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Journal of Orthopedics Research and Rehabilitation

Original Article

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Beyond pain: sleep quality impairment in lumbosacral radiculopathy neuropathic pain and sleep in lumbosacral radiculopathy

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ABSTRACT

Aims: Lumbosacral radiculopathy is one of the major causes of neuropathic pain, and sleep quality may be impaired secondary to neuropathic pain in these patients. In this study, we aimed to investigate the relationship between neuropathic pain and sleep quality in patients with lumbosacral radiculopathy.

Methods: In this retrospective study, 30 patients with lumbosacral radiculopathy detected on magnetic resonance imaging (MRI) were included. All patients were electrophysiologically evaluated for lumbosacral radiculopathy. The Douleur Neuropathique 4 (DN4) questionnaire was used to assess neuropathic pain, and the Jenkins Sleep Scale was administered to evaluate sleep quality. A DN4 score of 4 or higher indicates neuropathic pain. Patients with a Jenkins Sleep Scale score of ≤9 were assigned to the mild sleep impairment group, whereas those with a score >9 were assigned to the moderate-to-severe sleep impairment group.

Results: Thirty patients (12 males, 18 females) diagnosed with lumbosacral radiculopathy based on neuroimaging findings were included in the study. Electrophysiological findings confirmed lumbosacral radiculopathy in 17 patients. Neuropathic pain was present in all patients. Impaired sleep quality was observed in patients with higher neuropathic pain scores. A positive correlation was found between DN4 scores and Jenkins Sleep Scale scores (p=0.006, r=0.487).

Conclusion: Neuropathic pain associated with lumbosacral radiculopathy may lead to impaired nocturnal sleep quality. The relationship between neuropathic pain and sleep quality may be associated with the severity and duration of neuropathic pain. Further studies with larger sample sizes are needed to clarify this relationship.

Keywords: Lumbosacral radiculopathy, neuropathic pain, sleep quality

INTRODUCTION

The lumbar region is the most commonly affected site of radiculopathy, with the L5–S1 level being the most frequently involved segment.[1,2] This is mainly because it is the most mobile and weight-bearing segment of the spine. Degenerative changes associated with aging are the most common etiological factors in this region. Lumbosacral radiculopathy develops secondary to nerve root compression caused by conditions such as intervertebral disc herniation, spondylolisthesis, and spinal stenosis.[3] Patients with lumbosacral radiculopathy commonly present with complaints such as low back pain radiating to the leg and paresthesia.[1,4] The condition may develop acutely or chronically. Diagnosis is established through magnetic resonance imaging (MRI) and electrophysiological evaluation.[5,6]

Neuropathic pain is a subjective complaint that may impair sleep quality.[7,8] It can develop due to many different causes, and lumbosacral radiculopathy is one of the important causes of neuropathic pain.[9] The severity and duration of neuropathic pain are important factors affecting sleep quality.[10] Difficulty falling asleep, difficulty maintaining sleep, frequent awakenings, waking up feeling tired, and daytime sleepiness are indicators of impaired sleep quality.[11]

In this study, patients diagnosed with lumbosacral radiculopathy based on MRI findings were also evaluated electrophysiologically, and their neuropathic pain was assessed using the DN4 neuropathic pain questionnaire. In addition, nocturnal sleep quality was evaluated using the Jenkins Sleep Scale. Thus, the relationship between neuropathic pain associated with lumbosacral radiculopathy and impaired sleep quality was investigated.

METHODS

This study was approved by the Scientific Researches Ethics Committee of Adana City Training and Research Hospital (Date: 18.12.2025, Decision No: 946). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki.

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Patients older than 18 years of age who were referred to the Neuroelectrophysiology Clinic of Adana City Training and Research Hospital between April 1, 2025, and September 30, 2025, presenting with clinical complaints and diagnosed with lumbosacral radiculopathy based on neuroimaging findings, were included in this study.

Patients with fibromyalgia, diabetes mellitus, vasculitis, multiple sclerosis, peripheral neuropathy, or a history of spinal cord trauma were excluded from the study. All included patients were evaluated for neuropathic pain using the DN4 Neuropathic Pain Questionnaire. A DN4 score of 4 or higher was accepted as indicative of neuropathic pain.[12] The Jenkins Sleep Scale was administered to all patients to assess sleep quality during the previous month. According to the Jenkins Sleep Scale, scores between 0–9 were considered mild, scores between 10–20 were considered moderate-to-severe impairment in sleep.[13] Patients presenting with clinical symptoms and MRI findings suggestive of lumbosacral radiculopathy underwent electromyographic (EMG) evaluation. Although MRI findings were consistent with lumbosacral radiculopathy, electrodiagnostic studies may yield normal results in some patients.

Electrophysiological Tests

Electrodiagnostic tests were performed with the Cadwell Sierra Summit electromyography (EMG) unit (Cadwell Laboratories, Kennewick, Washington, USA). Nerve conduction studies were performed using previously suggested methods.[8,9] The normal values of our laboratory were used for the normal values of the nerve conduction study.[8,9] Needle EMG study was performed with concentric needle electrodes (length=50 mm, diameter=0.46 mm, Bionen Medical Devices, Florence, Italy). The band filter range for needle EMG was 10 Hz–10 kHz. The sweep speed/sensitivity during rest, during mild muscle contraction, and for interference pattern analysis were 10 ms/100 µV, 10 ms/500–1000 µV, and 100 ms/500–1000 µV, respectively. Needle EMG was applied visually. Positive sharp waves (PSWs) and fibrillation potentials (FPs) were carefully analyzed. If the motor unit action potential (MUAP) amplitude was >3 mV and the MUAP duration >15 ms, this MUAP was considered neurogenic. Tibialis anterior, medial gastrocnemius, vastus lateralis, peroneus longus, gluteus medius and gluteus maximus muscles were examined with needle EMG. Needle EMG findings were considered abnormal when PSWs, FPs, or MUAPs with neurogenic features were detected.

Statistical Analysis

Categorical variables were expressed as frequencies and percentages, whereas numerical variables were presented as mean±standard deviation and range. Categorical variables were compared between groups using the Pearson Chi-square test or Fisher's exact test, as appropriate. Numerical variables were compared using the Mann–Whitney U test. Correlations between variables were assessed using Spearman's rank correlation test. The strength of the correlation was interpreted according to the correlation coefficient (r) as follows: $r \geq 0.9$ or $r \leq -0.9$, very strong; $0.7 \leq r < 0.9$ or $-0.9 < r \leq -0.7$, strong; $0.5 \leq r < 0.7$ or $-0.7 < r \leq -0.5$, moderate; $0.3 < r \leq 0.5$ or $-0.5 \leq r < -0.3$, weak; and $-0.3 < r < 0.3$, negligible. A p-value<0.05 was considered statistically significant.

RESULTS

Thirty patients (12 males and 18 females) were included in the study. The mean age of the patients was 55.6±15.8 years (range, 22–82 years). The mean duration of symptoms was 40.3±25.3 months (range, 3–120 months). The mean DN4 Neuropathic Pain Questionnaire score was 5.7±1.1 (range, 4–8), and the mean Jenkins Sleep Scale score was 11.8±3.0 (range, 6–19). Since only patients with MRI-confirmed lumbosacral radiculopathy and clinically compatible symptoms were enrolled, all patients had a DN4 score of ≥4, consistent with the presence of neuropathic pain.

The Jenkins Sleep Scale score was between 0–9 in 6 patients and between 10–20 in 24 patients. Table 1 summarizes the associations of Jenkins and DN4 scores with clinical characteristics. A weak positive correlation was observed between Jenkins and DN4 scores (r=0.487, p=0.006). Needle EMG abnormalities were identified in "17 patients (56.7%)" (17/30 = 0.5667). Jenkins scores in patients with and without needle EMG abnormalities are compared in Table 2. Patients with abnormal needle EMG findings had significantly higher Jenkins scores than those with normal findings (p=0.004). Figure illustrates the distribution of patients according to needle EMG findings and sleep quality category. All patients with needle EMG abnormalities had Jenkins scores>9, whereas 7 patients without needle EMG abnormalities also had scores >9 (p=0.003).

Table 1. Correlation between Jenkins Sleep Scale score and clinical features

	Jenkins Score	
Clinical feature	**p value**	**r value**
Age	0.387	0.163
Disease duration (months)	0.617	0.099
DN4 Score	0.006	0.487

DN4: Douleur Neuropathique 4

Table 2. Questionnaire scores according to EMG findings

Questionnaire	Needle EMG abnormalities (+)	Needle EMG abnormalities (-)	p value
Jenkins	13.1±2.6 (12.0) (10-19)	10.2±2.9 (10.0) (6-17)	0.004
DN4	6.0±1.1 (6.0) (4-8)	5.3±1.0 (5.0) (4-7)	0.091

DN4: Douleur neuropathique 4, EMG: Electromyography

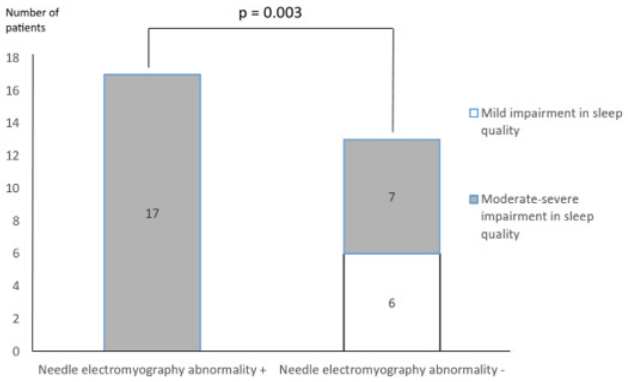

Figure. Distribution of patients according to needle EMG findings and sleep quality.
EMG: Electromyography

DISCUSSION

Neuropathic pain was identified in all patients included in the present study. This finding is consistent with the pathophysiological mechanisms of radiculopathy, in which nerve root involvement and ectopic impulse generation are considered major contributors to neuropathic pain.[14] The presence of neuropathic pain in all patients may be attributable to the study's inclusion criteria. Only individuals with clinical and imaging findings consistent with lumbosacral radiculopathy were enrolled, which may have contributed to the uniformly high prevalence of neuropathic pain observed in the cohort.

Neuropathic pain is associated not only with sensory symptoms but also with impairments in physical functioning, emotional well-being, and quality of life.[15] As pain severity increases in individuals with lumbosacral radiculopathy, limitations in daily activities may become more pronounced and sleep quality may also deteriorate. The positive association observed between neuropathic pain and sleep disturbance in our cohort supports this view and suggests that neuropathic pain may be an important factor contributing to impaired sleep in these patients. The association observed between neuropathic pain and sleep disturbance may reflect a reciprocal relationship, in which greater pain is accompanied by poorer sleep.[16,17] Accordingly, alleviation of neuropathic pain could contribute to better sleep quality in affected patients. Given the observed association between neuropathic pain and sleep disturbance, a comprehensive clinical assessment should include evaluation of sleep-related symptoms in addition to neuropathic pain and neuromuscular abnormalities. Accordingly, treatment outcomes should be assessed not only in terms of pain relief but also with regard to improvements in sleep quality.[18] Further studies that examine polysomnographic findings, pain duration, depression, and anxiety may help clarify the relationship between neuropathic pain and sleep disturbances in patients with radiculopathy.

Patients with radiculopathy confirmed by needle EMG exhibited higher Jenkins scores than those without electrophysiological abnormalities. Needle EMG abnormalities may reflect more severe nerve root involvement and axonal degeneration, which could contribute to the greater degree of sleep impairment observed in these patients. This observation suggests that sleep disturbance may be related not only to pain severity but also to the extent of neurological damage.[19] Electrophysiological findings may therefore help identify patients at risk of greater functional impairment.

Limitations

Several limitations of this study should be acknowledged. First, the retrospective design and relatively small sample size may limit the statistical power of the analyses and generalizability of the findings. Another limitation of this study is that sleep quality may be influenced by medications used for pain management. Analgesic agents, including neuropathic pain medications, nonsteroidal anti-inflammatory drugs, and other concomitant treatments, may independently affect sleep quality, either positively or negatively. In addition, electrodiagnostic assessment relied on needle EMG, which reflects motor axonal involvement but does not directly assess pain-related pathways. Future studies may benefit from the inclusion of techniques that provide information on pain pathway function, such as sympathetic skin response testing. Nevertheless, needle EMG remains valuable for identifying axonal degeneration and characterizing the extent of neurological involvement. Larger, prospective, multicenter studies are needed to confirm the relationship between neuropathic pain, sleep quality, and electrophysiological findings in patients with lumbosacral radiculopathy.

