Original Article

JHSMR Journal of Health Science and Medical Research

Influence of Text Neck Syndrome on Postural Sway and Cervical Proprioception in Adults with and Without Neck Pain

Vinosh Kumar Purushothaman, MPT, Ph.D. Scholar[1,2], Vinodhkumar Ramalingam, Ph.D.[1], Nithiyah Maruthey, MPT[2], Ambusam Subramaniam, M.Sc.[3], Arun Vijay Subbarayalu, Ph.D.[4], Madhan Kumar Soutallu Janakiram, Ph.D.[5], Vijayaraj Vediappan, Ph.D.[6]

[1]Saveetha College of Physiotherapy, Saveetha Institute of Medical and Technical Sciences, 602105 Chennai, India.

[2]Faculty of Health & Life Sciences, INTI International University Putra Nilai, 71800 Nilai, Negeri Sembilan, Malaysia.

[3]M Kandiah Faculty of Medicine and Health Sciences, Universiti Tunku Abdul Rahman, 43000 Kajang, Malaysia.

[4]Deanship of Quality and Academic Accreditation, Department of Physical Therapy, Imam Abdulrahman Bin Faisal University, 31441 Dammam, Saudi Arabia.

[5]Department of Anatomy, Faculty of Medicine, Manipal University College Malaysia, 75150 Melaka, Malaysia.

[6]Principal, Nehru College of Physiotherapy, The Tamilnadu Dr MGR Medical University, 641105 Chennai, India.

Received 5 June 2024 ● Revised 2 August 2024 ● Accepted 13 August 2024 ● Published online 9 January 2025

Abstract:

Objective: The objective of the study was to explore the influence of text neck syndrome on postural sway and cervical proprioception in adults with and without neck pain. The study also evaluated the connection between cervical proprioception and postural sway in individuals with and without neck pain under both eyes-open and eyes-closed conditions.

Material and Methods: This cross-sectional observational study included 16 participants with neck pain and 16 without neck pain. Subjects' postural sway was assessed with eyes open and closed for 30 seconds on a solid surface using a Wii board and physio-sensing software. Cervical proprioception was assessed with a laser pointer. Pearson correlation and the independent t-test were used to analyze the data.

Results: There were significant differences (p-value<0.05) in ellipse area and mean velocity in both eyes-closed and eyes-open conditions, as well as in cervical proprioception between subjects with and without neck pain. A significantly positive correlation (p-value<0.001) was observed between cervical proprioception error (extension, right and left rotation,

Contact: Vinosh Kumar Purushothaman, MPT, Ph.D. Scholar
Faculty of Health & Life Sciences, INTI International University Putra Nilai, 71800 Nilai, Negeri Sembilan, Malaysia.
E-mail: vinoshmpt@yahoo.com
Contact: Vinodhkumar Ramalingam, Ph.D.
Saveetha College of Physiotherapy Saveetha Institute of Medical and Technical Sciences, 602105, Chennai, India.

J Health Sci Med Res 2025;43(4):e20251140
doi: 10.31584/jhsmr.20251140
www.jhsmr.org

and right and left lateral flexion) and postural sway in both eyes-closed and eyes-open conditions in adults with and without neck pain.

Conclusion: The findings indicate that there are significant differences in cervical joint position inaccuracy and postural sway between individuals with and without neck pain. Assessing cervical joint position sensation and postural sway in patients with neck pain is important, and clinicians should consider this need. To address these issues, we recommend implementing targeted neck rehabilitation intervention programs to enhance patient outcomes.

