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ORIGINAL ARTICLE

Investigation of trunk muscle endurance and standing balance according to severity of disability in women with moderate to severe disability due to neck pain

Boyun ağrısıyla ilişkili özür seviyesi orta ve şiddetli olan kadınlarda gövde kas enduransı ve ayakta durma dengesinin özür seviyesine göre incelenmesi

Müge KIRMIZI,[1] Gamze YALÇINKAYA ÇOLAK,[2] Yeşim SALIK ŞENGÜL,[3] Orhan KALEMCİ[4]

Summary

Objectives: To investigate the association between trunk muscle endurance, standing balance, and neck disability in women with chronic neck pain (CNP) and to compare trunk muscle endurance and standing balance according to disability severity.

Methods: Thirty-one women with CNP and Neck Disability Index scores of 30%–70% were included. Isometric endurance times of neck flexors, trunk flexors, extensors, and lateral flexors were measured. Overall stability index (OSI), anterior/posterior stability index (APSI), and medial/lateral stability index (MLSI) were obtained to assess standing balance under the following conditions: eyes-open on a firm surface (EO-Firm), eyes-closed on a firm surface, eyes-open on foam, and eyes-closed on foam (EC-Foam). Higher index scores indicate larger postural sway. Linear regression analysis was used for association. Participants were divided into two groups based on their disability scores, either having moderate or severe disability, and the groups were compared.

Results: Trunk flexor endurance time had an effect on disability (R-squared=0.18, F(1.29)=6.453) and APSI under the EC-Foam condition (R-squared=0.17, F(1.29)=6.105) ($p<0.05$). Trunk extensor endurance time had an effect on OSI under the EO-Firm condition (R-squared=0.14, F(1.29)=4.775, $p<0.05$). Women with moderate disability had longer endurance times than those with severe disability for trunk flexors (Cohen's d=0.89, $p<0.05$).

Conclusion: Isometric endurance times of trunk flexors and extensors were associated with standing balance in women with CNP. Trunk flexor endurance was also associated with neck disability. Furthermore, women with moderate disability had better trunk flexor endurance than those with severe disability, with a large effect size.

Keywords: Neck pain; physical endurance; postural balance.

Özet

Amaç: Kronik boyun ağrılı kadınlarda gövde kas enduransı, ayakta durma dengesi ve boyun özür seviyesi arasındaki ilişkiyi incelemek ve gövde kas enduransı ile ayakta durma dengesini özür seviyesine göre karşılaştırmaktır.

Gereç ve Yöntem: Boyun Özür İndeksi skoru %30–%70 olan otuz bir kronik boyun ağrılı kadın dahil edildi. Boyun fleksörleri ve gövde fleksörleri, ekstansörleri ve lateral fleksörlerinin izometrik endurans süreleri ölçüldü. Overall denge indeksi (OSI), anterior/posterior denge indeksi (APSI) ve medial/lateral denge indeksi dört koşulda elde edildi: sert zemin üzerinde gözler açık (GA-Sert), sert zemin üzerinde gözler kapalı, yumuşak zemin üzerinde gözler açık ve yumuşak zemin üzerinde gözler kapalı (GK-Yumuşak). Daha yüksek indeks skorları, daha büyük postural salınımı ifade eder. İlişki için doğrusal regresyon analizi kullanıldı. Katılımcılar, özür skorlarına göre orta seviye özre veya şiddetli özre sahip olanlar olarak iki gruba ayrıldı ve gruplar karşılaştırıldı.

Bulgular: Gövde fleksör endurans süresi, özür seviyesi (R-kare=0.18, F(1.29)=6.453) ve GK-Yumuşak koşulda elde edilen APSI (R-kare=0.17, F(1.29)=6.105) üzerinde etkili bulundu ($p<0.05$). Gövde ekstansör endurans süresi, GA-Sert koşulda elde edilen OSI üzerinde etkili bulundu (R-kare=0.14, F(1.29)=4.775, $p<0.05$). Özür seviyesi orta olan kadınların gövde fleksörlerinin endurans süreleri, özür seviyesi şiddetli olan kadınlara göre uzundu (Cohen's d=0.89, $p<0.05$).