CONCLUSION

In this study, neuropathic pain was observed in all patients with lumbosacral radiculopathy, and sleep disturbances were frequently identified. Higher neuropathic pain scores were associated with greater impairment in sleep quality. Patients with radiculopathy findings on needle EMG also tended to have higher Jenkins scores, suggesting a possible link between electrophysiological abnormalities and sleep disturbance. These findings suggest that sleep-related symptoms may represent an important clinical feature of lumbosacral radiculopathy. Further studies with larger cohorts are needed to better clarify the relationships among neuropathic pain, electrophysiological findings, and sleep disturbance in this patient population.

ETHICAL DECLARATIONS

Ethics Committee Approval

This study was approved by the Scientific Researches Ethics Committee of Adana City Training and Research Hospital (Date: 18.12.2025, Decision No: 946).

Informed Consent

This retrospective study used pre-existing anonymized patient data. No additional intervention was performed, and there was no direct patient contact. The study was approved by the Ethics Committee, and the requirement for written informed consent was waived by the ethics committee.

Peer Review Process

This manuscript was subject to external peer review.

Conflict of Interest

The authors declare no conflicts of interest related to this study.

Financial Disclosure

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Author Contributions

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Original Article

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Pain intensity and pain catastrophizing in individuals with chronic temporomandibular disorders with and without neck pain: a cross-sectional study

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ABSTRACT

Aims: The aim of this study was to compare pain intensity and pain catastrophizing between individuals with chronic temporomandibular disorders (TMD) with and without accompanying neck pain.

Methods: Twenty-two individuals diagnosed with chronic TMD participated in this cross-sectional study. Participants were allocated into two groups: a TMD-only group (n=12) and a TMD with neck pain group (n=10). Pain intensity was assessed using the Numeric Rating Scale (NRS), and pain catastrophizing was assessed using the Pain Catastrophizing Scale (PCS).

Results: No statistically significant differences were observed between the TMD-only and TMD with neck pain groups in TMD-related jaw pain intensity at rest, during chewing and functional activities, or at night, or in PCS total and subscale scores (all $p>0.05$). Moderate effect sizes were observed for pain during chewing and functional activities, pain at rest, and PCS helplessness, while the remaining comparisons showed small effect sizes.

Conclusion: Accompanying neck pain was not associated with statistically significant differences in TMD-related jaw pain intensity or pain catastrophizing in individuals with chronic TMD. However, the moderate effect sizes observed for pain at rest, pain during chewing and functional activities, and PCS helplessness suggest that these outcomes may warrant further investigation in larger samples.

Keywords: Temporomandibular joint disorders, neck pain, pain measurement, catastrophization, temporomandibular joint

INTRODUCTION

Temporomandibular dysfunction (TMD), as defined within the diagnostic criteria for temporomandibular disorders (DC/TMD) framework,[1] encompasses a group of disorders affecting the masticatory system. In the classification of TMD, it is divided into two main groups: muscle-related (extra-articular) dysfunctions, such as myofascial pain, and joint-related (intra-articular) dysfunctions, such as disc displacements.[2] TMD has been identified as a common health problem affecting approximately 15–20% of the adult population. It has been reported in the literature that symptoms most frequently peak between the ages of 20 and 40, and the prevalence is higher in females than in males.[3]

TMD can cause pain severe enough to require a multidisciplinary approach in patients. It is considered that TMD may become an increasing problem today due to stress and the improper use of the masticatory system. One of its contributing factors is stress, which has a destructive effect on all components of the masticatory system and may lead to TMD.[4] In TMD, pain may have an etiological structure that is classified as either central (centralized) or peripheral, as demonstrated in the study by Yin et al.[5] in 2020. Various physiotherapy and rehabilitation approaches aimed at reducing pain intensity in individuals with TMD have been reported to be beneficial.[6]

Temporomandibular joint disorders (TMDs) are complex musculoskeletal problems that should be considered within the integrity of the craniocervical mandibular system, as they are frequently associated with cervical spine dysfunctions.[7] Clinical studies have shown that, in the majority of patients diagnosed with TMD, neck pain and restricted cervical movements coexist.[8] Alterations in craniocervical biomechanics, cervical mobility, muscle performance, and neck disability have also been reported in individuals with TMD.[9] From a biomechanical perspective, postural alterations in the cervical region, such as anterior head posture, have been suggested to be associated with changes in the position of the hyoid bone and muscle tone in the muscles responsible for mastication, which may influence the resting position of the mandible and its movement mechanics.[10] At the deeper level of anatomical connection,

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the convergence of the afferent fibers of the trigeminal nerve and the upper cervical nerves (C1–C3) within the trigeminocervical nucleus in the brainstem constitutes the main neurophysiological mechanism underlying the referral of pain originating from the cervical region to the orofacial region.[11] Therefore, evaluation of the cervical region should also be included in the management of craniomandibular pain and dysfunction.[12] The interaction between cervical and orofacial nociceptive inputs may contribute to the overall pain experience in individuals with TMD.[13] In persistent pain conditions, accompanying neck pain may further influence the interaction between nociceptive mechanisms and cognitive and emotional responses to pain, including pain catastrophizing.

From a neurophysiological perspective, pain catastrophizing is not only a cognitive condition but also a phenomenon associated with dysfunction of the pain modulation pathways in the central nervous system. Quantitative sensory testing studies conducted in healthy individuals have shown that high levels of pain catastrophizing are associated with a significant reduction in the effectiveness of the endogenous pain inhibition mechanism known as "diffuse noxious inhibitory control" (DNIC), or, as it is currently referred to, "conditioned pain modulation" (CPM).[14] When the prognosis of patients with chronic TMD is evaluated, pain emerges as one of the major factors negatively affecting the symptoms of the disorder, accompanied by increased pain catastrophizing scores.[15]

To the best of our knowledge, a review of the literature revealed no study investigating both neck pain accompanying chronic TMD and pain catastrophizing parameters together in patients with TMD. Previous studies have shown that both neck pain and pain catastrophizing are independently associated with TMD. Age and gender may also be associated with TMD and pain-related outcomes and should therefore be considered as potential confounding factors when interpreting these relationships. Therefore, the aim of this cross-sectional study was to compare TMD-related jaw pain intensity and pain catastrophizing between individuals with TMD with and without accompanying neck pain. We hypothesized that individuals with TMD and accompanying neck pain would have higher TMD-related jaw pain intensity and pain catastrophizing scores than individuals with TMD without neck pain.

METHODS

This study was approved by the Non-interventional Clinical Researches Ethics Committee at the Kırıkkale University (Date: 22.10.2025, Decision No: 2025.10.36). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki.

Present study is a cross-sectional comparative study involving two groups. The study was conducted between January 2026 and May 2026. Patients with a previous diagnosis of TMD who presented to the Department of Physiotherapy and Rehabilitation at Kırıkkale University were included in the study.

Volunteers aged between 18 and 65 years who had been diagnosed with chronic TMD, had not previously undergone surgical intervention or similar treatment related to TMD, and had experienced pain persisting for more than 6 months were included in the study. Participants were allocated to the TMD with neck pain group based on their self-reported presence of neck pain. No specific duration criterion was defined for neck pain; participants were classified according to the presence or absence of accompanying neck pain. The exclusion criteria of our study were determined as the presence of systemic musculoskeletal diseases (such as fibromyalgia, rheumatoid arthritis, etc.), neurological disorders, a history of acute trauma to the face or jaw region, a history of psychiatric disorders, pregnancy, and a previous history of surgical intervention involving the temporomandibular joint (TMJ) or the cervical region.

The socio-demographic and clinical characteristics of the participants were recorded, including age, height, weight, gender, occupation, smoking and alcohol consumption, exercise habits, sleep duration, mandibular deviation, limitation of jaw movements or the presence of joint sounds and locking during movement, presence or absence of bruxism, morning stiffness in the jaw.

Pain related to the TMJ, the duration of pain, pain intensity, and pain catastrophizing were evaluated. The numeric rating scale (NRS-11) was used to determine the participants' pain levels. The Pain Catastrophizing Scale (PCS) was used to assess the participants' pain catastrophizing scores. Due to the nature of the study design, the researcher performing the assessments could not be blinded to group allocation. Pain intensity was recorded based on the participants' self-reported responses. All questionnaire items were completed, with no missing responses.

Assessment of Pain Intensity

The pain levels of the participants (at rest- pain during chewing and functional activities, at night) were determined using the NRS-11 due to its ease of application and practicality in clinical settings. The NRS-11 is an 11-point scale ranging from 0 to 10, where 0 indicates no pain and 10 indicates the worst imaginable pain.[16]

Assessment of Pain Catastrophizing

The pain catastrophizing levels of the participants were determined using the PCS, which consists of 13 items. Participants were asked to evaluate their cognitive and emotional responses to pain using a 5-point Likert scale ranging from 0 ("not at all") to 4 ("all the time"). The PCS assesses three main dimensions of pain catastrophizing: rumination, magnification, and helplessness.[17] The Turkish version of the questionnaire has demonstrated validity and reliability.[18]

Statistical Analysis

Data analyses were performed using IBM SPSS Statistics, version 31.0 (IBM Corp., Armonk, NY, USA). The normality of distribution for continuous variables was assessed using both visual methods (histograms and Q-Q plots) and analytical methods (the Shapiro-Wilk test). Descriptive statistics were presented as frequency and percentage for categorical variables, and as median and 25^{th}–75^{th} percentile for continuous variables. Fisher's Exact Test was used instead

of the Chi-square test for the comparison of independent categorical variables, as the expected cell frequency was below 5 in at least one cell for every comparison. The Mann-Whitney U test was used for the comparison of continuous variables between independent groups, as the assumption of normal distribution was not met;[19,20] the median difference between groups was calculated and reported together with the corresponding 95% confidence interval. Effect sizes were calculated as the r coefficient, obtained by dividing the Z statistic by the square root of the sample size ($r=|Z|/\sqrt{N}$); r values below 0.10 were interpreted as small, values around 0.30 as moderate, and values above 0.50 as large effect sizes.[21] For all analyses, a type I error level below 5% was considered statistically significant.

RESULTS

A total of 31 individuals diagnosed with chronic TMD were assessed for eligibility. Of these, seven individuals were excluded because they had received botulinum toxin treatment, and two individuals declined to participate (Figure). Twelve participants were included in the TMD-only group, while ten participants were included in the TMD with neck pain group.

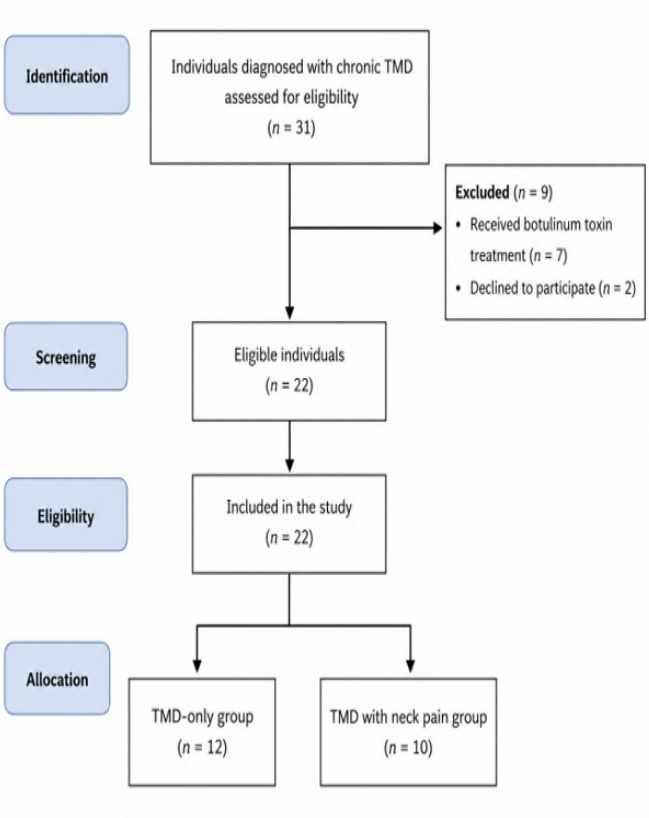

Figure. Flow chart
TMD: Temporomandibular disorders

The demographic and clinical characteristics of the participants are presented in Table 1. No statistically significant differences were found between the TMD-only and TMD+Neck Pain groups regarding age, body mass index, or duration of TMJ pain (all p>0.05). Similarly, no statistically significant differences were observed between groups for gender distribution, smoking status, alcohol consumption, exercise habits, mandibular deviation, bruxism, morning jaw stiffness, jaw motion limitation, TMJ sounds, or locking/sticking episodes (all p>0.05, Table 1).