Keywords: cervical proprioception, health risk, neck pain, postural sway, text neck syndrome

Introduction

Text Neck Syndrome (TNS) could be considered an emerging episode or "the pain of the modern era." This clinical condition, known as overuse syndrome, was originally discovered by Dr. Fishman, an American chiropractor[1]. It primarily affects the head, neck, and shoulders and is typically caused by excessive stress on the spine resulting from prolonged use of portable electronic devices such as mobile phones, video game devices, computers, and e-readers. This can lead to symptoms such as headaches, cervical pain, shoulder and arm discomfort, impaired breathing, and several other manifestations[2]. Chronic neck pain has been shown to result in greater ranges of sway and cause difficulty performing balance tasks[3]. A systematic review by Ruhe, Fejar, and Walker reported that patients with nonspecific neck pain and whiplash-associated disorders have greater center of pressure (COP) excursions compared to healthy patients, indicating greater postural instability[4]. This is hypothetically consistent with a report that 32% of injuries experienced by people during the time they were required to stay at home because of the COVID-19 pandemic were the result of falls[5]. Studies have shown that prolonged smartphone use affects postural stability and cervical proprioception in healthy adults[6]. However, no study to date has examined the influence of text neck syndrome on postural sway. The gap exists because text neck syndrome is caused by all handheld devices, not just smartphones[7].

Neck pain is also strongly associated with cervical proprioception impairment, resulting in cervical sensorimotor disturbances, which is considered a protective mechanism to limit further stimulation of the painful tissue[8]. Specifically, neck pain and inflammation significantly influence the function of muscle spindle sensory cells through various mechanisms. A primary pathway involves the alteration of somatosensory input from the neck, which may impact postural control and balance, as neck pain and injury often results in abnormal sensory feedback from the affected muscles[9]. Apart from pain, inflammation in the cervical region influences the excitability of muscle spindle sensory cells via multiple intricate mechanisms, the principal one being the sensitization of nociceptors, which are pain-detecting sensory neurons. Inflammatory mediators such as NGF, serotonin, interleukin-1, and bradykinin increase the expression of acid-sensitive ion channels (ASICs) in sensory neurons, leading to increased excitability and pain perception[10]. Moreover, alterations in the activity of muscle spindle sensory cells have a notable impact on proprioception and alignment in the region. Furthermore, the dynamic adjustment of muscle spindle activity plays a crucial role in refining proprioceptive input and consequently influences neck alignment and coordinated movements. This highlights the complex relationship between sensory feedback and motor control[9,11]. There is an assortment of empirical evidence and various explanations regarding why using a smartphone for a long period of time can lead to neck pain and its effects on structures in the neck region. Studies have shown that prolonged smartphone use often results in a flexed neck posture, which increases strain on the neck muscles and limits range of motion (ROM) in extension and lateral rotation, resulting in pain and stiffness[12,13]. In addition to causing muscle fatigue and passive stretching of the neck tissues, this flexed posture compromises spinal stability and raises the risk of musculoskeletal pain[14]. Further, prolonged neck flexion during smartphone use is associated with increased muscle activity, particularly in the upper trapezius (UT) and cervical erector spinae (CES). When the head angle exceeds 20°, discomfort scores increase noticeably[15]. Additionally, the length of time spent using a smartphone and the position in which it is used are important considerations. Seated positions – particularly unsupported sitting – are associated with higher pain thresholds than standing or supported sitting positions[13]. One other recent study found that a forward head posture, like staring at a smartphone, reduces cervical proprioception function, which is crucial because it provides sensory feedback to the human body's nervous system, ensuring optimal body alignment[16].

Despite this empirical evidence pointing to the destructive effects of prolonged smartphone use, no studies have examined the effects of cervical proprioception on text neck syndrome, which is a more common clinical condition among smartphone users. Examination of cervical proprioception is crucial in text neck syndrome with or without pain because it allows accurate positioning of the head in three-dimensional space and is a hallmark of balance and coordination activities[17]. In addition, there is evidence that assessment of cervical proprioception in patients with text neck syndrome, regardless of the presence of pain, may provide valuable insights into early musculoskeletal disorders and enable timely and targeted interventions to prevent further complications[18]. Thus, this study aimed to explore how text neck syndrome affects postural sway and cervical proprioception in adults with and without neck pain. The authors also seek to evaluate the connection between cervical proprioception and postural sway in individuals with and without neck pain, under both eyes-open and eyes-closed conditions. The knowledge gap in the current study could have implications for holistic training recommendations for individuals suffering from text neck syndrome.