Sonuç: Kronik boyun ağrılı kadınlarda gövde fleksör ve ekstansör kasların izometrik endurans süreleri ayakta duruş dengesi ile ilişkiliydi. Gövde fleksör enduransı, boyun özür seviyesi ile de ilişkiliydi. Ayrıca, özür seviyesi orta olan kadınlar, şiddetli olanlara göre daha iyi gövde fleksör enduransına sahipti ve farkın etki büyüklüğü büyüktü.

Anahtar sözcükler: Boyun ağrısı; fiziksel endurans; postüral denge.

[1]Department of Physiotherapy and Rehabilitation, İzmir Katip Çelebi University, Faculty of Health Sciences, İzmir, Türkiye
[2]Department of Physiotherapy and Rehabilitation, Yozgat Bozok University, Faculty of Health Sciences, Yozgat, Türkiye
[3]Dokuz Eylül University, Faculty of Physical Therapy and Rehabilitation, İzmir, Türkiye
[4]Department of Neurosurgery, Dokuz Eylül University, Faculty of Medicine, İzmir, Türkiye

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Correspondence: Dr. Müge Kırmızı. İzmir Katip Çelebi Üniversitesi, Sağlık Bilimleri Fakültesi, Fizyoterapi ve Rehabilitasyon Bölümü, İzmir, Türkiye.
Phone: +90 - 505 - 601 33 48 **e-mail:** mugekirmizi1@gmail.com

Introduction

Neck pain is a multifactorial condition leading to considerable pain, disability, and economic costs. It is a significant public health burden in modern society, with high prevalence, incidence, and years lived with disability.[1,2] There is a tendency for neck pain to become a chronic issue, which increases the personal, familial, and economic burdens.[1,3] There is a growing body of research suggesting that chronic neck pain (CNP) may have broader effects beyond localized discomfort and functional loss in the cervical spine. Several studies have explored the potential impact of CNP on various aspects of physical function, including standing balance and gait characteristics.[4–6]

The ability to maintain upright standing balance is required for most human activities.[7] Decreased standing balance ability in people with CNP has been attributed to neck pain and associated musculoskeletal impairments, which in turn affect afferent inputs from the cervical region to the sensorimotor control system.[4,5,8] We assumed that decreased trunk muscle endurance might be another factor associated with quiet standing balance in people with CNP. Trunk muscle endurance has been reported to be associated with standing balance in various populations, but it has not been explored in patients with CNP.[9–11] A systematic review published in 2019 indicated that standing postural control is altered in asymptomatic people following trunk muscle fatigue. The authors mentioned that this finding may suggest that training for trunk muscle endurance is crucial to address standing balance impairments in chronic musculoskeletal spinal conditions.[12] Considering the importance of trunk muscle endurance in maintaining spinal stability, it is necessary to clarify the association between standing postural control and trunk muscle endurance in people with CNP to move toward a comprehensive approach in managing spinal pain conditions.

There is convincing evidence that neck pain affects the physical health of the spine beyond the cervical spine. Moseley et al.[13] suggested that spinal pain impairs trunk muscle control assessed via the abdominal drawing-in task, irrespective of the specific spinal level where the pain is experienced. Falla et al.[14] indicated that people with CNP walk with reduced trunk rotation, suggesting that neck pain may impact general functional movements. Also, Alsultan et al.[15] explored that people with CNP have reduced variability of trunk rotation during walking with continuous head rotations. Furthermore, Salahzadeh et al.[16] indicated that people with forward head posture (FHP) have lower endurance times of trunk muscles than those without FHP, and increased FHP is related to lower endurance times of trunk muscles. Clarifying the association between trunk muscle endurance and disability level due to neck pain in patients with CNP will provide valuable information regarding the role of trunk muscle fatigability in disability in chronic spinal conditions where pain is experienced in the neck region. This would also contribute to moving toward a comprehensive approach in managing spinal pain conditions.

In light of the above-mentioned information, the present study was designed to investigate the association between trunk muscle endurance, standing balance, and neck disability in women with moderate to severe disability due to neck pain. It also aimed to compare trunk muscle endurance and standing balance according to disability severity in the aforementioned population.