Table 1. Comparison of demographic and clinical characteristics between groups

	TMD-only (n=12)	TMD+NP (n=10)	p
Age (years)	30.50 (24.50/37.00)	26.00 (23.00/30.00)	0.155
BMI (kg/m²)	24.23 (22.66/26.42)	21.78 (21.31/24.38)	0.106
Duration of TMJ pain (years)	2.00 (1.00/8.00)	3.00 (2.00/4.00)	0.895
Gender			
Male	3 (25.00)	2 (20.00)	1.000
Female	9 (75.00)	8 (80.00)	
Smoking			
Yes	3 (25.00)	6 (60.00)	0.192
No	9 (75.00)	4 (40.00)	
Alcohol consumption			
Yes	4 (33.33)	6 (60.00)	0.391
No	8 (66.67)	4 (40.00)	
Exercise habit			
Yes	11 (91.67)	6 (60.00)	0.135
No	1 (8.33)	4 (40.00)	
Mandibular deviation			
Yes	3 (25.00)	7 (70.00)	0.084
No	9 (75.00)	3 (30.00)	
Bruxism			
Yes	9 (75.00)	9 (90.00)	0.594
No	3 (25.00)	1 (10.00)	
Morning jaw stiffness			
Yes	9 (75.00)	7 (70.00)	1.000
No	3 (25.00)	3 (30.00)	
Jaw motion limitation			
Yes	3 (25.00)	5 (50.00)	0.378
No	9 (75.00)	5 (50.00)	
TMJ sounds			
Yes	7 (58.33)	6 (60.00)	1.000
No	5 (41.67)	4 (40.00)	
Locking or sticking			
Yes	3 (25.00)	4 (40.00)	0.652
No	9 (75.00)	6 (60.00)	

Data are presented as median (25^{th}/75^{th} percentile) or n (%). TMD: Temporomandibular disorder, TMJ: Temporomandibular joint, NP: Neck pain, BMI: Body-mass index, n: Number, %: Percentage. Continuous variables were compared using the Mann-Whitney U test; categorical variables were compared using Fisher's Exact Test.

Comparisons of pain intensity, and pain catastrophizing between groups are presented in Table 2. None of the assessed variables, including NRS scores at rest, during activity, and at night, the PCS subscale and total scores, demonstrated a statistically significant between-group difference (all p>0.05). Effect sizes (r) ranged from 0.099 to 0.353; NRS during activity (r=0.353), NRS at rest (r=0.324), and PCS helplessness (r=0.324) reached a moderate magnitude, whereas the remaining comparisons showed small effects.

Table 2. Comparison of pain severity, and pain catastrophizing between groups

		TMD-only (n=12)	TMD+NP (n=10)	Δ (95% CI)	p	ES
NRS	At rest	2.00 (0.25/2.00)	2.50 (1.00/4.00)	1.00 (0.00/3.00)	0.128	0.324
	Activity	5.00 (4.00/6.00)	7.00 (4.00/7.00)	1.00 (0.00/3.00)	0.098	0.353
	Night	2.00 (1.00/3.50)	2.50 (2.00/4.00)	1.00 (-1.00/2.00)	0.400	0.179
PCS	Rumination	3.50 (1.00/7.00)	5.00 (1.00/8.00)	1.00 (-3.00/4.00)	0.642	0.099
	Magnification	6.00 (4.00/7.00)	4.50 (3.00/6.00)	-1.00 (-3.00/1.00)	0.170	0.293
	Helplessness	7.50 (3.50/11.00)	12.00 (7.00/14.00)	3.00 (-1.00/8.00)	0.128	0.324
	Total	16.50 (10.50/24.50)	22.50 (13.00/26.00)	3.00 (-6.00/12.00)	0.448	0.162

Data are presented as median (25th/75th percentile). TMD: Temporomandibular disorder, NP: Neck pain, NRS: Numeric Rating Scale, PCS: Pain Catastrophizing Scale, Δ: Represents the median difference between the TMD+NP and TMD-only groups; CI: Confidence interval, ES: Effect size, p: Mann-Whitney U test.

DISCUSSION

The present study investigated the association of accompanying neck pain with TMD-related jaw pain intensity and pain catastrophizing in individuals with TMD. No statistically significant differences in TMD-related jaw pain intensity or pain catastrophizing were observed between individuals with TMD with and without accompanying neck pain.

Previous studies have consistently reported that TMD are frequently accompanied by cervical dysfunction. Jaw dysfunction has been shown to be associated with neck disability and tenderness of the cervical and masticatory muscles in individuals with chronic TMD.[8] Alterations in craniocervical biomechanics, cervical range of motion, muscle performance, and neck disability have also been reported in individuals with TMD.[9] The biomechanical relationship between the cervical spine and the TMJ has been described within the craniocervical-mandibular system.[10] Neurophysiological convergence within the trigeminocervical complex provides a mechanism through which cervical pain may be perceived as orofacial pain.[11] The association between cervical pain and TMD pain has been demonstrated in previous studies.[22] No statistically significant differences were observed between the groups with respect to pain intensity at rest or during activity. However, the moderate effect sizes observed for both resting and activity-related pain suggest that the intervention may have a clinically meaningful effect on pain intensity. The absence of statistical significance may be attributable to the limited sample size and, consequently, insufficient statistical power.

Pain catastrophizing is considered an important psychological factor influencing pain perception in chronic musculoskeletal disorders.[17] Psychological factors are recognized as important contributors to the development and persistence of chronic pain, including chronic TMD pain.[23] Experimental studies have shown that higher pain catastrophizing is associated with impaired endogenous pain inhibition mechanisms.[14] Higher pain catastrophizing levels have also been associated with greater pain severity and poorer clinical outcomes in patients with TMD.[15] A previous study reported that individuals with TMD exhibited higher levels of pain catastrophizing.[24] Another previous study comparing individuals with neck pain and cervico-craniofacial pain found no significant differences in pain catastrophizing scores between the groups.[25] Although no statistically significant between-group differences were observed in pain catastrophizing, the helplessness subscale demonstrated a moderate effect size, whereas the magnification, rumination, and total PCS scores showed only small effects.

Limitations

This study has several limitations that should be considered when interpreting the findings. First, the sample size was determined by pragmatic participant availability during the study period rather than an a priori power calculation. A sensitivity analysis indicated that, with the present sample size (n1=12, n2=10) and a two-tailed alpha of 0.05, the study had 80% power to detect only a large effect (r≥0.53), whereas the observed effect sizes for the primary outcomes (r=0.324–0.353) fell below this threshold; this should be taken into account when interpreting the non-significant between-group comparisons, as the study may have been underpowered to detect effects of a smaller magnitude. Second, participants were classified according to the presence or absence of neck pain using a binary approach, without quantifying its severity or associated functional disability, which may have obscured a potential dose-response relationship between neck pain and pain catastrophizing. Third, although the age range of participants was broad (18–65 years) and no formal age-matching procedure was applied between groups, the median age did not differ significantly between the TMD-only and TMD+Neck pain groups. The cross-sectional design also limits the interpretation of causal relationships. Objective assessment of cervical posture and function was not performed, representing another limitation of the present study. In addition, psychological factors such as anxiety and depression, which may influence pain perception and pain catastrophizing, were not evaluated. Furthermore, central sensitization, which is considered an important mechanism underlying chronic pain conditions, was not assessed. Despite these limitations, the present study contributes to the literature by examining pain intensity and pain catastrophizing together in patients with chronic TMD and accompanying neck pain, within an analytical framework that reports effect sizes and confidence intervals alongside p-values. Future prospective studies with larger, a priori sample-size-justified cohorts and comprehensive cervical and psychological assessments are needed to clarify these relationships.

CONCLUSION

This study investigated the effect of accompanying neck pain on pain intensity and pain catastrophizing in individuals with TMD. In this cross-sectional study, no statistically significant differences in TMD-related jaw pain intensity

or pain catastrophizing were observed between individuals with chronic TMD with and without accompanying neck pain. Therefore, the study hypothesis was not supported. These findings should be interpreted cautiously considering the small sample size. Assessment of the cervical region may be beneficial during the evaluation and management of individuals with TMD.

ETHICAL DECLARATIONS

Ethics Committee Approval

This study was approved by the Non-interventional Clinical Researches Ethics Committee at the Kırıkkale University (Date: 22.10.2025, Decision No: 2025.10.36).

Informed Consent

Written informed consent was obtained from all individual participants prior to their inclusion in the study. Participants were fully informed about the study's aims, procedures, potential risks and benefits, and their rights—including the right to withdraw at any time without consequence. All participants voluntarily signed a written informed consent form.

Peer Review Process

This manuscript was subject to external peer review.

Conflict of Interest

The authors declare no conflicts of interest related to this study.

Financial Disclosure

The authors received no financial support for the conduct or publication of this research.

Author Contributions

Concept: EG, ESE; Design: EG, ESE; Control: EG, ESE; Data Collection and/or Processing: EG; Analysis and/or Interpretation: EG, ESE; Literature Review: EG; Writing the Article: EG; Critical Review: ESE.

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Behavioral and psychosocial correlates of multisite musculoskeletal symptoms in university students: green-space use, physical activity, and perceived stress

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ABSTRACT

Aims: This study examined behavioral, psychosocial, and environmental correlates of recent multisite musculoskeletal symptom burden among university students, with particular attention to green-space access and use, physical activity, and perceived stress.

Methods: This cross-sectional study included 619 students aged 18–30 years at Selçuk University in Konya, Turkiye. Data were collected in March–April 2026 using an anonymous online questionnaire. The primary outcome was the number of anatomical regions with symptoms during the previous 4 weeks. Perceived green-space access was assessed using a four-item composite, and recent green-space use was measured as the number of visit days during the previous 7 days. Direct associations were evaluated using negative binomial regression, with zero-inflated negative binomial models as sensitivity analyses. Exploratory pathway-oriented analyses estimated indirect statistical associations through physical activity and perceived stress.

Results: Overall, 353 students (57.0%) reported at least one 4-week musculoskeletal symptom. The neck (34.6%), low back (24.7%), shoulders (23.7%), and upper back (23.4%) were the most frequently affected regions. Neither perceived green-space access nor visit frequency was directly associated with symptom burden. Green-space visit frequency was positively associated with log-transformed total physical activity (β=0.296; $p<0.001$). Log-transformed physical activity (incidence rate ratio (IRR)=1.11; $p=0.002$) and perceived stress (IRR=1.05; $p<0.001$) were positively associated with symptom burden. A positive indirect statistical association through physical activity was observed (estimate=0.0306; 95% confidence interval (CI), 0.0114–0.0538; $p<0.001$), whereas the indirect association through perceived stress was not significant.

Conclusion: Multisite musculoskeletal symptom burden was common among university students. Green-space access and visit frequency were not directly associated with symptom burden, whereas physical activity and perceived stress showed positive cross-sectional associations. Given the cross-sectional design, these findings do not establish causal relationships or the direction of the observed associations. Student musculoskeletal health assessments should therefore consider activity context and psychosocial factors rather than assume a direct protective effect of green-space access or use.

