the frequency of falls in the past year was documented. Participants underwent several assessments, including static posturography, dizziness handicap inventory (DHI), cervical vestibular evoked myogenic potential (cVEMP), subjective visual vertical (SVV), neck disability index (NDI), and cervical joint position error test (CJPET). MRI scans were performed using a Philips Achieva 1.5 Tesla MRI machine (Germany), where the narrowest cervical canal CSA (in cm^2) was measured from axial T2-weighted images (Figure 1). For ultrasonographic imaging of the neck flexor muscles, a Samsung RS85 Prestige real-time US device (Korea) was used, equipped with an 8-MHz, 38.7-mm linear array transducer. The probe was placed transversely at the C5-C6 level (corresponding to the thyroid cartilage) to visualize the L Cap and L Colli muscles, ensuring no overlap. The SCM muscle was imaged consistently at a specific level between its origin and insertion. Each muscle was measured three times, and the average CSA (cm²) was recorded (Figure 2). The anteroposterior (AP) diameter of the spinal canal and thecal sac CSA was measured using sagittal and axial slices of all cervical intervertebral levels by MRI. The narrowest area was recorded. Thecal sac CSA was measured for stenosis severity, and <75 mm^2 was defined as severe stenosis, 75-100 mm^2 as moderate stenosis, and more than 100 mm^2 as normal spinal canal (10). To rule out vertebrobasilar insufficiency, Doppler sonography of the carotid and vertebral arteries was conducted. Psychometric tests used in the study included the NDI, a 10-item scale with scores ranging from 0 to 5, where higher scores indicate greater neck disability, and the DHI, a 25-item questionnaire scored from 0 to 4, with higher scores indicating increased balance impairment (11,12). Cervical proprioception was assessed using the CJPET, where a target point was placed on a wall 90 cm away from the participant. The participant, wearing a head-mounted laser, was instructed to align the laser with the target and then close their eyes while performing 10 head movements (left-right/up-down, with approximately 45° rotations). The deviation from the target was recorded, and errors greater than or equal to 4.5° were considered abnormal (13). SVV was evaluated using a black bucket with a white vertical line drawn on it. Participants were asked to adjust the line to match their perceived verticality, and the deviation angle was measured from the back of the bucket. For cVEMP testing, the Neuro-Audio device (Neurosoft, Ivanovo, Russia, Version 1.0.104.1) was used. Participants sat upright with electrode sites cleaned using abrasive gel. The active electrode was placed on the upper third of the SCM, the reference electrode on the sternoclavicular joint, and the ground electrode on the forehead. The electrode impedance was kept below 10 ohms. To maintain muscle contraction, participants turned their heads opposite to the ear being recorded, and a 500 Hz tone-burst stimulus at 100 dB was applied.

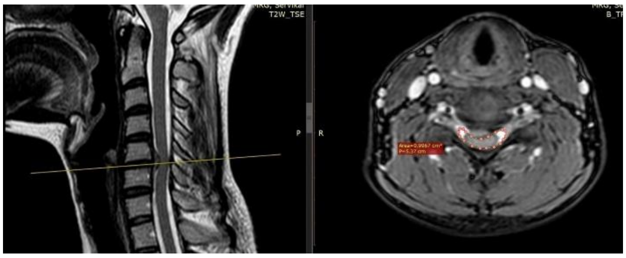

Figure 1. Cervical spinal canal cross-sectional area from the sagittal-axial T2 images

Figure 2. Cervical muscles' cross-sectional area from the ultrasound imaging

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics v.21. The Shapiro-Wilk test was used to assess the normality of data. Variables with a normal distribution were presented as mean±standard deviation, while variables without a normal distribution were presented as median, 25th-75th quartile, and minimum-maximum. For group comparisons, if both groups showed a normal distribution, the independent samples t-test was used. If at least one group did not meet the assumption, the Mann-Whitney U test was applied. To assess the relationship between continuous variables, Pearson or Spearman correlation tests were used based on the normality of the data. Categorical variables were analyzed using the Chi-square test or Fisher's exact test, depending on the expected cell counts. The level of p<0.05 was considered statistically significant.