Material and Methods

The study was conducted at Dokuz Eylul University between March 2023 and September 2023. Ethical approval for this study was obtained from Dokuz Eylul University Institutional Non-invasive Research Ethics Board (Number: 2023/04-02 - Date: 15.02.2023). All procedures were conducted according to the Declaration of Helsinki. All participants read and signed the informed consent before their participation.

Participants

Thirty-one women with chronic non-specific neck pain were included. The inclusion criteria were as follows: (1) being between 25 and 55 years of age, (2) having neck pain lasting longer than three months, (3) having a score obtained from the Neck Disability Index (NDI) 30%–70%, (4) having no neurological deficits resulting from neck disorders. The exclusion criteria were as follows: (1) having a history of spinal pain lasting longer than three months except for neck pain, (2) having current spinal pain except for neck pain, (3) having a history of trauma or surgery in the spine or head regions, (4) having other musculoskeletal problems which may affect standing balance performance, (5) having been diagnosed with any neurological, vestibular, metabolic, or endocrine disorders which may affect standing balance performance.

Procedure

The NDI was used to assess self-reported neck pain-related disability. The Biodex Stability System was used to assess standing balance, followed by trunk muscle endurance tests. To assess endurance, the neck flexor endurance test, trunk flexor endurance test, Sorensen test, and side bridge endurance test were performed in a random order. The time to hold test positions was measured with a stopwatch with a precision of 1/100 s. All endurance tests were repeated twice, and the higher time from the two attempts was used for statistical analysis. The participants had at least five minutes of rest between consecutive endurance tests.

The Neck Flexor Endurance Test

The participant was in a supine position with the knees bent to 90 degrees and the hands on the abdomen. The participant was instructed to retract the chin maximally and lift the head until it was approximately 2.5 cm above the table while maintaining the chin tuck position. Once the participant took the position, the examiner drew a line across the approximating two antero-lateral neck skin folds and placed her fingers on the table just below the participant's head at the most posterior aspect of the occiput. Then, the participant was asked to relax the neck, resting her head on the examiner's fingers. Next, the participant was again instructed to retract the chin maximally and lift the head approximately 2.5 cm from the table. The participant was instructed to maintain this position for as long as possible. When the participant did not maintain the test position, verbal commands were given that directed her to resume the proper position and continue the trial. The test was terminated when the edges of the lines no longer approximated each other due to loss of chin tuck, the participant's head touched the examiner's hand for more than 1 second, or the participant could not continue due to excessive fatigue or discomfort, and the time was recorded.[17]

The Trunk Flexor Endurance Test

The participant was in a supine position with arms crossed over the chest and knees and hips flexed at a 90-degree angle. The trunk was set at a 60-degree angle relative to the table using a universal goniometer. The participant was instructed to maintain this position for as long as possible. Two examiners conducted the measurements: one secured the participant's toes while the other observed whether the trunk angle of 60 degrees was maintained. When the participant did not maintain the test position, verbal commands were given that directed her to resume the proper position and continue the trial. The test was terminated when the participant did not maintain the trunk position for more than three seconds or the participant could not continue due to excessive fatigue or discomfort, and the time was recorded.[18,19]

The Sorensen Test

The participant was in a prone position with the level of the anterior superior iliac spines aligned with the edge of the table and secured to the table at three levels using seat belts: (1) at the ankles as close to the malleoli as possible, (2) at the knee creases, (3) at the greater trochanter of the femur. The participant was allowed to rest her upper body on a chair placed in front of her. The participant was asked to cross the arms over the chest, lift the upper trunk to the horizontal position, and maintain this position for as long as possible. The examiner observed whether the upper trunk remained in the horizontal position. When the participant did not maintain the test position, verbal commands were given that directed her to resume the proper position and continue the trial. The test was terminated when the participant did not maintain the upper trunk in the horizontal position for more than three seconds, the participant could not continue due to excessive fatigue or discomfort, or the holding time exceeded 240 seconds, and the time was recorded.[19,20]