Keywords: Young adult, pain, environment, cross-sectional studies, health behavior

INTRODUCTION

Musculoskeletal conditions are major contributors to pain, disability, functional limitation, and reduced participation across the life course.[1] University students are an important population for early preventive assessment because prolonged sitting, intensive screen use, study-related postural demands, irregular physical activity, poor sleep, and academic stress may contribute to musculoskeletal symptoms.[2-4] These symptoms commonly involve the neck, low back, shoulders, and other anatomical sites.[3,4] Environmental and contextual determinants are also relevant.[5] Study, living, and transportation environments may influence activity opportunities, sedentary time, psychological restoration, and exposure to postural or mechanical strain.[6-8] Such factors frequently coexist in university life.[4,5,8]

Green spaces, including parks, gardens, and campus green areas, may support walking, recreation, social participation, and psychological recovery.[7,9] However, their relationship with musculoskeletal outcomes is less established than their association with general health and well-being.[7] Musculoskeletal implications may depend on whether visits involve sitting, walking, vigorous exercise, sport, uneven terrain, or repeated mechanical loading.[8] Physical activity has a complex relationship with musculoskeletal symptoms.[10,11] Regular aerobic and muscle-strengthening activities are recommended for health and musculoskeletal function.[12] Observational evidence indicates that associations between physical activity and musculoskeletal symptoms may vary according to activity level, domain, and loading context.[10,11]

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Physical activity may therefore provide preventive or rehabilitative benefits but may contribute to muscular pain when excessive, repetitive, or poorly matched to recovery capacity.[11] Measuring green-space use only as visit frequency cannot capture differences in activity type, terrain, intensity, and recovery context.[13,14]

Psychosocial stress is another correlate of multisite musculoskeletal symptoms.[15–17] Stress, non-restorative sleep, and physical inactivity may increase later chronic pain risk, while perceived stress has been associated with musculoskeletal pain among students.[15,16] Stress and pain may reinforce each other through physiological, cognitive, behavioral, and social mechanisms, with sleep disturbance further influencing pain sensitivity and recovery.[17,18] Nature exposure may support stress reduction, mental health, and psychological restoration.[7,19,20] However, the potential involvement of perceived stress in associations between green-space exposure and musculoskeletal symptoms remains unclear.[7,21] Green-space exposure is also multidimensional.[13,21] Perceived access reflects whether nearby spaces are considered available, reachable, safe, and usable, whereas recent use reflects behavioral engagement.[22] These dimensions may represent environmental opportunity and actual green-space-related behavior, respectively.[13,22] They should therefore be distinguished when examining musculoskeletal symptom burden.[13,21]

Limited evidence has examined perceived green-space access and recent use together with physical activity and perceived stress in relation to multisite musculoskeletal symptoms among university students. This study therefore aimed to examine behavioral, psychosocial, and environmental correlates of 4-week multisite musculoskeletal symptom burden, with particular attention to perceived green-space access, recent green-space use, physical activity, and perceived stress. Secondary objectives were to describe the regional distribution of symptoms, explore indirect statistical associations through physical activity and perceived stress, and evaluate associations after adjustment for relevant demographic and lifestyle-related factors.

METHODS

Ethics

The study complied with the Declaration of Helsinki and was approved by the Selçuk University Faculty of Health Sciences Non-interventional Clinical Researches Ethics Committee (Date: 04.02.2026, Decision No: 2026/89). All participants provided electronic informed consent. Participation was voluntary and anonymous.

Study Design and Setting

This cross-sectional observational study was conducted among undergraduate and associate-degree students at Selçuk University in Konya, Turkiye. Data were collected between 20 March and 20 April 2026 using a self-administered online questionnaire prepared in Google Forms. Reporting followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement.[23]

Participants and Procedure

Students were recruited through voluntary convenience sampling, with the survey link distributed via student WhatsApp groups used for academic communication. The number of students who received or opened the invitation was not recorded; therefore, a formal response rate could not be calculated. No academic credit, financial payment, or other incentive was provided.

Eligible participants were actively enrolled undergraduate or associate-degree students aged 18–30 years who provided electronic informed consent. Students were excluded if they reported rheumatic or inflammatory disease, fibromyalgia, major trauma or orthopedic surgery, neurological disorders, or chronic systemic diseases with substantial musculoskeletal involvement. These conditions were self-reported and not verified through medical records.

Before accessing the questionnaire, participants received information about the study purpose, voluntary participation, anonymity, and absence of incentives. They proceeded only after providing electronic consent. No names, student numbers, telephone numbers, institutional email addresses, or other direct identifiers were collected. All questionnaire items were mandatory.

Sample Size

The minimum sample size was calculated using the single-population proportion formula. A conservative expected musculoskeletal symptom prevalence of 50% was selected because it maximizes the required sample when prevalence is uncertain.[24,25] At a 95% confidence level and 5% absolute precision, 385 participants were required. Allowing for 20% potentially unusable records increased the target to 482. This calculation was intended to provide adequate precision for prevalence estimation rather than to detect prespecified regression or indirect-association effect sizes; the latter analyses were therefore considered exploratory.

Measures

Sociodemographic and lifestyle variables: Recorded variables included age, gender, faculty group, class year, housing type, self-reported height and weight, daily sitting, screen and study time, smoking, regular exercise, and current paid employment. Body-mass index was calculated as weight in kilograms divided by height in meters squared. Faculty programs were grouped as health sciences; social, administrative, legal, and communication sciences; science, engineering, technical, and agricultural fields; arts, design, tourism, and sports; or other. Regular exercise was defined as exercising at least twice weekly.

Green-space access and use: Perceived green-space access was assessed using four study-specific items covering availability within walking distance, ease of access, safety, and everyday usability. Each item was rated from 1, strongly disagree, to 5, strongly agree. The composite score was the mean of the four items, with higher scores indicating more favorable perceived access. Full item wording is provided in **Supplementary Table S1**.

Recent green-space use was measured as the number of days participants visited outdoor natural or semi-natural spaces,

Supplementary Table S1. Study-specific perceived green-space access items

Item no	Dimension assessed	Item wording
1	Availability within walking distance	There is a green space, such as a park or garden, within walking distance of where I live, including my home or dormitory.
2	Ease of access	It is easy for me to reach green spaces.
3	Perceived safety	Green spaces are sufficiently safe for use.
4	Everyday accessibility	Green spaces in the area where I live are accessible in my daily life.

Notes: Items were translated from Turkish and rated from 1 (strongly disagree) to 5 (strongly agree). The composite was calculated as their mean; higher scores indicate more favorable access. Cronbach's α was 0.930.

including parks, gardens, and campus green areas, during the previous 7 days. The primary environmental exposures were perceived access and visit days. Additional descriptive questions addressed visit duration, approximate distance, and active and passive use days.

Musculoskeletal symptoms: Musculoskeletal symptoms were assessed using the Turkish Extended Nordic Musculoskeletal Questionnaire, which records pain or discomfort in the neck, shoulders, upper back, elbows, wrists/hands, low back, hips/thighs, knees, and ankles/feet.[26] Symptoms were recorded for the previous 12 months and 4 weeks. Multisite symptom counts were calculated by summing symptomatic regions for each period. The primary outcome was the number of symptomatic regions during the previous 4 weeks; regional prevalence and the presence of any 4-week symptom were secondary descriptive outcomes.

Perceived stress: Perceived stress was assessed using the 10-item Perceived Stress Scale (PSS-10).[27] The Turkish version has demonstrated acceptable validity and reliability.[28] Items are scored from 0, never, to 4, very often; four positively worded items are reverse-coded. Total scores range from 0 to 40, with higher scores indicating greater perceived stress.

Physical activity and sitting time: Physical activity was assessed using the International Physical Activity Questionnaire–Short Form, which has demonstrated acceptable validity and reliability in Turkish populations.[29] Participants reported vigorous and moderate activity and walking during the previous 7 days. Total physical activity was calculated in MET-min/week using standard coefficients and scoring criteria.[30] Sitting time was recorded separately and was not included in the total physical activity score.

Data management and quality control: Responses were screened for eligibility, out-of-range values, internal inconsistencies, implausible anthropometric or physical activity values, and exact duplicate response patterns. Scores were calculated according to the specified instrument rules. Exact duplicate response patterns were removed. Because all items were mandatory, the final dataset contained no item-level missing data.

Statistical Analysis

Analyses were performed using R version 4.5.3. Data were summarized as mean and standard deviation, median and interquartile range, or number and percentage, as appropriate. The internal consistency of the perceived green-space access composite was evaluated using Cronbach's alpha.

Because the primary outcome—the 4-week symptomatic-region count—was overdispersed, negative binomial regression was used. Perceived green-space access and visit frequency were examined in separate crude and adjusted models, with incidence rate ratios and 95% confidence intervals reported. Adjusted models included age, gender, body-mass index, faculty group, class year, housing type, daily screen and study time, smoking, and current paid employment. Covariates were selected a priori based on their relevance to the exposures, intermediate variables, or outcome. Multicollinearity was assessed using variance inflation factors.

Model evaluation included overdispersion, Akaike information criterion, and simulation-based residual diagnostics. Because 43.0% of participants reported no symptomatic region, zero-inflated negative binomial models were examined as sensitivity analyses. Although these models yielded lower AIC values, simulation-based diagnostics indicated no problematic residual dispersion or zero inflation in the negative binomial models, and substantive conclusions were unchanged. Negative binomial regression was therefore retained as the more parsimonious primary model.

Exploratory pathway-oriented analyses evaluated indirect statistical associations through physical activity and perceived stress. Total physical activity was transformed as ln(MET-min/week+1), and indirect associations were estimated using 5,000 bootstrap resamples. An additional exploratory negative binomial model simultaneously examined walking, moderate-intensity, and vigorous-intensity physical activity, each transformed as ln(MET-min/week+1), with adjustment for green-space visit frequency and the prespecified covariates. Analyses were restricted to participants reporting female or male gender because other responses were too few for stable estimation. Green-space visits and physical activity referred to the previous 7 days, whereas musculoskeletal symptoms referred to the previous 4 weeks. Because these recall periods did not fully overlap, some reported symptoms may have preceded the measured exposures. Consequently, temporal ordering could not be established, and the exploratory indirect statistical associations were not interpreted as evidence of causal mediation. All tests were two-sided, with $p<0.05$ considered statistically significant.

RESULTS

Participant Flow and Sample Characteristics

A total of 698 submitted records were screened. Of these, 78 records were excluded based on the predefined eligibility criteria: 76 participants reported at least one exclusionary clinical condition, and three were outside the eligible age range of 18-30 years, with one participant meeting both exclusion criteria. Consequently, 620 records remained eligible. One record with an exact duplicate response pattern across questionnaire items was subsequently removed, yielding a final analytic sample of 619 students.

The sample was predominantly female and mainly comprised students from health sciences programs. Perceived green-space access was generally high, whereas more than one-third of participants were classified as physically inactive according to IPAQ categories. The four perceived green-space

access items showed high internal consistency (Cronbach's α=0.930). The median weekly physical activity was 495 MET-min/week (IQR: 247.5-924) for walking, 4 MET-min/week (IQR: 0-240) for moderate-intensity activity, and 0 MET-min/week (IQR: 0-320) for vigorous-intensity activity. Participant characteristics are summarized in Table 1. Regarding daily lifestyle characteristics, the most frequently reported screen time was 5-7 hours/day (49.8%, n=308), study time was 1-2 hours/day (46.0%, n=285), and sitting time was 4-6 hours/day (42.6%, n=264).

Table 1. Participant characteristics, green-space variables, physical activity, perceived stress, and musculoskeletal symptom burden

Characteristic	Value
Final analytic sample, n	619
Age, years, mean±SD	20.71±2.01
Height, cm, mean±SD	167.23±8.80
Weight, kg, mean±SD	63.96±13.97
BMI, kg/m², mean±SD	22.73±3.72
Perceived green-space access, mean±SD	3.85±1.10
Green-space visit days in previous 7 days, median (IQR)	3.00 (2.00–4.00)
PSS-10 total score, mean±SD	21.49±5.88
IPAQ total physical activity, MET-min/week, median (IQR)	822.0 (396.0–1642.5)
4-week musculoskeletal region count, mean±SD	1.39±1.67
12-month musculoskeletal region count, mean±SD	1.51±1.72
Female, n (%)	472 (76.3)
Male, n (%)	139 (22.5)
Prefer not to say, n (%)	8 (1.3)
Health sciences, n (%)	451 (72.9)
Social/administrative/legal/communication sciences, n (%)	81 (13.1)
Science/engineering/technical/agricultural fields, n (%)	36 (5.8)
Arts/design/tourism/sports, n (%)	38 (6.1)
Other faculty/program group, n (%)	13 (2.1)
Dormitory housing, n (%)	331 (53.5)
Shared student house, n (%)	16 (2.6)
Living alone, n (%)	20 (3.2)
With family, n (%)	252 (40.7)
Smoking, yes, n (%)	159 (25.7)
Regular exercise, yes, n (%)	194 (31.3)
Current paid employment, yes, n (%)	98 (15.8)
IPAQ inactive, n (%)	234 (37.8)
IPAQ minimally active, n (%)	321 (51.9)
IPAQ very active, n (%)	64 (10.3)
Any 4-week musculoskeletal symptom, n (%)	353 (57.0)
Cronbach's alpha for perceived green-space access items	0.930

Abbreviations: SD: Standard deviation, BMI: Body-mass index, IPAQ: International Physical Activity Questionnaire, IQR, Interquartile range, MET: Metabolic equivalent of task, PSS-10: 10-item Perceived Stress Scale, Min: Minute

Musculoskeletal Symptom Burden and Regional Distribution

More than half of the participants reported at least one musculoskeletal symptom region during the previous 4 weeks. The distribution of the 4-week musculoskeletal region count was overdispersed, supporting the use of count models that allow for overdispersion. The most frequently reported 4-week symptom regions were the neck (34.6%), low back (24.7%), shoulders (23.7%), and upper back (23.4%). The corresponding 12-month prevalence values were 38.4% for the neck, 27.8% for the low back, 25.0% for the shoulders, and 23.9% for the upper back (Figure 1). Detailed regional prevalence estimates for all anatomical regions are presented in Supplementary Table S2.