RESULTS

Of the 23 patients in the CSS group, 17 (73.9%) were female, 6 (26.1%) were male, and the mean age was 42.86±10.47 (range, 20-55) years, and in the control group, 17 (73.9%) were female, 6 (26.1%) were male, and the mean age was 39.60±6.59 (range, 26-53) years. There was no significant difference in age between the groups (p=0.078). The symptom duration, NDI scores, stenosis levels, spinal stenosis CSA, and the CSA of L Colli, L Cap, and SCM muscles in the CSS group were summarized in Table 1. Thecal sac CSA (stenosis severity) of patients with CSS was 82.28±10.45. Patients in the CSS group experienced a higher frequency of falls in the past year compared to the control group (p=0.009). Among the participants, 14 (60.9%) patients in the CSS group reported symptoms of imbalance, compared to 1 (4.3%) in the control group (p<0.001). There was no significant difference between the groups in

Table 1. Symptom duration, disability, spinal canal, and cervical muscles cross-sectional area of patients

Variables	Values
Duration of Symptoms	36 (12-60) [1-240]
NDI	25.52±11.09
Cervical Spinal Canal Diameter	1.02 (0.94-1.18) [0.77-2.54]
Spinal Stenosis Level, n (%)	
C3-4	2 (8.7%)
C4-5	3 (13.0%)
C5-6	10 (43.5%)
C6-7	8 (34.8%)
Right Side Muscle CSA	
m. SCM	2.58±1.05
m. Longus Colli	0.56±0.18
m. Longus Capitis	0.27 (0.22-0.55) [0.13-2.92]
Left Side Muscle CSA	
m. SCM	2.58±1.06
m. Longus Colli	0.54±0.20
m. Longus Cap	0.27 (0.21-0.45) [0.14-1.90]

NDI: neck disability index, C: cervical, CSA: cross-sectional area, m.: musculus, SCM: sternocleidomastoid, data were expressed as number of patients (percentage), mean±standard deviation, and median (25th-75th quartile) [minimum-maximum] the eyes open firm surface (p=0.629) and eyes closed firm surface (p=0.553) posturography scores. However, the balance scores on the eyes open and closed foam surface posturography were significantly worse in the CSS group compared to the control group (p=0.034 and p=0.015, respectively). Additionally, the DHI score was significantly higher in the CSS group, indicating greater balance impairment, compared to the control group (p<0.001). Fall status, static posturography scores, and DHI scores for both groups were provided in Table 2. In the CSS group, no significant relationships were observed between DHI scores, eyes open and closed foam surface balance scores, CSS symptom duration, stenosis severity (CSA), and NDI scores. The CJPET scores were worse in the CSS group compared to the control group (p=0.032). In the CSS group, there was no significant correlation between the CJPET scores and symptom duration (p=0.602), left L Cap CSA (p=0.742), right L Cap CSA (p=0.728), spinal stenosis CSA (p=0.324), left L Colli (p=0.968), left SCM (p=0.380), right SCM (p=0.342), right L Colli (p=0.510), or NDI scores (p=0.605). The mean CJPET score for CSS patients with dizziness symptoms (n=14) was 9.89±6.21, while the mean CJPET score for CSS patients without dizziness symptoms (n=9) was 8.94±6.16. There was no significant difference in CJPET scores between patients with and without dizziness symptoms (p=0.724). Furthermore, no significant differences were found in terms of SVV between the groups (p=0.862). Bilateral cVEMP could not be recorded in 4 (17.4%) of the patients in the CSS group. Unilateral cVEMP was obtained in 1 (4.3%) patient from the control group. There was no significant difference in abnormal cVEMP responses between the groups (p=0.346). Of the 14 CSS patients with dizziness symptoms, 3 (21.4%) had abnormal cVEMP responses, while 1 (11.1%) of the 9 CSS patients without dizziness symptoms had an abnormal result. There was no significant difference in abnormal cVEMP responses between patients with and without dizziness symptoms (p=0.483). No significant differences were found between the groups regarding the normal vestibular evoked myogenic potential (VEMP) latency, amplitude, and asymmetry rates. SVV, VEMP latency, amplitude, and asymmetry rates for both groups were summarized in Table 2. Additionally, there were no significant correlations between the right-sided SCM CSA and right ear cVEMP P1 latency, N1 latency, or response amplitude (p=0.171, p=0.069, and p=0.296, respectively). Similarly, there was no significant correlation between left-sided SCM CSA and left ear cVEMP P1 latency, N1 latency, or response amplitude (p=0.124, p=0.806, and p=0.123, respectively).