The Side Bridge Endurance Test

The participant was in a side-lying position on the dominant side with legs extended, resting on the forearm and elbow with the shoulder abducted at a 90-degree angle and elbow flexed at a 90-degree angle. The participant was asked to lift the hip off the bed and maintain a straight line between the shoulder, hip, and feet, and place the hand of the free arm on the contralateral shoulder. The examiner observed whether the whole body remained in a straight line. When the participant did not maintain the test position, verbal commands were given that directed her to resume the proper position and continue the trial. The test was terminated when the participant did not maintain the straight position for more than three seconds or the participant could not continue due to excessive fatigue or discomfort, and the time was recorded.[18,19]

Assessment of Standing Balance

The Biodex Stability System (BSS) (Biodex Medical Systems, Shirley, New York, USA) was used to assess standing balance performance. The BSS consists of a platform interfaced with computer software (version 1.32; Biodex Medical Systems), adjustable support handles, and a 12.1″ high-resolution color touchscreen LCD display. The Postural Stability Test protocol of the BSS was used. The BSS generates the overall stability index (OSI), anterior/posterior stability index (APSI), and medial/lateral stability index (MLSI) using the amount of movement of the center of pressure (COP). The BSS sampling rate of the COP is 40 Hz.[21] These indices are the standard deviations assessing fluctuations around the zero point at the center of the platform. The APSI and MLSI are calculated based on the fluctuations around the anterior-posterior and medial-lateral axes, respectively. The OSI is calculated from the combined fluctuations around the anterior-posterior and medial-lateral axes, therefore it is sensitive to postural sway in both directions.[22] A higher index score means larger postural sway. The BSS was reported to be a reliable method for assessing balance performance in different conditions, such as standing on firm or foam surfaces with eyes-open and eyes-closed.[23–25]

The stability index scores, OSI, APSI, and MLSI, were obtained using the BSS in four conditions: Eyes-open on a firm surface (EO-Firm), eyes-open on foam, eyes-closed on a firm surface, and eyes-closed on foam (EC-Foam) (Fig. 1). Balance assessment was performed barefoot on the BSS platform with arms resting at their sides. Participants were instructed to stand upright on two legs with a shoulder-width distance between feet. Participants stood on the foam mat provided with the BSS in both foam conditions. Since the BSS assesses fluctuations around the zero point, participants were asked to adjust their foot placement to ensure that the dot on the LED screen is at the zero point during their comfortable posture.[21] Then, the foot position coordinates were recorded into the system for each participant. The foot placement procedure was also repeated after placing the soft pad. During all tests, the platform stability was set to static. Each test condition lasted 20 seconds. Also, each test condition was repeated two times with an interval of 10 seconds and averaged.[23] One-minute rest was given between each test condition.

Figure 1. Assessment of standing balance on a firm surface and foam.

Statistical Analyses

The statistical analyses were performed on the thirty-one participants using IBM® SPSS® Statistics 25. The Shapiro–Wilk test and descriptive statistics showed that data did not have a normal distribution. The square root transformation was applied to all endurance and balance data in order to provide a normal distribution. After the transformation, all data were normally distributed. Pearson correlation coefficients between trunk muscle endurance, standing balance, and disability were determined, and the statistically significant correlation coefficients were interpreted according to the guide by Schober.[26] Then, simple linear regression was used to identify the associations between the aforementioned variables. Furthermore, participants were divided according to the NDI scores into the moderate disability group (n=23) and the severe disability group (n=8), then independent samples t-test was

Table 1. Demographic characteristics of participants

Variables	All participants (n=31) Mean (SD)	Moderate disability group (n=23) Mean (SD)	Severe disability group (n=8) Mean (SD)	p[a] Moderate vs severe disability groups
Age, years	41.45 (7.98)	41.26 (8.23)	42 (7.71)	0.826
Weight, kg	70.94 (9.60)	70.13 (9.64)	73.25 (9.74)	0.438
Height, cm	163.84 (6.71)	163.70 (7.20)	164.25 (5.47)	0.844
BMI, kg/m^2	26.41 (3.06)	26.16 (3.09)	27.13 (3.04)	0.449
NDI, %	41.94 (9.32)	37.74 (5.76)	54 (6.59)	<0.001

a: Independent Samples t-Test; SD: Standard deviation; BMI: Body Mass Index; NDI: Neck Disability Index.