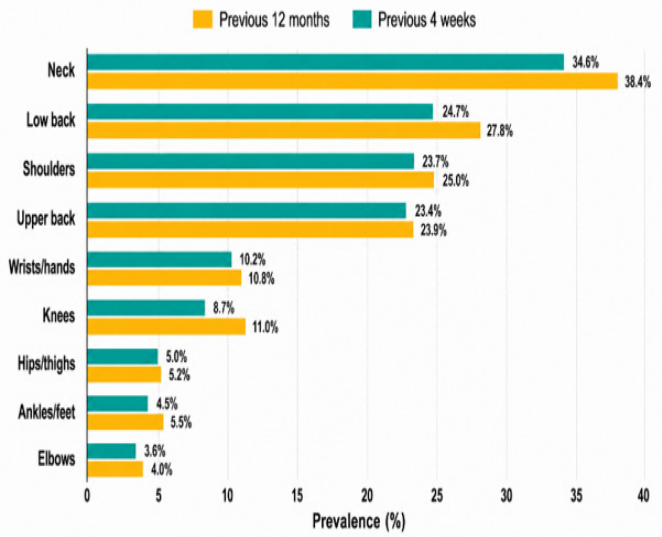

Figure 1. Regional prevalence of musculoskeletal symptoms during the previous 12 months and previous 4 weeks (n=619).

Supplementary Table S2. Regional prevalence of musculoskeletal symptoms during the previous 12 months and previous 4 weeks

Region	12-month symptoms, n (%)	4-week symptoms, n (%)
Neck	238 (38.4)	214 (34.6)
Low back	172 (27.8)	153 (24.7)
Shoulders	155 (25.0)	147 (23.7)
Upper back	148 (23.9)	145 (23.4)
Wrists/hands	67 (10.8)	63 (10.2)
Knees	68 (11.0)	54 (8.7)
Hips/thighs	32 (5.2)	31 (5.0)
Ankles/feet	34 (5.5)	28 (4.5)
Elbows	25 (4.0)	22 (3.6)

Notes: Percentages are based on the final analytic sample (n=619).

Direct Associations with Multisite Musculoskeletal Symptom Burden

Poisson models showed evidence of overdispersion, and negative binomial models were therefore used as the primary models. Multicollinearity diagnostics did not indicate problematic collinearity.

In crude and adjusted negative binomial models, neither perceived green-space access nor green-space visit frequency was significantly associated with 4-week multisite musculoskeletal symptom burden. Because 43.0% of participants had no symptomatic region during the previous 4 weeks, zero-inflated negative binomial models were additionally examined as sensitivity analyses. These

models did not change the substantive conclusions. The direct association estimates are presented in Table 2. Model diagnostics and zero-inflated negative binomial sensitivity analyses are presented in Supplementary Table S3.

Table 2. Direct associations of green-space variables with 4-week multisite musculoskeletal symptom burden

Exposure	Model	IRR	95% CI	p value
Perceived green-space access	Crude negative binomial	1.07	0.971–1.18	0.160
Perceived green-space access	Adjusted negative binomial	1.06	0.964–1.17	0.214
Perceived green-space access	ZINB, count component	1.03	0.943–1.12	0.521
Green-space visit days, previous 7 days	Crude negative binomial	1.03	0.980–1.08	0.259
Green-space visit days, previous 7 days	Adjusted negative binomial	1.02	0.968–1.07	0.520
Green-space visit days, previous 7 days	ZINB, count component	1.03	0.989–1.07	0.157

Notes: Adjusted and ZINB models included the prespecified covariates. Abbreviations: IRR: Incidence rate ratio, CI: Confidence interval, ZINB: Zero-inflated negative binomial

Supplementary Table S3. Diagnostics for adjusted negative binomial models and zero-inflated negative binomial sensitivity analyses

Diagnostic	Perceived green-space access model	Green-space visit frequency model
Outcome mean	1.394	1.394
Outcome variance	2.773	2.773
Variance-to-mean ratio	1.989	1.989
Poisson overdispersion ratio	1.916	1.914
Poisson overdispersion p value	<0.001	<0.001
Poisson AIC	2171.500	2173.240
Negative binomial AIC	2024.696	2025.790
ZINB AIC	2003.054	2001.496
Observed zero counts, n (%)	266 (43.0)	266 (43.0)
Expected zero counts under negative binomial model, n (%)	251.0 (40.6)	251.0 (40.6)
Expected zero counts under ZINB model, n (%)	266.0 (43.0)	267.0 (43.1)
Vuong test, raw p value	0.0145	0.0093
Vuong test, AIC-corrected p value	0.0228	0.0149
Vuong test, BIC-corrected p value	0.0559	0.0377
DHARMa dispersion test p value for negative binomial model	0.164	0.172
DHARMa zero-inflation test p value for negative binomial model	0.242	0.242
DHARMa KS uniformity test p value for negative binomial model	0.174	0.554

Notes: Negative binomial models were retained as primary because residual diagnostics were acceptable and conclusions were unchanged in ZINB analyses. **Abbreviations:** AIC: Akaike information criterion, ZINB: Zero-inflated negative binomial, BIC: Bayesian information criterion, KS: Kolmogorov–Smirnov

Exploratory Pathway-Oriented Analyses

Exploratory pathway-oriented analyses were conducted among participants reporting female or male gender because the very small number of responses outside these categories led to unstable model estimates. The analytic sample for these models included 611 participants.

Perceived green-space access was not significantly associated with log-transformed total physical activity or perceived stress. In the corresponding outcome model, perceived green-space access was not significantly associated with musculoskeletal symptom burden, whereas both log-transformed total physical activity and perceived stress were positively associated with symptom burden.

Green-space visit frequency was positively associated with log-transformed total physical activity, but it was not associated with perceived stress. In the outcome model, green-space visit frequency was not directly associated with musculoskeletal symptom burden. However, log-transformed total physical activity and perceived stress were both positively associated with musculoskeletal symptom burden. Bootstrap analyses suggested a positive indirect statistical association between green-space visit frequency and musculoskeletal symptom burden through physical activity, whereas the indirect statistical association through perceived stress was not significant. The pathway-oriented estimates are summarized in Table 3, detailed bootstrap direct and indirect statistical association estimates are presented in Supplementary Table S4, and the exploratory statistical associations involving green-space visit frequency, physical activity, perceived stress, and musculoskeletal symptom burden are illustrated in Figure 2.

In an additional exploratory negative binomial regression model simultaneously examining walking, moderate-intensity, and vigorous-intensity physical activity, walking-related activity was positively associated with musculoskeletal symptom burden (IRR=1.09, 95% CI 1.02-1.16; p=0.008), whereas moderate-intensity (IRR=1.01, 95% CI 0.97-1.05; p=0.605) and vigorous-intensity activity (IRR=0.98, 95% CI 0.94-1.01; p=0.203) were not significantly associated with symptom burden. All three components were entered simultaneously as log-transformed MET-min/week values, with adjustment for the prespecified covariates.

DISCUSSION

This study found that recent multisite musculoskeletal symptom burden was common among university students, with the neck, low back, shoulders, and upper back being the most frequently affected regions. Neither perceived green-space access nor recent visit frequency was directly associated with symptom burden. Green-space visit frequency was positively associated with physical activity, while physical activity and perceived stress were positively associated with symptom burden in the exploratory pathway-oriented models. A positive indirect statistical association through physical activity was also observed; however, the cross-sectional design does not establish temporal ordering, the direction of associations, or causal mediation.

The absence of a direct association between broad green-space indicators and musculoskeletal symptom burden is noteworthy. Green-space exposure has been associated with general health, well-being, physical activity, stress reduction, and psychological restoration.[7,9,19,20] Musculoskeletal symptoms are also influenced by mechanical loading, posture, sedentary exposure, recovery, sleep, stress, and previous or ongoing pain.[2–5,8,15–18] Perceived access may therefore be too distal to demonstrate a direct association with symptom burden. Access indicates environmental opportunity but does not determine whether students visit green spaces or whether

Table 3. Exploratory pathway-oriented analyses for 4-week multisite musculoskeletal symptom burden

Exposure	Path or effect	Estimate	95% CI or bootstrap CI	p value
Perceived green-space access	Access → log total physical activity, β	0.108	−0.0262 to 0.243	0.114
Perceived green-space access	Access → PSS-10 total score, β	0.0784	−0.363 to 0.520	0.728
Perceived green-space access model	Perceived green-space access → symptom burden, IRR	1.04	0.944 to 1.14	0.429
Perceived green-space access model	Log total physical activity → symptom burden, IRR	1.10	1.04 to 1.18	0.002
Perceived green-space access model	PSS-10 total score → symptom burden, IRR	1.05	1.03 to 1.07	<0.001
Perceived green-space access	Indirect association through physical activity	0.0106	−0.00213 to 0.0280	0.112
Perceived green-space access	Indirect association through perceived stress	0.00387	−0.0187 to 0.0236	0.759
Green-space visit days	Visit days → log total physical activity, β	0.296	0.230 to 0.363	<0.001
Green-space visit days	Visit days → PSS-10 total score, β	0.0248	−0.207 to 0.256	0.834
Green-space visit frequency model	Green-space visit days → symptom burden, IRR	0.992	0.943 to 1.04	0.760
Green-space visit frequency model	Log total physical activity → symptom burden, IRR	1.11	1.04 to 1.18	0.002
Green-space visit frequency model	PSS-10 total score → symptom burden, IRR	1.05	1.03 to 1.07	<0.001
Green-space visit days	Indirect association through physical activity	0.0306	0.0114 to 0.0538	<0.001
Green-space visit days	Indirect association through perceived stress	0.00123	−0.0126 to 0.0146	0.842
Green-space visit days	Total indirect association	0.0318	0.00693 to 0.0593	0.013

Notes: Analyses included 611 participants and were adjusted for the prespecified covariates. Indirect estimates were calculated on the log-count scale using 5,000 bootstrap resamples and do not indicate causal mediation. **Abbreviations:** β: Regression coefficient, CI: Confidence interval, IRR: Incidence rate ratio, MET: Metabolic equivalent of task, PSS-10: 10-item Perceived Stress Scale

Supplementary Table S4. Bootstrap direct and indirect statistical association estimates

Exposure	Effect	Estimate	95% bootstrap CI	p value
Perceived green-space access	Indirect association through physical activity	0.0106	−0.00213 to 0.0280	0.112
Perceived green-space access	Indirect association through perceived stress	0.00387	−0.0187 to 0.0236	0.759
Perceived green-space access	Total indirect association	0.0144	−0.0129 to 0.0411	0.296
Perceived green-space access	Direct association	0.0380	−0.0533 to 0.149	0.363
Green-space visit days	Indirect association through physical activity	0.0306	0.0114 to 0.0538	0.0004
Green-space visit days	Indirect association through perceived stress	0.00123	−0.0126 to 0.0146	0.842
Green-space visit days	Total indirect association	0.0318	0.00693 to 0.0593	0.0132
Green-space visit days	Direct association	−0.00784	−0.0570 to 0.0423	0.745

Notes: Analyses included 611 participants and were adjusted for prespecified covariates. Bootstrap estimates are presented on the log-count scale and do not indicate causal mediation. **Abbreviations:** CI: Confidence interval

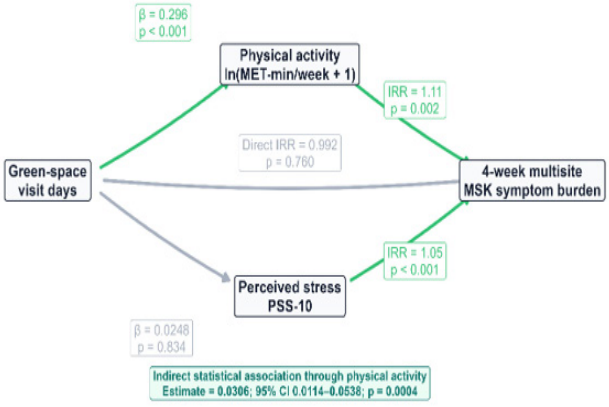

Figure 2. Pathways linking green-space visits to symptom burden. Green and gray lines indicate significant and nonsignificant associations, respectively. IRR: Incidence rate ratio, MET: Metabolic equivalent of task, MSK: Musculoskeletal, PSS-10: 10-item Perceived Stress Scale, Min: Minute

visits involve sitting, walking, exercise, social activity, or recovery.