Material and Methods

A cross-sectional observational study was conducted in order to examine the influence of text neck syndrome on postural sway and cervical proprioception among young adults with and without neck pain. A criterion-based, purposive sampling approach was used to select participants, consisting predominantly of students and office workers aged between 18 and 35 years, as a higher prevalence of smartphone use was observed in this vulnerable group, which contributes to the widespread occurrence of text neck syndrome[19]. A set of inclusive criteria was adopted in order to include the samples and consisted of: subjects who use smartphones for a minimum of 3 hours daily and exhibit symptoms including neck pain, neck and shoulder discomfort, upper back pain, upper body numbness, headaches, and insomnia. People who had previously suffered a cervical spine fracture and those with vestibular problems were not included in the study.

Participants

G-power 3.1 was used to determine the sample size, with a significance level of p-value<0.05 and a power analysis of 80%. Based on the study by Portelli & Reid (2018), calculation using mean and standard deviation (S.D.) for cervical proprioception measures 4.48 (1.84) and 3.62 (1.57), respectively[13]. The required sample size for this study was 28. Considering a drop-out rate of 10%, the total sample size was 31. One hundred and seventy-nine participants were screened and 32 participants who met the inclusion criteria were recruited for the study.

The participants were divided into groups 1 and 2. The subjects in group 1 (n=16) were classified as having neck pain. Participants who did not have neck pain but used smartphones for more than 3 hours were assigned to group 2 (n=16). A visual analogue scale was used to measure the intensity of the pain (VAS). All the participants had the study procedures explained to them clearly. Informed consent was obtained prior to the experiment. Ethical approval for this study was obtained from the Institutional Research and Ethics Committee, reference number INTI-IU/FHLS-RC/BPHTI/1NY12022/029.

Cervical proprioception error measurement

CPE was assessed by having subjects sit in chairs with back supports. Throughout the test, participants were instructed to maintain this posture, keeping their feet on the floor and bending their knees and hips at a 90-degree angle. The laser pointer was attached to the subject's head with tape and adhesives to keep it in place. Once the participants were comfortable with the test, they completed 3 trials and were instructed to move their necks in all directions without straining. Joint position error (JPE) was determined by averaging the 3 trials' scores for each movement. In order to prevent participants from trying to alter their head orientation by visually perceiving the laser pointer, their eyes were purposefully closed. The test was modified to include a predefined target and a neutral head position. The places on the wall were measured in centimeters and then transformed to degrees using the formula: angle=tan^-1 (error distance/90 cm). JPE exceeding 4.5 indicated reduced head and neck adjustment precision[20].

Postural sway assessment

The Wii Balance Board (WBB) measured the total COP sway length, which is the sum of postural sway in the anteroposterior and mediolateral directions. The WBB demonstrated moderate to high levels of reliability in assessing balance in healthy young people, with an intraclass correlation coefficient (ICC) ranging from 0.66 to 0.76[21].

After assessing their eligibility, the participants' PS was assessed by the same research assistant. The WBB was connected to a laptop computer running a customized Microsoft Windows 11 operating system to establish a Bluetooth connection and connect to the WBB. The data from the force platform were sampled at 100 Hz. It has 2 dual-channel analog-to-digital converters (ADC) to sample the 4 load cells in each corner of the platform. Postural sway was analyzed through Physiosensing Balance Software® v.21.5.0.0. Sensing Future, Coimbra, Portugal. The participants were instructed to position themselves on the WBB (Sensing Future Technology, Portugal). The sway assessment included 3 distinct conditions: eyes open on a firm surface (EO), eyes closed on a firm surface (EC), and participants' feet, with their eyes open, positioned in a narrow stance on either side of the centerline of the WBB. They were instructed to maintain a stable posture by keeping their arms at their sides and fixating on a specific point on the wall directly in front of them for 30 seconds. The same procedure was repeated for 30 seconds with eyes closed. Participants were given the opportunity to take one practice test per condition to familiarize themselves with the instructions and test criteria[21]. WBB was connected to a computer using a special cable. The Physio-Sensing Balance software was used to analyze the ellipse area (mm^2), the displacement of the COP in the anteroposterior (AP) and mediolateral (ML) directions, and the mean velocity (mm/s).