DISCUSSION

This study demonstrated that patients with CSS had worse balance function and impaired proprioceptive sensory input compared to healthy controls. However, vestibular functions were comparable between the groups. No significant relationship was found between the severity and duration of stenosis and balance, proprioception, disability, or neck muscle CSA. Cervical stenosis may contribute to dizziness in patients, as increased pressure on nerves due to canal stenosis can cause headaches and balance disturbances (14). As vertebral degeneration progresses, dizziness may worsen over time, a condition often referred to as cervicogenic vertigo, which is typically triggered by excessive stress on the spine (15). A previous study showed that approximately 90% of patients with CSS, as assessed by MRI, experienced dizziness (15). This could be related to the vestibular, sensory, and vertebrobasilar circulation. Other studies suggest that functional cervical spine issues, such as postural misalignment, proprioception, and range of motion, may also contribute (6,16). However, these factors have not been adequately investigated in CSS and are mainly reported in case studies (15,16). It has been noted that cervical vertigo is prevalent in patients with cervical myelopathy, a condition characterized by cervical spinal cord compression (17). Another study also suggests that chronic neck pain and persistent dizziness may result from cervical disc degeneration (18). As cervical disc degeneration can be associated with canal stenosis, it is crucial

Table 2. SVV, VEMP latency, amplitude, asymmetry rate, fall, static posturography, and DHI results by groups

	CSS Group (n=23)	Control Group (n=23)	p
SVV (cm)	0 (-0.5-2) [-2-2]	0 (0-1) [-1-1]	0.862
Asymmetry Rate (%)	-1.21±19.17	-3.36±20.38	0.763
Right Ear-P1 (msec)	14.4 (14.0-14.7) [11.3-15.5]	14.4 (14.1-14.8) [11.2-15.5]	0.781
Right Ear-N1 (msec)	22.47±2.00	22.50±1.23	0.945
Right Ear-Amplitude (μV)	94.2 (91.3-98.6) [54.1-101.9]	96.4 (96.0-97.4) [88.1-104.6]	0.222
Left Ear-P1 (msec)	14.4 (13.9-14.8) [11.3-15.6]	14.1 (13.3-14.4) [13.1-15.5]	0.156
Left Ear-N1 (msec)	22.22±2.02	22.55±1.59	0.558
Left Ear-Amplitude (μV)	94.9 (93.3-97.1) [72.1-102.1]	95.3 (94.2-96.4) [90.0-99.8]	0.916
Falling, n (%)	7 (30.4%)	0 (0.0%)	**0.009**
Firm Surface-Eyes Open	92.55 (87.48-95.95) [68.76-96.86]	92.90 (90.89-94.04) [82.47-95.92]	0.629
Firm Surface-Eyes Closed	90.46 (86.13-92.86) [70.35-96.46]	91.41 (88.71-93.33) [81.13-95.62]	0.553
Foam Surface-Eyes Open	84.48 (75.30-89.92) [66.10-93.84]	98.64 (85.94-92.02) [62.54-96.27]	**0.034**
Foam Surface-Eyes Closed	77.21 (71.83-83.93) [48.12-90.37]	84.22 (77.75-87.63) [71.75-93.93]	**0.015**
DHI	6 (0-32) [0-56]	0 (0-0) [0-4]	**<0.001**
CJPET	9 (1-9) [0-20.5]	4.5 (5.5-14) [0-25]	**0.032**