Green-space exposure is multidimensional. Perceived access, objective proximity, safety, quality, aesthetics, restorative potential, and actual use represent related but distinct dimensions.[13,21] In this study, perceived access reflected the subjective availability and usability of nearby green spaces, whereas visit frequency reflected recent behavioral engagement. Frequent visits may involve diverse activities ranging from quiet sitting to active transportation, vigorous exercise, or sport. This heterogeneity may partly explain why perceived access and visit frequency were not directly associated with symptom burden.

The positive association between green-space visit frequency and physical activity supports the view that green spaces may enable movement, recreation, and active transportation.[6,7,9,13,14] Nevertheless, the musculoskeletal implications of activity depend on its type, intensity, duration, mechanical demands, and recovery context. Regular physical activity is beneficial for health and musculoskeletal function.[12] However, associations between physical activity and pain may vary according to activity level, domain, and loading context.[10,11] The present findings should therefore not be interpreted as indicating that physical activity or green-space use is harmful. One possible explanation is that students who visit green spaces more frequently are also more active and consequently experience greater movement- or load-related exposure. Reverse directionality is also possible because students with symptoms may use green spaces for walking, coping, or recovery. Furthermore, the observed positive association may differ according to activity type and intensity. Vigorous exercise, sports participation, repetitive mechanical

loading, and sports-related injuries may contribute to musculoskeletal symptom reporting in some students. These explanations remain speculative because detailed sports participation, injury history, and activity context were not assessed. In the additional exploratory analysis, the positive association was observed for walking-related activity but not for moderate- or vigorous-intensity activity. This finding may reflect differences in activity patterns or symptom-related changes in walking behavior rather than a harmful effect of walking. Given the cross-sectional design and differing recall periods, this association should be interpreted cautiously.

Interpretation is further limited by the IPAQ-SF, which estimates overall activity volume but does not distinguish leisure walking, structured exercise, sport, commuting, muscle-strengthening activity, terrain-related loading, or activity performed despite pain. Moderate and appropriately progressed activity may support function, whereas abrupt increases, repetitive loading, inadequate recovery, or activity performed in the presence of symptoms may contribute to symptom reporting.[10,11] More detailed assessment of activity context is therefore needed.

Perceived stress was positively associated with multisite symptom burden, consistent with evidence that stress and pain may reinforce each other through physiological, cognitive, behavioral, and social mechanisms.[15,17] Increased muscle tension, altered pain sensitivity, sleep disturbance, reduced recovery, and greater attention to bodily discomfort may contribute to this relationship.[15,17,18] Green-space exposure has been associated with restorative and stress-related benefits.[7,19,20] However, perceived stress did not show a significant indirect statistical association between green-space variables and symptom burden. Simple access and visit-frequency measures may not capture whether a green-space experience is safe, quiet, comfortable, restorative, or socially supportive.[13,21,22]

The regional pattern was consistent with previous university-student studies identifying the neck, low back, upper back, and shoulders as frequent symptom sites.[2-5,16] Research involving university students in Turkiye has also addressed internet-based education and its implications for student health, as well as sleep quality and musculoskeletal pain.[31,32] A recent study by Güler et al.[33] identified associations between digital burnout, academic procrastination, and neck and low back pain among university students. Similarly, Bayraktar and Mohammadzadeh[34] reported associations of screen time, sitting time, and physical activity with multisite musculoskeletal pain, supporting the importance of considering multiple behavioral factors in this population. These symptoms should be considered within a multifactorial framework that includes behavioral, ergonomic, psychosocial, and recovery-related factors. Recent research comparing academic and examination periods has also highlighted the relevance of physical activity, sleep quality, and musculoskeletal discomfort among university students, further supporting the need to consider academic and lifestyle contexts when interpreting symptom-related associations.[35] The present findings do not demonstrate that specific modifications to campus green spaces would reduce musculoskeletal symptoms. Instead, they support further investigation of how green-space quality, activity type, sedentary accumulation, ergonomics, recovery opportunities, and psychosocial context jointly relate to student musculoskeletal health.

The study addressed an underexplored topic, evaluated multisite rather than single-region symptoms, distinguished perceived green-space access from recent use, and applied established measures of musculoskeletal symptoms, perceived stress, and physical activity. The use of negative binomial regression with simulation-based diagnostics and zero-inflated sensitivity analyses also strengthened the analytical approach.

Future research should use longitudinal, multi-campus designs combining objective and subjective green-space measures with device-based physical activity, sedentary-time, and posture assessments. Detailed measures of green-space quality, restorative experience, activity type, symptom severity, disability, sleep, ergonomics, and recovery may clarify when green-space use is beneficial, neutral, or associated with greater symptom reporting.

Limitations

Several limitations should be considered. The cross-sectional design prevents conclusions about temporality, directionality, or causal mediation. An additional methodological limitation arises from the differing recall periods of the principal variables. Green-space visits and physical activity were assessed over the previous 7 days, whereas musculoskeletal symptoms were assessed over the previous 4 weeks. Thus, symptoms reported during the first 3 weeks of the symptom recall period may have occurred before the measured green-space visits and physical activity. This temporal mismatch limits the interpretation of the observed associations, particularly the exploratory indirect statistical associations, which should not be regarded as evidence of causal pathways. Convenience sampling from a single university, the predominance of female students (76.3%) and health sciences students (72.9%), and the unavailable response rate limit the generalizability of the findings, particularly to students from other universities, academic disciplines, and demographic backgrounds. Participants were recruited through student WhatsApp groups, which may have introduced selection bias. Eligibility and exclusion criteria were based on self-reported information without verification through medical records, potentially leading to misclassification of participants' eligibility. Musculoskeletal symptoms were also self-reported and not clinically verified. Pain intensity, disability, treatment seeking, and detailed symptom duration were not assessed. The four-item perceived green-space access measure was developed specifically for this study and has not undergone comprehensive psychometric validation. Although the composite demonstrated high internal consistency (Cronbach's α=0.930), its construct validity, test-retest reliability, and measurement properties across different student populations have not been established. Accordingly, the findings involving perceived green-space access should be interpreted cautiously. The quality and specific characteristics of green spaces, including maintenance, aesthetics, vegetation, and available recreational facilities, were not systematically assessed. Furthermore, the purpose of visits, objective environmental exposure, and activity context were

not comprehensively measured, limiting the interpretation of green-space-related associations. The sample-size calculation was designed for prevalence estimation rather than prespecified regression or indirect-association effect sizes. Residual confounding from ergonomics, sleep, academic workload, mental health, previous injury, and seasonal conditions also remains possible.

CONCLUSION

Recent multisite musculoskeletal symptom burden was common among university students, particularly in the neck, low back, shoulders, and upper back. Perceived green-space access and recent visit frequency were not directly associated with symptom burden. Green-space visit frequency was positively associated with physical activity, while physical activity and perceived stress were positively associated with symptom burden in exploratory pathway-oriented models. Because of the cross-sectional design, the observed associations cannot establish causality or temporal direction, and the indirect statistical association through physical activity should not be interpreted as evidence of causal mediation. Longitudinal studies using more detailed measures of green-space use, activity context, ergonomics, recovery, and symptom severity are needed to clarify these relationships.

ETHICAL DECLARATIONS

Ethics Committee Approval

Approved by the Selçuk University Faculty of Health Sciences Non-interventional Clinical Researches Ethics Committee (Date: 04.02.2026, Decision No: 2026/89).

Informed Consent

Electronic informed consent was obtained from all participants through Google Forms before they accessed the anonymous online questionnaire. Participants were informed about the study aims, procedures, and voluntary nature of participation. Only participants who provided electronic consent proceeded to the questionnaire. No handwritten signatures were obtained.

Peer Review Process

This manuscript was subject to external peer review.

Conflict of Interest

The authors declare no conflicts of interest related to this study.

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Author Contributions

Concept: MAG, MBG; Design: MAG, MBG; Control: MAG; Resources: MAG, MBG; Data Collection and/or Processing: MAG, MBG; Analysis and/or Interpretation: MAG, MBG; Literature Review: MAG, MBG; Writing the Article: MAG, MBG; Critical Review: MAG, MBG; Final Approval of the Manuscript: MAG, MBG; Visualization: MAG.

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Comparison of ChatGPT-5.2 and DeepSeek-V3.2 responses to frequently asked patient questions about hallux valgus surgery

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ABSTRACT

Aims: To compare ChatGPT-5.2 and DeepSeek-V3.2 responses to frequently asked patient questions about hallux valgus surgery in terms of accuracy, informativeness, comprehensibility, and currency.

Methods: A Google search performed with a newly created account without previous search activity was used to identify patient-oriented questions about hallux valgus surgery. Two researchers reviewed 100 questions and consolidated overlapping items into 10 representative questions. On February 1, 2026, the same questions were submitted in English to ChatGPT-5.2 and DeepSeek-V3.2. The first response from each model was recorded without editing. Ten orthopedic specialists with at least five years of professional experience independently and blindly rated each response on a 5-point Likert scale for accuracy, informativeness, comprehensibility, and currency. For each question, the 10 ratings were averaged, and question-level mean scores (n=10 paired observations per domain) were compared using the Wilcoxon signed-rank test.

Results: Both models answered all 10 questions. ChatGPT-5.2 had numerically higher mean scores for accuracy (4.7±0.3 vs 4.6±0.4; p=0.214), informativeness (4.6±0.4 vs 4.4±0.5; p=0.081), comprehensibility (4.6±0.4 vs 4.5±0.4; p=0.197), and currency (4.5±0.4 vs 4.3±0.5; p=0.064). None of the between-model differences reached statistical significance.

Conclusion: ChatGPT-5.2 and DeepSeek-V3.2 both generated responses that orthopedic specialists rated highly across the four evaluated domains. Neither model demonstrated statistically significant superiority; however, this exploratory study was not designed to test equivalence, and the absence of significant differences should not be interpreted as evidence that the models perform comparably. These systems may support patient education as supplementary information tools, but their outputs should remain subject to clinical verification and should not replace individualized patient-physician communication.

Keywords: Hallux valgus, patient education as topic, large language models, health literacy, comprehension, generative artificial intelligence

INTRODUCTION

Hallux valgus is a common forefoot deformity whose prevalence rises with age and is consistently higher among females. A recent global meta-analysis estimated an overall prevalence of approximately 19%, emphasizing the substantial population burden of the condition.[1]

For patients considering surgery, the decision extends beyond radiographic correction. Expectations regarding pain relief, footwear, recovery time, recurrence, complications, cosmetic appearance, and return to activity all influence the treatment experience. Contemporary expert work has therefore emphasized shared decision-making and patient-centered priorities, while qualitative research shows that people with painful hallux valgus may struggle to obtain information that is both trustworthy and relevant to their lived concerns.[2,3]

Surgical management is also difficult to summarize for a lay audience because numerous procedures and technique variations are available. Systematic reviews indicate that surgery can improve pain and function, yet the certainty of evidence and comparative advantages of individual techniques vary. Open and minimally invasive approaches may provide broadly comparable outcomes in selected patients, but differences in technique, rehabilitation, and complication profiles make individualized counseling essential.[4,5]

Patients increasingly seek this counseling outside the clinic. Online resources devoted to hallux valgus have previously shown variable accuracy, quality, and readability, creating a gap between information availability and information usability.[6]

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That gap is clinically relevant because patient education in hallux valgus is not limited to naming an operation. A patient must understand why surgery is being considered, what alternatives exist, which expectations are realistic, and which postoperative restrictions are temporary or potentially persistent. Information that is technically correct but overly generic, excessively complex, or insufficiently qualified may therefore have limited value in shared decision-making. The communication task is especially demanding when the answer depends on deformity severity, procedure choice, rehabilitation protocol, activity goals, or surgeon-specific practice.