Statistical analysis

The Statistical Package for Social Sciences (SPSS), version 21, was used to analyze the data. For continuous data, the descriptive analysis involved calculating the mean and standard deviation, and for categorical data, frequency, and percentage were used to present the results. The normality test was conducted using the Shapiro-Wilk test, and the normal distribution of the data was observed; therefore, a parametric independent t-test was utilized to examine the difference in postural sway and cervical proprioception between the groups with and without neck pain. The correlation between CPE and PS between the groups was examined using Pearson correlation.

Results

The study involved 32 volunteers, half of whom had neck pain and half of whom did not. There were no significant differences found in the age, body mass index (BMI), and duration of smartphone usage between the 2 groups. However, there were noticeable variations in the visual analogue score and time spent on smartphones, which were statistically significant (p-value<0.05) and are presented in Table 1.

Further, Table 2 demonstrates no significant variations found in the excursion of the COP between the groups in the anterior-posterior (AP) and medial-lateral (ML) directions in both conditions. However, significant changes were observed in the ellipse area and mean velocity with closed eyes on firm surfaces.

Table 1 Demographics of the participants

Variables	With Neck Pain (n=16)	Without neck pain (n=16)
Age (years, mean±S.D.)	23.75±5.33	26.93±5.61
Sex (%)		
Male	7 (43.75)	9 (56.25)
Female	9 (56.25)	7 (43.75)
BMI (kg/m^2, mean±S.D.)	20.46±3.51	22.19±3.18
VAS (mean±S.D.)	6.31±1.19	0.0
Duration of smartphone usage (years, mean±S.D.)	8.938±1.06	9.313±1.53
Time spent in smartphone (hours, mean±S.D.)	7.688±4.28	5.063±2.59

BMI=body mass index, S.D.=standard deviation, VAS=visual analog scale, Independent t-test revealed a significant difference (p-value<0.05) in the elliptical area and mean postural sway velocity between participants with and without neck discomfort, both with eyes closed and opened conditions

Table 2 Comparison of PS between the participants with and without neck pain

Condition	Postural Sway	With Neck pain (Mean ± S.D.)	Without Neck pain (Mean±S.D.)	T statistic (df)	p-value
Firm surface (EO)	COP excursion AP (mm)	23.81±8.33	11.77±8.43	0.72 (30)	0.476
	COP excursion ML (mm)	11.69±5.09	10.06±7.33	0.86 (30)	0.396
	Ellipse Area (mm^2)	494.59±246.22	301.18±100.85	2.90 (30)	0.070
	Mean Velocity (mm/sec)	27.46±5.57	14.43±6.88	5.88 (30)	0.000*
Firm surface (EC)	COP excursion AP (mm)	31.24±10.08	17.24±9.39	1.39 (30)	0.174
	COP excursion ML (mm)	17.66±9.86	13.03±6.96	0.11 (30)	0.907
	Ellipse Area (mm^2)	535.85±248.90	283.09±125.27	3.62 (30)	0.001*
	Mean Velocity (mm/sec)	26.73±11.68	18.61±7.22	2.36 (30)	0.025*

*p-value<0.05, S.D.=standard deviation, PS=postural sway, AP=anteroposterior, ML=mediolateral, COP=centre of pressure, EO=eyes open, EC=eyes closed

Table 3 shows a statistically significant difference (p-value<0.05) in cervical joint proprioception error between the 2 groups, except for lateral flexion. Consequently, an evident correlation between cervical proprioception and neck pain was observed.

Table 4 reveals the relationship between cervical proprioception error and postural sway (eyes open and closed). The table indicates a significant relationship between CPE and postural sway (anterior-posterior direction) among participants with neck pain in all joint positions except flexion.