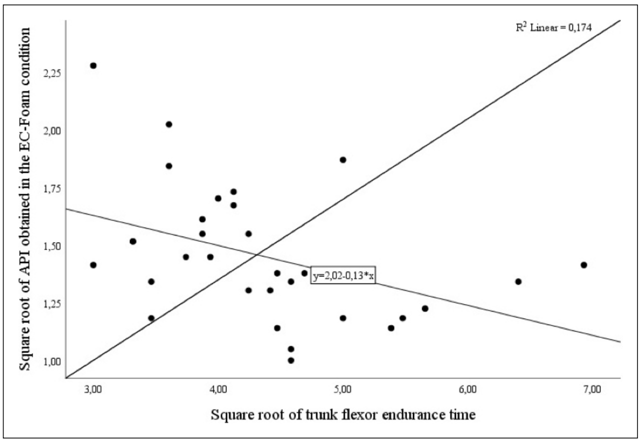

Figure 2. Association between trunk flexor endurance and standing balance.

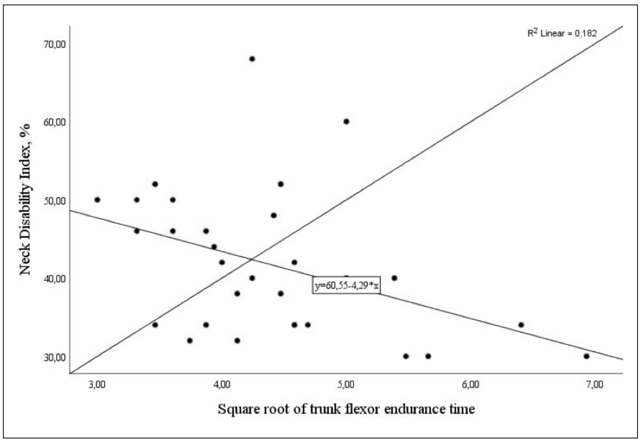

Figure 3. Association between trunk flexor endurance and disability due to neck pain.

used to compare groups regarding endurance and standing balance. The effect sizes, Cohen's d, were calculated for the significant comparison results and interpreted as follows: A d value less than 0.20 represents a small effect, 0.50 a medium effect, and 0.80 a large effect.[27] The level of significance was set at $p<0.05$.

Results

Demographic characteristics were presented in Table 1. No difference was found between women with moderate disability and those with severe disability in terms of age, weight, height, and body mass index ($p>0.05$).

There was a moderate negative correlation between trunk flexor endurance time and APSI obtained in the EC-Foam condition ($r=-0.417$, $p<0.05$). Also, a weak negative correlation was found between trunk extensor endurance time and OSI obtained in the EO-Firm condition ($r=-0.376$, $p<0.05$). None of the other endurance times were correlated with any balance variables ($p>0.05$). Neck disability score was significantly correlated only with trunk flexor endurance time ($r=-0.427$, $p<0.05$). Linear regression analysis showed that trunk flexor endurance time had an effect on APSI in the EC-Foam condition (R-squared=0.17, $F(1,29)=6.105$) and neck disability (R-squared=0.18, $F(1,29)=6.453$) ($p<0.05$) (Fig. 2, 3). Also, trunk extensor endurance time had an effect on OSI in the EO-Firm condition (R-squared=0.14, $F(1,29)=4.775$, $p<0.05$) (Fig. 4).

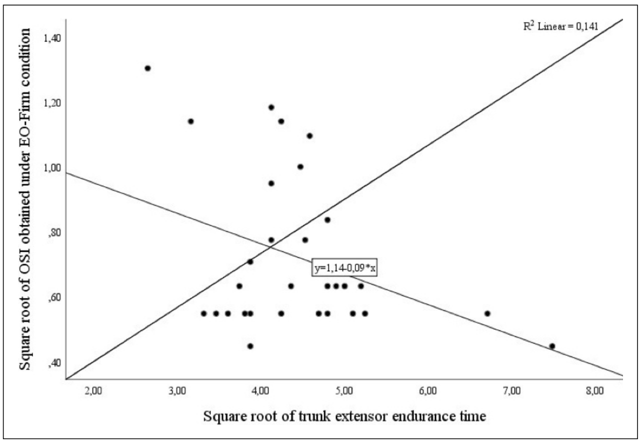

Figure 4. Association between trunk extensor endurance and standing balance.