CSS: cervical spinal stenosis, SVV: subjective visual vertical, VEMP: vestibular evoked myogenic potential, DHI: dizziness handicap inventory, CJPET: cervical joint position error test, data were expressed as number of patients (percentage), mean±standard deviation, and median (25^{th}-75^{th} quartile) [minimum-maximum] to explore this relationship in patients with stenosis (1). In this study, patients with stenosis had higher dizziness scores, with more CSS patients reporting dizziness symptoms. This may be due to multiple underlying mechanisms contributing to dizziness. Despite this, vestibular functions were similar across groups, suggesting that other factors might be involved in the heightened dizziness symptoms in CSS patients. The central nervous system achieves sensorimotor integration by integrating proprioceptive, vestibular, and visual inputs. Disruption of this integration may affect balance and postural control in conditions such as dizziness originating from the cervical spine (18,19). Changes in cervical proprioceptive inputs may increase dizziness symptoms due to incorrect orientation of the vestibular system (19). In this context, preserving vestibular functions in CSS patients suggests that symptoms of dizziness may be explained by alternative mechanisms such as sensorimotor integration disorder. Proprioception plays a critical role in maintaining correct postural organization. Receptors in the joint capsules and muscles of the cervical region contribute to cervical activity control, eye movement, and postural stability (3,20). Cervical disc degeneration and stenotic changes can disrupt this organization, impairing proprioceptive input (21). This impairment is a significant issue for patients with neck pain, often resulting in sensory and motor control dysfunction (22). Reddy et al. (23) reported that patients with cervical spondylosis exhibited impaired proprioception compared to healthy controls, with higher pain intensity correlating with greater deviations in position sense. However, it remains unclear to what extent proprioception is affected in CSS. This study found that CSS patients exhibited worse proprioception than healthy individuals, which may be attributed to various factors. Pain and reduced joint movement due to stenosis may lead to forward head posture and altered cervical posture, potentially affecting mechanoreceptor activity and further impairing proprioception in CSS patients (21,24). This dysfunction could also contribute to dizziness. Due to degeneration in the cervical region, damaged receptors can transmit abnormal signals to the vestibular nucleus, which may lead to cervicogenic vertigo and worsened dizziness (3). Within the CSS group, no significant difference in proprioception was observed between patients with and without dizziness. It has been reported that half of all proprioceptors in the cervical region are located between C1 and C3 (14). Since most patients in this study had stenosis at levels C3 and below, proprioceptive effects from stenosis may have been less pronounced. No significant relationships were found between stenosis severity and dizziness, proprioception, or disability. Therefore, it is hypothesized that postural changes, rather than proprioceptive inputs, may contribute more to the increased dizziness symptoms in CSS. Balance is influenced by visual input, proprioception, and the vestibulocochlear systems (8,25). Issues that cause neck pain affect balance and mobility by impairing cervical proprioception and sensorimotor control (8). This could contribute to symptoms observed in CSS. Additionally, impaired spinal biomechanics in CSS patients lead to forward head posture (24). Current evidence highlights a link between increased forward head posture and decreased stability, balance, and cervical proprioception (25). It is believed that these parameters may be affected by degeneration occurring in CSS. A study indicated that patients with myelopathy due to spinal cord compression showed increased central oscillation and head sway in both AP and right-left directions compared to healthy patients (26). Similarly, another study reported that there was an impaired standing balance in cervical myelopathy patients (27). However, these findings were not observed in CSS. This study revealed that patients with CSS exhibited worse balance on foam surfaces than healthy individuals, with no significant difference on firm surfaces, possibly due to better proprioceptive return on stable surfaces. Compression and degeneration of receptors in the dorsal column may have contributed to balance deterioration in activities involving foam surfaces and walking (27). No significant relationships were found between stenosis severity and balance functions. This could be due to including patients with relatively mild stenosis in the study. Inputs from the saccule reach the lateral vestibular nucleus via the inferior vestibular nerve, then the accessory nerve or, through the spinal cord and vestibulo-spinal pathway, to the motor neurons innervating somatic muscles (28). The accessory nerve innervates the SCM and generates cVEMP responses (29). Contraction of the SCM muscle is essential for recording VEMPs, and the response amplitude increases with tonic muscle activation (30). Neck pain often leads to changes in neck muscles, potentially due to pain avoidance behavior (31). Although abnormal cVEMP responses in individuals with neck problems may not indicate vestibular involvement, they may reflect efferent pathway dysfunction (29). This could also play a role in the mechanism of cervicogenic dizziness.

However, no significant differences in cVEMP responses were observed between the groups in this study, suggesting that cervical involvement in CSS was not severe enough to affect the SCM muscle. This may be due to the severity of mild stenosis in the CSS patients in this study. Additionally, no significant relationship was found between SCM thickness and cVEMP responses, as cVEMP responses are associated with tonic contraction rather than muscle thickness in the neutral position.