Large language models (LLMs) offer a different form of access because users can ask questions in natural language and receive immediate, conversational responses. Unlike static webpages, an LLM can adapt the wording and scope of an answer to the user's question, which may make it attractive for preoperative information seeking. At the same time, the same flexibility can produce variation in depth, emphasis, and certainty across prompts. Hallux valgus-specific work has already shown that LLM answers can be detailed but may exceed ideal reading levels.[7]

More recent studies have extended this question to newer models. ChatGPT-5.2 and Gemini produced similarly high-quality responses about minimally invasive bunion surgery but remained limited in actionability and reading accessibility, while simulated hallux valgus cases showed progressively improved surgical recommendation consistency across newer ChatGPT versions.[8,9]

Outside foot and ankle surgery, studies have likewise found that generative AI can produce clinically useful patient-facing information, sometimes approaching physician-rated quality, although limitations in reliability and contextual judgment remain.[10,11]

In orthopedics, direct comparisons between ChatGPT and DeepSeek have expanded rapidly. Studies involving hand fractures, anterior cruciate ligament surgery, meniscus injuries, rotator cuff disorders, spinal surgery, and knee osteoarthritis show that relative performance varies by clinical topic: one model may be more comprehensive while another is clearer or easier to read.[12–17] Complementary work on orthopaedic spine and oncology patient-education materials further suggests that LLMs can improve readability without necessarily sacrificing accuracy, although the balance between simplification, completeness, and comprehension remains model- and task-dependent.[18,19]

The ability of LLMs to answer specialist-level orthopedic questions has also been demonstrated in examination settings, but good performance on knowledge tasks does not necessarily establish suitability for patient counseling.[20]

Against this background, a direct comparison of ChatGPT-5.2 and DeepSeek-V3.2 using the same frequently asked hallux valgus surgery questions may clarify whether either model offers a meaningful advantage for patient-facing information. The aim of this exploratory study was to compare the two models in accuracy, informativeness, comprehensibility, and currency as judged by experienced orthopedic specialists. The study hypothesis was that the two models would differ significantly in at least one evaluation domain.

METHODS

Ethics

No patients, patient records, biological samples, identifiable personal data, or personal health information were used. The orthopedic specialists participated solely as voluntary professional evaluators of anonymized AI-generated responses, and no personal, sensitive, or clinical data were collected from them. No institutional ethics committee approval or formal exemption was obtained for this study. The study was conducted in accordance with the relevant ethical principles and publication ethics standards.

Study Design and Question Selection

This cross-sectional comparative study evaluated responses generated by two LLMs to frequently asked questions about hallux valgus surgery. The study was designed to assess the quality of model-generated information rather than to test diagnosis, treatment decisions, or outcomes in individual patients.

To identify questions that reflect common public information needs, a newly created Google account with no previous search history was used. The search was performed on February 1, 2026 using the single keyword "hallux valgus" in the Google search engine (Google LLC, Mountain View, CA, USA) from Kocaeli, Turkiye, with the interface language set to English. Questions appearing in the "People also ask" section were progressively expanded and collected until a total of 100 questions had been recorded.

Two researchers experienced in hallux valgus surgery independently reviewed the initial pool of 100 questions obtained from Google's "People also ask" section. No exclusion criteria were applied during the initial collection of questions. Questions addressing identical or substantially overlapping topics were grouped according to their content. Disagreements regarding question selection were resolved through discussion until consensus was reached between the two researchers. Through this process, 10 representative questions covering the main aspects of hallux valgus surgery, including surgical indications, operative techniques, postoperative recovery, pain, recurrence, footwear, cosmetic expectations, complications, return to physical activity, and postoperative joint mobility, were selected (**Table 1**). This approach was intended to evaluate responses to commonly encountered online questions rather than to represent all possible clinical scenarios associated with hallux valgus surgery.

Artificial Intelligence Models and Query Procedure

The models evaluated were ChatGPT-5.2 (OpenAI, San Francisco, CA, USA) and DeepSeek-V3.2 (Hangzhou DeepSeek Artificial Intelligence Co., Ltd., Hangzhou, China). Separate newly created user accounts without prior interaction history were used for each platform. ChatGPT-5.2 was accessed through the web interface using a ChatGPT Plus subscription in Thinking mode. DeepSeek-V3.2 was accessed through its web interface with the DeepThink feature enabled. Web search was disabled on both platforms. Each question was submitted in a separate, newly initiated chat session to minimize potential contextual influences from previous questions. On February 1, 2026, all 10 questions were

Table 1. Ten representative patient questions about hallux valgus surgery selected from Google's "People also ask" section.

Question no	Question
1	Is hallux valgus surgery necessary? When should I have surgery?
2	How is hallux valgus surgery performed? What surgical methods are there?
3	How long does the recovery process after surgery take?
4	Is there pain after surgery?
5	Is there a risk of recurrence after hallux valgus surgery?
6	When can I start wearing shoes after surgery?
7	What are the aesthetic (cosmetic) results? Will the foot appearance improve?
8	What are the risks and complications of hallux valgus surgery?
9	Can I do sports or exercise after surgery?
10	Is there a permanent limitation or loss of movement after hallux valgus surgery?

entered in English using identical wording for both models. Questions were submitted at different times throughout the day rather than in immediate succession.

The models were not instructed to cite sources, use a particular format, or restrict response length. The first response generated for each question was saved. Regeneration was not used, and no wording was added to, removed from, or otherwise edited within the model outputs before evaluation.

Expert Evaluation of Responses

Ten orthopedic and traumatology specialists with clinical expertise in foot surgery and at least five years of experience after completion of specialty training independently reviewed the 20 model responses. The evaluators were recruited from the same hospital through direct personal invitations from the researchers. None of the evaluators was a co-author of the study, and all participated voluntarily after providing verbal consent.

Before evaluation, model names and other model-identifying information were removed from the responses. All responses were converted into plain text, with headings, bullet points, bold formatting, and other distinctive formatting elements removed to minimize potential identification of the models. The anonymized responses were presented to the evaluators in Microsoft Word documents, and the presentation order of the two models' responses was varied across questions to reduce potential order-related bias. All evaluators assessed the responses independently, without any consensus meetings or joint scoring sessions.

Each response was rated on a 5-point Likert scale, where 1 indicated very poor performance and 5 indicated very good performance, across four predefined domains: accuracy (medical correctness), informativeness (adequacy of scope and detail), comprehensibility (clarity for a reader without professional medical training), and currency (alignment with contemporary clinical knowledge). No external reference standard was specified for the assessment of information currency. The rating scale was developed specifically for this study and had not undergone formal validation. Each specialist therefore scored responses from both models to all 10 questions in each domain.

Statistical Analysis

The data analyses were performed with IBM SPSS Statistics version 28.0 (IBM Corp., Armonk, NY, USA). For each question, the scores assigned by the 10 evaluators were averaged separately for each model and domain, and the question was used as the unit of analysis (n=10 paired observations per domain). Likert scores were summarized as mean and standard deviation to facilitate descriptive comparison with prior LLM studies. Because the same evaluators assessed responses from both models to corresponding questions, model comparisons were treated as paired. Given the ordinal scale of the ratings, the Wilcoxon signed-rank test was used. No a priori sample-size calculation was performed, and no equivalence margin was prespecified; the analysis was therefore exploratory. Tests were two-sided, and $p<0.05$ was considered statistically significant.

RESULTS

All 10 selected questions were answered by both LLMs, yielding 20 responses for expert assessment. The questions are shown in Table 1. On the investigators' qualitative reading, ChatGPT-5.2 generally produced longer and more elaborated answers, whereas DeepSeek-V3.2 tended to provide shorter responses; response length was not quantified and was not used as an outcome measure.

Both models received high scores in all four domains (Table 2). Mean accuracy was 4.7±0.3 for ChatGPT-5.2 and 4.6±0.4 for DeepSeek-V3.2, with no significant difference (p=0.214). Mean informativeness scores were 4.6±0.4 and 4.4±0.5, respectively (p=0.081).

Table 2. Expert evaluation scores for ChatGPT-5.2 and DeepSeek-V3.2 responses.

Evaluation criterion	Model	Mean	SD*	p-value
Accuracy	ChatGPT-5.2	4.7	0.3	0.214
	DeepSeek-V3.2	4.6	0.4	
Informativeness	ChatGPT-5.2	4.6	0.4	0.081
	DeepSeek-V3.2	4.4	0.5	
Comprehensibility	ChatGPT-5.2	4.6	0.4	0.197
	DeepSeek-V3.2	4.5	0.4	
Currency	ChatGPT-5.2	4.5	0.4	0.064
	DeepSeek-V3.2	4.3	0.5	

*SD: Standard deviation. Ratings used a 1–5 Likert scale (1=very poor; 5=very good). Means and SDs were calculated from question-level mean scores (n=10 questions, each rated by 10 evaluators). p-values were calculated with the Wilcoxon signed-rank test for paired model scores.

Comprehensibility was rated 4.6±0.4 for ChatGPT-5.2 and 4.5±0.4 for DeepSeek-V3.2 (p=0.197). Currency scores were 4.5±0.4 and 4.3±0.5, respectively (p=0.064). Although ChatGPT-5.2 had a numerically higher mean score in each domain, none of the paired comparisons reached the predefined threshold for statistical significance. All mean scores lay between 4.3 and 4.7 on the 5-point scale.

DISCUSSION

The principal finding was that both ChatGPT-5.2 and DeepSeek-V3.2 generated hallux valgus surgery answers that experienced orthopedic specialists rated highly. ChatGPT-5.2 was numerically higher in all four domains, but the differences were statistically non-significant. The

data therefore do not support a claim of superiority for either model. Equally, they do not demonstrate equivalence: the study was not powered for small between-model differences, and no equivalence margin was prespecified.

These findings should be interpreted in the context of rapidly evolving foot and ankle AI literature. Hlavinka et al.[7] found that LLMs could address common hallux valgus concerns but that readability remained a limitation. A more recent study of minimally invasive bunion surgery compared ChatGPT-5.2 with Gemini and found no significant difference in overall information quality, while actionability and reading complexity remained problematic.[8] Our study extends this literature by evaluating DeepSeek-V3.2 against ChatGPT-5.2 across broader hallux valgus surgery questions and by using blinded ratings from 10 orthopedic specialists.

Hallux valgus counseling is particularly suitable for this type of evaluation because patients commonly ask questions that involve uncertainty rather than a single factual answer. Recovery duration, return to shoes or exercise, recurrence, residual stiffness, and complication risk vary with deformity severity, procedure selection, surgeon preference, and patient-specific factors. Evidence comparing operative strategies confirms that multiple procedures can be effective and that no single approach can be presented as universally optimal.[4,5] Consequently, a useful patient-education response should not only be factually correct; it should also communicate conditionality and avoid presenting population-level information as individualized advice.

The broader orthopedic literature also suggests that model strengths are domain-dependent. ChatGPT and DeepSeek have shown different profiles of comprehensiveness, clarity, and readability in hand fracture, anterior cruciate ligament, meniscus, and rotator cuff education,[12–15] and studies of spinal surgery and knee osteoarthritis indicate that readability and information quality do not necessarily move together.[16,17] LLM-assisted simplification of orthopaedic materials can improve readability while largely preserving accuracy, but performance varies with the model, prompt, and target reading level.[18,19]

The consistently high ratings in our study are also compatible with the broader ability of LLMs to generate medically coherent information.[10,20] However, knowledge performance should not be equated with clinical decision-making, and persuasive language can mask error: LLMs can produce unsupported claims and fabricated references, and reviews emphasize variable reliability and the need for human verification.[21,22] In the present study the models were deliberately not asked to provide references, so citation accuracy and evidence hierarchy were not tested. A high expert score therefore indicates that a response appeared clinically appropriate within the study framework; it does not establish that every statement was traceable to a high-quality source.

The high scores also need to be read alongside the rating instrument. With means of 4.3–4.7 on a 5-point scale, ratings clustered near the upper limit, and a ceiling effect may have compressed real differences between the models. Together with the unvalidated, endpoint-anchored scale, this further limits the ability of the study to discriminate between two high-performing systems. The near-significant differences in informativeness (p=0.081) and currency (p=0.064) may reflect a tendency for ChatGPT-5.2 to provide longer answers, but response length could not be quantified, so this explanation remains speculative. A longer answer can increase perceived completeness while creating cognitive burden; a shorter response may be easier to follow yet omit important caveats. Future comparisons should therefore combine expert ratings with validated instruments such as DISCERN and PEMAT-P,[23,24] objective length and readability measures, inter-rater reliability statistics, and patient-based assessment.