Table 2. Comparison for trunk muscle endurance

Endurance variables	Moderate disability group (n=23) Median (Q1/Q3)	Severe disability group (n=8) Median (Q1/Q3)	p^a, d*
Neck flexor endurance, seconds	17 (13/24)	17 (14.25/18)	0.508
Trunk flexor endurance, seconds	19.5 (15/25)	12.50 (9.5/19.5)	**0.038, 0.89**
Trunk extensor endurance, seconds	20.5 (15/26)	18 (15.13 /21.5)	0.527
Trunk lateral flexor endurance, seconds	10 (8/12.5)	11.5 (9.13/13.63)	0.808

a: Independent Samples t-Test; Q: Quartile; *: Cohen's d for significant result.

Table 3. Comparison for standing balance variables

Balance assessment conditions	Moderate disability group (n=23) Median (Q1/Q3)			Severe disability group (n=8) Median (Q1/Q3)			$p^{a,1}$	$p^{a,2}$	$p^{a,3}$
	OSI	APSI	MLSI	OSI	APSI	MLSI			
EO-Firm	0.4 (0.3/0.6)	0.3 (0.2/0.4)	0.2 (0.1/0.3)	0.35 (0.3/0.98)	0.3 (0.2/0.73)	0.1 (0.1/0.5)	0.801	0.752	0.559
EC-Firm	1.7 (1.1/2.4)	1 (0.8/1.7)	0.6 (0.4/1.2)	0.9 (0.6/1.7)	0.65 (0.5/1)	0.4 (0.33/1.25)	0.069	0.1	0.429
EO-Foam	0.6 (0.6/0.9)	0.5 (0.4/0.7)	0.4 (0.3/0.5)	0.6 (0.53/0.78)	0.45 (0.33/0.6)	0.35 (0.3/0.48)	0.610	0.243	0.949
EC-Foam	3 (2.4/3.7)	2 (1.5/2.6)	1.6 (1.3/2)	2.9 (2.35/3.88)	1.95 (1.48/3.13)	1.8 (1.15/2.1)	0.595	0.517	0.888

a: Independent Samples t-Test; Q: Quartile; OSI: Overall Stability Index; APSI: Anterior/Posterior Stability Index; MLSI: Medial/Lateral Stability Index; p1: Comparison for OSI; p2: Comparison for APSI; p3: Comparison for MLSI.

The original data for trunk muscle endurance and standing balance were presented separately for the moderate disability and severe disability groups in Table 2 and Table 3, respectively. Women with moderate neck disability had longer trunk flexor endurance time than those with severe neck disability (Cohen's d=0.89, $p<0.05$), but other endurance times and balance variables did not significantly differ between the moderate disability and severe disability groups ($p>0.05$).

Discussion

The present study was designed to investigate the association between trunk muscle endurance, standing balance, and neck disability in women with CNP, and to compare trunk muscle endurance and standing balance according to disability severity. The results indicated that trunk flexor and extensor endurance times were associated with standing balance in women with CNP. Trunk flexor endurance time was also associated with neck disability; furthermore, women with moderate disability had better trunk flexor endurance than those with severe disability, with a large effect size.