This study has several limitations. First, the sample size was small, and it was a single-center study, which may limit the generalizability of the results. Cervical posture, which may contribute to changes in proprioception and dizziness, was not evaluated. Alterations in cervical posture could affect muscle length-tension relationships and muscle function, depending on the severity of stenosis. Thus, assessing cervical posture and craniovertebral angle could provide valuable insights for interpreting the results. Another limitation is that intramuscular fat analysis cannot be performed by giving the total cross-sectional area of the muscle, which may affect neck posture.

CONCLUSION

Patients with CSS exhibited increased dizziness symptoms and impairments in balance and proprioception compared to healthy individuals. However, the contributions of balance, proprioception, and vestibular functions to the formation of dizziness in CSS appear to be less significant, and these parameters were not correlated with stenosis severity. The problems and underlying mechanisms that may cause dizziness in CSS should be examined in future studies.

Ethics Committee Approval: The study was approved by the Non-interventional Clinical Research Ethics Committee of Karabük University (05.12.2023, 1521).

Conflict of Interest: None declared by the authors.

Financial Disclosure: None declared by the authors.

Acknowledgments: The authors would like to thank Prof. Dr. Mehmet Zileli for his great efforts.

Author Contributions: Idea/Concept: HK, BB, ES, MG, NKK; Design: HK, MG, NKK, TGS; Data Collection/ Processing: BB, ES, TGS, ASA; Analysis/Interpretation: HK, NKK, TGS, ASA; Literature Review: HK, BB, MG, NKK, ASA; Drafting/Writing: ES, MG, NKK, ASA; Critical Review: HK, BB, ES, TGS, ASA.