Table 3 Comparing cervical proprioception errors in participants with and without neck pain

Cervical proprioception error (degrees)	With Neck pain (Mean±S.D.)	Without Neck pain (Mean±S.D.)	T statistic (df)	p-value
Flexion	5.16±1.39	2.33±1.05	6.45 (30)	0.000*
Extension	6.97±0.86	2.96±1.17	10.99 (30)	0.000*
RR	6.25±1.29	3.13±1.68	5.86 (30)	0.000*
LR	7.05±0.94	3.45±1.74	7.27 (30)	0.000*
RLF	3.76±1.43	3.53±1.74	0.41 (30)	0.685
LLF	2.86±1.32	3.50±1.61	-1.20 (30)	0.237

*p-value<0.05, S.D.=standard deviation, RR=right rotation, LR=left rotation, RLF=right lateral flexion, LLF=left lateral flexion

Table 4 Correlation between CPE and PS between the groups with eyes open and closed

Cervical proprioception error (degrees)	Postural sway (Eyes closed)							
	With neck pain				Without neck pain			
	COP excursion AP (mm)		COP excursion ML (mm)		COP excursion AP (mm)		COP excursion ML (mm)	
	r	p-value	r	p-value	r	p-value	r	p-value
Flexion	0.421	0.105	0.333	0.207	-0.129	0.633	0.133	0.624
Extension	0.686	<0.001*	0.194	0.472	0.316	0.233	0.183	0.499
Right rotation	0.770	<0.001*	0.073	0.789	0.305	0.250	0.273	0.307
Left rotation	0.675	<0.001*	0.007	0.978	0.228	0.395	0.087	0.748
Right lateral flexion	0.786	<0.001*	0.317	0.232	0.107	0.692	0.452	0.079
Left lateral flexion	0.242	<0.001*	0.245	0.381	0.221	0.410	0.103	0.992
Cervical proprioception error (degrees)	**Postural sway (Eyes open)**							
	With neck pain				**Without neck pain**			
	COP excursion AP (mm)		**COP excursion ML (mm)**		**COP excursion AP (mm)**		**COP excursion ML (mm)**	
	r	**p-value**	**r**	**p-value**	**r**	**p-value**	**r**	**p-value**
Flexion	-0.183	0.317	0.026	0.886	0.047	0.863	0.237	0.377
Extension	0.733	<0.001*	0.134	0.464	0.271	0.310	0.376	0.301
Right rotation	0.637	<0.001*	0.316	0.078	-0.341	0.196	0.408	0.116
Left rotation	0.666	<0.001*	0.205	0.261	0.230	0.392	0.074	0.786
Right lateral flexion	0.648	<0.001*	0.283	0.117	-0.417	0.108	0.393	0.132
Left lateral flexion	0.666	<0.001*	-0.051	0.780	-0.252	0.347	0.131	0.630

*p-value<0.05, PS=postural sway, CPE=cervical proprioception error

Discussion

The findings of this investigation shed important light on how TNS affects cervical proprioception and PS in people with and without neck pain. The findings suggest that individuals with neck pain, presumably due to prolonged smartphone usage, exhibit significant differences in the ellipse area and mean postural sway velocity, especially with closed eyes, which aligns with the existing literature that emphasizes the impact of neck pain on postural control[22]. In a recent study, researchers investigated the changed neuromuscular activity and postural stability of persons with non-specific neck pain (NP) while doing standing balance tasks where participants were compared to healthy controls. According to that study's findings, individuals who had NP displayed increased activity in the muscles of the neck, trunk, and lower extremities, except the upper trapezius. This increased muscular activity was related to more postural sway, suggesting neck pain may impair postural control strategies[23]. This may be due to the condition rather than an inherent postural instability[24,25]. This supports our findings that TNS, characterized by similar symptoms, could lead to compromised postural stability, particularly in challenging conditions like standing with eyes closed.