Maintaining standing posture during daily activities necessitates sustained, low-level activation of postural muscles. This implies that the endurance of related muscles may be more crucial than strength, particularly in situations where a response to extreme postural perturbations is not required.[28,29] The isometric trunk muscle endurance tests, commonly used to assess trunk stability, are simple, practical, and can be conducted with minimal, inexpensive, or no equipment in clinical settings.[17–20] Significant associations between the times of these tests and standing balance have been reported in various populations.[9–11] On the other hand, studies revealing the disturbing effect of trunk muscle fatigue on standing postural control also emphasize the importance of trunk muscle endurance in chronic musculoskeletal spinal conditions. Lin et al.[30] reported that fatigue of bilateral lumbar extensors caused more disruption in postural control during quiet standing than fatigue of unilateral ankle plantar flexors, knee extensors, and shoulder flexors. A systematic review published in 2019 indicated that trunk muscle fatigue impaired standing postural control, suggesting that improving trunk muscle endurance may be necessary to address postural impairments during standing in chronic musculoskeletal spinal conditions.[12] Consistent with the aforementioned literature, our results reveal that trunk flexor and extensor endurance times are associated with standing balance in people with CNP. Considering the existing literature, which provides convincing evidence that CNP causes decreased standing balance and altered function of the spine beyond the neck, it can be said that trunk muscle endurance training may improve standing balance in people with CNP. Future studies investigating the effects of endurance training of the trunk muscles on standing balance in people with CNP are needed.

Neck flexor muscle fatigue has also been reported to impair postural stability.[31] However, neck flexor endurance time was not found to be associated with standing balance in the present study. Quek et al.[5] reported that in their study, wavelet analysis suggested that sensory reweighting may occur to engage lower limb proprioception to compensate for deficits in neck proprioception in older adults with CNP. On the other hand, neck flexor endurance was reported to be lower in people with CNP than in asymptomatic controls.[17,32] We thought that due to the presence of neck pain and relatively lower muscular endurance, people with CNP may be more dependent on the activation of trunk muscles to maintain their standing balance.

In the present study, trunk flexor endurance time was found to be associated with disability due to neck pain, while, interestingly, neck flexor endurance was not. Consistent with our result, two previous related studies reported that neck flexor endurance, assessed with the same isometric muscle endurance test used in the present study, was not related to disability due to neck pain in people with CNP.[32,33] However, Dere and Alemderoğlu-Gürbüz reported that disability due to neck pain was related to isometric endurance times of neck flexors, trunk extensors, and trunk lateral flexors in people with CNP.[34] Although in the present study, neck and trunk muscle endurance and disability were assessed in the same way as in their study, we found that isometric endurance time of trunk flexors, not trunk extensors and lateral flexors, was related to disability due to neck pain. However, the disability level due to neck pain in our study population was higher than that in the population included in Dere and Alemderoğlu-Gürbüz's study, which may be a possible reason for the different results. Although the muscle groups whose endurance was found to be related to disability are different, both studies have indicated that in the management of neck pain-related disability, not only the cervical spine but all spinal regions should be considered.

There are several limitations that need to be addressed. The main limitation is that the study did not include a control group composed of people without neck pain. Future studies are needed to clarify whether there is a clinically significant difference in trunk muscle endurance between people with and without neck pain. Secondly, our sample consisted only of female participants aged between 25 and 55 years; thus, the results cannot be generalized to all gender and age groups with CNP. On the other hand, the prevalence of neck pain is higher in women and peaks during middle age,[1–3] and we determined our sample group accordingly. Moreover, further long-term studies addressing training for trunk muscles in people with CNP are needed.

Conclusion

As a conclusion, isometric endurance times of trunk flexors and extensors were associated with standing balance in women with CNP. Trunk flexor endurance was also associated with neck disability; furthermore, women with moderate disability had longer trunk flexor endurance time than those with severe disability, with a large effect size. Further studies with a larger sample of subgroups should be conducted to clarify our findings. Conclusively, trunk flexor and extensor endurance should be addressed in the management of CNP.

***Ethics Committee Approval:** The Dokuz Eylül University Clinical Research Ethics Committee granted approval for this study (date: 15.02.2023, number: 2023/04-02).*

***Authorship Contributions:** Concept – MK, GYÇ, YSŞ; Design – MK, GYÇ, YSŞ, OK; Supervision – YSŞ; Resource – YSŞ, OK; Materials – YSŞ, OK; Data collection and/or processing – MK, GYÇ, OK; Analysis and/or interpretation – MK; Literature review – MK, GYÇ; Writing – MK; Critical review – MK, YSŞ.*

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