REFERENCES

1. Meyer F, Börm W, Thomé C. Degenerative cervical spinal stenosis: current strategies in diagnosis and treatment. Dtsch Arztebl Int. 2008;105(20):366-72.
2. Goodwin AM, Hsu WK. Congenital cervical stenosis: a review of the current literature. Curr Rev Musculoskelet Med. 2023;16(9):438-45.
3. Li Y, Peng B. Pathogenesis, diagnosis, and treatment of cervical vertigo. Pain Physician. 2015;18(4):583-95.
4. Colledge NR, Barr-Hamilton RM, Lewis SJ, Sellar RJ, Wilson JA. Evaluation of investigations to diagnose the cause of dizziness in elderly people: a community based controlled study. BMJ. 1996;313(7060):788-92.
5. Sremakaew M, Sungkarat S, Treleaven J, Uthaikhup S. Impaired standing balance in individuals with cervicogenic headache and migraine. J Oral Facial Pain Headache. 2018;32(3):321-8.
6. Reid SA, Callister R, Katekar MG, Rivett DA. Effects of cervical spine manual therapy on range of motion, head repositioning, and balance in participants with cervicogenic dizziness: a randomized controlled trial. Arch Phys Med Rehabil. 2014;95(9):1603-12.
7. Fife TD, Colebatch JG, Kerber KA, Brantberg K, Strupp M, Lee H, et al. Practice guideline: Cervical and ocular vestibular evoked myogenic potential testing: Report of the Guideline Development, Dissemination, and Implementation Subcommittee of the American Academy of Neurology. Neurology. 2017;89(22):2288-96.
8. Peng B, Yang L, Li Y, Liu T, Liu Y. Cervical proprioception impairment in neck pain-pathophysiology, clinical evaluation, and management: a narrative review. Pain Ther. 2021;10(1):143-64.
9. Goni VG, Hampannavar A, Gopinathan NR, Singh P, Sudesh P, Logithasan RK, et al. Comparison of the oswestry disability index and magnetic resonance imaging findings in lumbar canal stenosis: an observational study. Asian Spine J. 2014;8(1):44-50.
10. Kuittinen P, Sipola P, Saari T, Aalto TJ, Sinikallio S, Sakari S, et al. Visually assessed severity of lumbar spinal canal stenosis is paradoxically associated with leg pain and objective walking ability. BMC Musculoskelet Disord. 2014;15:348.
11. Kesiktas N, Ozcan E, Vernon H. Clinimetric properties of the Turkish translation of a modified neck disability index. BMC Musculoskelet Disord. 2012;13:25.
12. Canbal M, Cebeci S, Çamur Duyan G, Kurtaran H, Arslan İ. A study of reliability and validity for the Turkish version of dizziness handicap inventory. TJFMPC. 2016;10(1):19-24. Turkish.
13. Quartey J, Ernst M, Bello A, Oppong-Yeboah B, Bonney E, Acquaah K, et al. Comparative joint position error in patients with non-specific neck disorders and asymptomatic age-matched individuals. S Afr J Physiother. 2019;75(1):568.
14. Yi YY, Xu HW, Zhang SB, Hu T, Wang SJ, Wu DS. Does the C3/4 disc play a role in cervical spondylosis with dizziness? A retrospective study. Int Orthop. 2020;44(6):1159-68.
15. Takahashi S. Importance of cervicogenic general dizziness. J Rural Med. 2018;13(1):48-56.
16. Reid SA, Callister R, Katekar MG, Treleaven JM. Utility of a brief assessment tool developed from the Dizziness Handicap Inventory to screen for Cervicogenic dizziness: A case control study. Musculoskelet Sci Pract. 2017;30:42-8.
17. Kadanka Z Jr, Kadanka Z Sr, Jura R, Bednarik J. Vertigo in patients with degenerative cervical myelopathy. J Clin Med. 2021;10(11):2496.
18. Yang L, Chen J, Yang C, Pang X, Li D, Wu B, et al. Cervical intervertebral disc degeneration contributes to dizziness: a clinical and immunohistochemical study. World Neurosurg. 2018;119:686-93.
19. Yacovino DA, Hain TC. Clinical characteristics of cervicogenic-related dizziness and vertigo. Semin Neurol. 2013;33(3):244-55.
20. de Vries J, Ischebeck BK, Voogt LP, van der Geest JN, Janssen M, Frens MA, et al. Joint position sense error in people with neck pain: A systematic review. Man Ther. 2015;20(6):736-44.
21. Yang L, Yang C, Pang X, Li D, Yang H, Zhang X, et al. Mechanoreceptors in diseased cervical intervertebral disc and vertigo. Spine (Phila Pa 1976). 2017;42(8):540-6.
22. Treleaven J. Sensorimotor disturbances in neck disorders affecting postural stability, head and eye movement control. Man Ther. 2008;13(1):2-11.
23. Reddy RS, Tedla JS, Dixit S, Abohashrh M. Cervical proprioception and its relationship with neck pain intensity in subjects with cervical spondylosis. BMC Musculoskelet Disord. 2019;20(1):447.
24. Kim DH, Kim CJ, Son SM. Neck pain in adults with forward head posture: effects of craniovertebral angle and cervical range of motion. Osong Public Health Res Perspect. 2018;9(6):309-13.
25. Lin G, Zhao X, Wang W, Wilkinson T. The relationship between forward head posture, postural control, and gait: A systematic review. Gait Posture. 2022;98:316-29.
26. Haddas R, Lieberman I, Boah A, Arakal R, Belanger T, Ju KL. Functional balance testing in cervical spondylotic myelopathy patients. Spine (Phila Pa 1976). 2019;44(2):103-9.
27. Ver MLP, Gum JL, Glassman SD, Carreon LY. Assessment of standing balance in normal versus cervical spondylotic myelopathy patients. N Am Spine Soc J. 2020;3:100023.

28. Caria MA, Tavera C, Melis F, Mameli O. The vestibulospinal reflex in humans: effects on paraspinal muscle activity. Acta Otolaryngol. 2003;123(7):817-25.
29. Solarino B, Coppola F, Di Vella G, Corsalini M, Quaranta N. Vestibular evoked myogenic potentials (VEMPs) in whiplash injury: a prospective study. Acta Otolaryngol. 2009;129(9):976-81.
30. Colebatch JG, Halmagyi GM, Skuse NF. Myogenic potentials generated by a click-evoked vestibulocollic reflex. J Neurol Neurosurg Psychiatry. 1994;57(2):190-7.
31. Prushansky T, Gepstein R, Gordon C, Dvir Z. Cervical muscles weakness in chronic whiplash patients. Clin Biomech (Bristol). 2005;20(8):794-8.