From a clinical perspective, the most defensible role for these tools is supplementary. An LLM may help patients formulate questions, review general concepts before or after a consultation, and revisit information in accessible language. It cannot examine the foot, interpret weight-bearing radiographs, determine deformity severity, incorporate comorbidities or patient priorities reliably, or select a procedure with the accountability expected of a treating surgeon. The model response should therefore be treated as an informational aid that remains subordinate to individualized clinical assessment and shared decision-making.[2,11]

Limitations

Several limitations should be considered. First, the evaluation was restricted to 10 frequently asked questions and may not represent uncommon, technically complex, or patient-specific scenarios; the small number of questions also limited statistical power, and no sample-size calculation was performed. Second, the question set was derived from a Google “People also ask” search; search-engine results are dynamic and can vary with time, region, language, and platform configuration, and the reduction from 100 to 10 questions may have introduced selection bias. Third, the responses were generated once for each question, so within-model variability and reproducibility across repeated prompts were not examined. Fourth, the expert scoring system, although blinded and clinically intuitive, was a study-specific, unvalidated scale with anchors defined only at its endpoints and without an operational reference standard for currency; ratings clustered near the ceiling of the scale. Fifth, comprehensibility was judged by orthopedic specialists rather than by patients, and objective readability metrics and response length were not calculated; because the archived responses are no longer available, these measures cannot be derived retrospectively, and question-level scores and the content of the lowest-rated responses cannot be reported. Sixth, the models were not asked to provide citations, preventing assessment of source quality, reference accuracy, or evidence hierarchy. Finally, LLMs are updated frequently; the findings apply specifically to the ChatGPT-5.2 and DeepSeek-V3.2 versions accessed on February 1, 2026, under the settings described above, and may not generalize to later model iterations.

CONCLUSION

ChatGPT-5.2 and DeepSeek-V3.2 both produced responses to common hallux valgus surgery questions that received high expert ratings for accuracy, informativeness,

comprehensibility, and currency. ChatGPT-5.2 scored numerically higher in every domain, but no comparison reached statistical significance. Because this exploratory study was small, used an unvalidated scale with a ceiling effect, and was not designed to test equivalence, the results neither establish superiority nor show that the models perform comparably. These findings support the potential use of current LLMs as adjunctive patient-education tools while reinforcing the need for clinical verification, appropriate health-literacy assessment, and preservation of patient-physician communication as the basis of individualized surgical counseling.

ETHICAL DECLARATIONS

Ethics Committee Approval

The study did not involve patients, patient records, identifiable personal data, biological materials, or any clinical intervention. The orthopedic specialists served solely as voluntary professional evaluators of AI-generated responses. No institutional ethics committee approval or formal exemption was obtained.

Informed Consent

Patient informed consent was not applicable because no patients or identifiable patient data were included in the study. The orthopedic specialists participated voluntarily as professional evaluators and provided verbal consent to participate.

Peer Review Process

This manuscript was subject to external peer review.

Conflict of Interest

The authors declare no conflicts of interest related to this study.

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Author Contributions

Concept: VEÇ, FÖ, MK; Design: VEÇ, FÖ; Data Collection and/or Processing: VEÇ, FÖ, BK; Analysis and/or Interpretation: VEÇ, BK, AFT, HO; Literature Review: VEÇ, FÖ, MK; Writing the Article: VEÇ, FÖ, AFT; Critical Review: VEÇ, FÖ, MK, BK, AFT, HO.

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Case Report

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Unilateral foot drop following bariatric surgery: a case report

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ABSTRACT

Neurological complications following bariatric surgery (BS) are uncommon but may cause significant functional impairment if not recognized early. We report the case of a 38-year-old female who developed sudden-onset right foot drop seven months after BS, following an approximately 30-kg weight loss. Neurological examination demonstrated severe weakness of ankle dorsiflexion and foot eversion without sensory deficits. Electrophysiological studies revealed an acute-to-subacute partial demyelinating lesion of the common peroneal nerve at the fibular head with evidence of secondary axonal regeneration, whereas laboratory and imaging studies excluded metabolic and structural causes. The patient underwent a comprehensive rehabilitation program, including therapeutic exercises, neuromuscular electrical stimulation, gait training, and an ankle-foot orthosis, resulting in marked functional improvement after 15 treatment sessions. This case highlights rapid weight loss as an important risk factor for common peroneal neuropathy after BS and emphasizes the value of early electrophysiological evaluation and multidisciplinary rehabilitation in optimizing functional recovery.

Keywords: Bariatric surgery, foot drop, common peroneal neuropathy, rapid weight loss, rehabilitation

INTRODUCTION

Obesity is a chronic disease with an increasing global prevalence and is associated with numerous comorbidities, including cardiovascular disease, type 2 diabetes mellitus, hypertension, dyslipidemia, and musculoskeletal disorders.[1] Bariatric surgery (BS) is considered one of the most effective treatment options for patients with morbid obesity or inadequate weight loss despite conservative treatment, providing sustained weight reduction and improvement of obesity-related complications.[2]

Neurological complications following BS are uncommon but may cause significant functional impairment. Peripheral neuropathies are among the most frequently reported neurological complications and are associated with rapid weight loss, micronutrient deficiencies, malabsorption, inadequate nutritional intake, and intraoperative positional nerve compression.[3]

Foot drop after BS is an uncommon manifestation, most commonly resulting from common peroneal nerve compression at the fibular head due to the loss of protective adipose tissue following rapid weight loss. Prolonged surgical positioning and nutritional deficiencies may also contribute to its development.[4] If not recognized promptly, foot drop may lead to persistent motor deficits and impaired quality of life. Early neurological assessment, electrophysiological evaluation, nutritional assessment, and appropriate rehabilitation are essential for improving functional outcomes.[5]

Herein, we present a case of unilateral foot drop following BS and discuss its clinical presentation, possible pathophysiological mechanisms, diagnostic evaluation, and management in light of the current literature.

CASE REPORT

A 38-year-old female presented to the outpatient physical medicine and rehabilitation clinic with sudden-onset right foot drop that had progressively worsened over two weeks. She denied pain, numbness, paresthesia, recent trauma, or mechanical risk factors for common peroneal nerve compression. Her medical history was unremarkable except for BS performed seven months earlier for morbid obesity, after which she had lost approximately 30 kg.

Neurological examination revealed severe weakness of right ankle dorsiflexion, foot eversion, and great toe dorsiflexion (Medical Research Council [MRC] grade 1/5), while plantar flexion, sensory examination, and deep tendon reflexes were normal. Laboratory investigations, including serum glucose, thyroid function tests, vitamin B12, and folate levels, were within normal limits. Ultrasonography of the sciatic and peroneal nerves and magnetic resonance imaging of the right knee and lower leg showed no structural abnormalities or evidence of nerve entrapment. Muscle strength in the remaining lower-extremity muscle groups was normal (MRC grade 5/5).

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Electrophysiological studies demonstrated a partial demyelinating lesion of the right common peroneal nerve at the fibular head with evidence of secondary axonal regeneration, consistent with acute-to-subacute peroneal neuropathy. Based on the clinical history and diagnostic findings, rapid weight loss following BS was considered the most likely etiological factor. More specifically, right peroneal motor nerve conduction demonstrated a marked reduction in response amplitude proximal to the fibular head compared with the distal stimulation site, together with reduced conduction velocity and prolonged latency. Needle electromyography of the right tibialis anterior and peroneus longus muscles revealed 2+ positive sharp waves and fibrillation potentials at rest. During voluntary contraction, prolonged-duration, polyphasic giant motor unit potentials and a reduced recruitment pattern were observed. These findings were interpreted as a partial lesion of the right common peroneal nerve proximal to the fibular head, predominantly demyelinating in nature, with secondary axonal regeneration in the acute-to-subacute stage. Quantitative nerve conduction values were not available in the supplied report.

The patient underwent a comprehensive rehabilitation program consisting of therapeutic exercises, neuromuscular electrical stimulation, gait training, and an ankle-foot orthosis. After 15 treatment sessions, ankle dorsiflexion and great toe extension improved to MRC grade 3/5, with marked functional improvement in gait. The patient remains under regular clinical and rehabilitation follow-up. Rehabilitation was delivered five days per week for a total of 15 sessions. Treatment included ankle and foot range-of-motion exercises, strengthening exercises targeting the muscles innervated by the peroneal nerve (particularly the ankle dorsiflexors and evertors), neuromuscular electrical stimulation applied to the ankle dorsiflexors and evertors, and gait training. An ankle-foot orthosis (AFO) was used during physiotherapy and during activities of daily living, including ambulation. Following treatment, ankle eversion strength also improved from MRC grade 1/5 to 3/5.

DISCUSSION

Peroneal neuropathy is one of the most common mononeuropathies of the lower extremity and is particularly vulnerable to compression at the fibular head because of the superficial course of the common peroneal nerve.[6] Clinically, it presents with foot drop due to weakness of ankle dorsiflexion and foot eversion, while sensory symptoms may be absent in cases with predominantly motor involvement.[6,7] In our patient, the absence of pain and sensory deficits was consistent with the electrophysiological findings.

Common causes of peroneal neuropathy include trauma, knee surgery, prolonged external compression, and rapid weight loss.[7,8] In the present case, the absence of trauma, mechanical risk factors, or structural abnormalities on imaging suggested rapid postoperative weight loss as the most likely cause.

Neurological complications occur in approximately 2%-16% of patients after BS and include metabolic and compression neuropathies.[9-11] Rapid weight loss may predispose patients to common peroneal neuropathy by reducing the protective adipose tissue around the fibular head, thereby increasing susceptibility to external compression.[4,7,12,13] Our patient developed symptoms seven months after surgery following a 30-kg weight loss, consistent with the typical onset reported in the literature.[4,14] Although vitamin deficiencies are recognized causes of peripheral neuropathy after BS, normal serum vitamin levels do not exclude neuropathy, as rapid weight loss alone may contribute to nerve compression.[4,10,15] The spectrum of neurological complications after BS extends beyond isolated unilateral common peroneal mononeuropathy. Reported peripheral nervous system manifestations include bilateral peroneal neuropathy, generalized polyneuropathy, and less commonly plexopathy or radiculopathy; central neurological syndromes associated with nutritional deficiencies have also been described.[3,5,9-11,15-17] These presentations may differ in their distribution, mechanism, and time course. Nutritional and metabolic factors may contribute to more diffuse neuropathic presentations, whereas loss of protective adipose tissue and focal mechanical vulnerability may favor compressive mononeuropathy. In contrast to bilateral or generalized involvement, our patient had an isolated unilateral motor-predominant deficit, with electrodiagnostic localization to the right common peroneal nerve at the fibular head. This distinction highlights the importance of considering the full postoperative neurological differential while using the pattern of weakness and electrophysiological findings to establish localization.

Electrophysiological evaluation is the gold standard for confirming the diagnosis and determining lesion severity.[7] In our patient, nerve conduction studies and needle electromyography demonstrated an acute-to-subacute partial common peroneal nerve lesion with secondary axonal regeneration, consistent with previous reports.[12,14] Differential diagnoses, including L5 radiculopathy, sciatic neuropathy, central nervous system disorders, and hereditary or vasculitic neuropathies, were excluded based on clinical, imaging, and electrophysiological findings.[7,18]

Early rehabilitation, including an ankle-foot orthosis, strengthening exercises, neuromuscular electrical stimulation, and gait training, plays a key role in functional recovery.[7,8,17,19] In our patient, muscle strength improved from MRC grade 1/5 to 3/5 after 15 rehabilitation sessions, highlighting the importance of early diagnosis and rehabilitation in patients with foot drop following BS. In addition to ankle dorsiflexion and great toe extension, ankle eversion improved from MRC grade 1/5 to 3/5. The rehabilitation schedule comprised five sessions per week, with range-of-motion and targeted strengthening exercises, electrical stimulation of the ankle dorsiflexors and evertors, and gait training. The AFO supported mobility both during treatment and in daily activities.

CONCLUSION

Rapid weight loss following BS may increase the risk of common peroneal neuropathy, even in patients with normal serum vitamin levels. Early electrophysiological evaluation and timely multidisciplinary rehabilitation are essential for improving functional outcomes in patients presenting with foot drop after BS.

ETHICAL DECLARATIONS

Informed Consent

Written informed consent was obtained from the patient included in this report. Signed consent forms are retained by the authors and are available upon request.

Peer Review Process

This report underwent external peer review.

Conflict of Interest

The authors declare no conflicts of interest.

Financial Disclosure

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Author Contributions

Concept: MD, VT, PÖB, AGD; Design: MD, VT, PÖB, AGD; Control: MD, VT, PÖB, AGD; Resources: MD, VT, PÖB, AGD; Materials: MD, VT, PÖB, AGD; Data Collection and/or Processing: MD, VT, PÖB, AGD; Analysis and/or Interpretation: MD, VT, PÖB, AGD; Literature Review: MD, VT, PÖB, AGD; Writing the Article: MD, VT, PÖB, AGD; Critical Review: MD, VT, PÖB, AGD.

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Ayşe Gülşen Doğan is a member of the Editorial Board of this journal. She was not involved in the editor assignment, reviewer selection, peer review process, or editorial decision for this manuscript. The peer review process was managed independently by another editor.

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