Contrastingly, our study found no significant differences in the COP excursions in the anteroposterior and mediolateral directions between the groups, which might seem inconsistent with some previous studies. For instance, it is suggested that chronic neck pain could lead to larger sway areas, reflected in greater COP excursions[26]. It is possible that the disparity can be due to the various approaches utilized in the evaluation of postural sway, as well as the diverse definitions and populations investigated in relation to TNS[3,27]. There is also the possibility that TNS influences postural control in more subtle ways, which may not always be visible by COP excursions alone but rather through more sensitive metrics such as the ellipse area and mean velocity[28].

The considerable disparities in cervical proprioception errors between people with and without neck discomfort support the idea that TNS causes altered cervical proprioception[29,30]. Extended utilization of smartphones can exert a deleterious impact on the endurance of the cervical flexor musculature[31]. This phenomenon can be attributed to the posture adopted during prolonged engagement with these devices, typically characterized by forward head inclination and sustained neck flexion[32]. Such postural deviations can lead to increased strain on the neck muscles, particularly the deep cervical flexors which are instrumental in maintaining cervical alignment and stability[33]. Over time, this sustained stress may culminate in a decrement of muscular endurance, rendering the neck musculature less capable of performing its stabilizing functions effectively[34]. This is consistent with the study's findings that participants with persistent neck pain (CNP) showed a reduced capacity for endurance and a compromised sense of proprioception in comparison to those without symptoms[35]. The findings suggest that addressing impaired proprioception and endurance capacity may be important in the management of chronic neck pain[36]. Our findings extend this knowledge by explicitly linking TNS with proprioceptive impairments, highlighting the importance of cervical proprioception in maintaining neck health and stability. However, the lack of significant differences in lateral flexion proprioception errors between the groups is intriguing and suggests that TNS might not uniformly affect all aspects of cervical proprioception. This could be due to the specific postures adopted during smartphone use, which disproportionately affect certain movements or directions[37,38].

Strong positive correlations were observed in several instances, particularly in extension, right rotation, left rotation, right lateral flexion, and left lateral flexion, especially among those with neck pain. Individuals with neck pain generally exhibit stronger correlations between CPE and PS compared to those without neck pain. This suggests that neck pain might exacerbate the relationship between cervical proprioception and postural sway, indicating a potential impairment in sensorimotor integration in those with neck pain[39]. Extension consistently shows strong positive correlations across both eyes-open and eyes-closed conditions, indicating a significant association between impaired cervical proprioception and increased postural sway during extension[40]. There were notable differences in correlation patterns between the eyes-open and eyes-closed conditions. Correlations tend to be stronger with eyes closed, suggesting that visual input might play a role in modulating the relationship between cervical proprioception and postural control[41]. For instance, extension and right rotation show stronger correlations with PS under eyes-closed conditions compared to eyes-open conditions These findings underscore the importance of assessing both cervical proprioception and postural control in individuals with neck pain. Clinically, interventions targeting cervical proprioception might have implications for improving postural stability, especially in individuals with neck pain. Additionally, understanding the impact of visual input on this relationship can inform the development of rehabilitation strategies tailored to specific sensory conditions[40].

Limitations and recommendations

This study has a few limitations. First, the participants were not categorized as low or high intensity, which could have influenced the results. Second, postural sway using other challenging conditions, like unstable foam surfaces, could be implemented to assess the involvement of other sensory components that may impact the results. Finally, future research should also examine the long-term implications of these findings and the effectiveness of targeted interventions to improve postural and proprioceptive function in individuals with pain and TNS.

Conclusion

In conclusion, our study contributes to the growing evidence on the deleterious effects of prolonged smartphone use, particularly TNS, and its effects on postural control and cervical proprioception. The results of our study indicate a necessity for additional research to explore the complex effects of TNS on various proprioceptive capacities and their associations with the specific activities that contribute to TNS.

Acknowledgement

The authors express their sincere gratitude to all the volunteers who participated in this study.

Conflict of interest

There is no conflict of interest declared.

Funding sources

The current study was funded by INTI International University with Research Seeding Grant funding (INTI-FHLS-05-03-2021).

Ethical approval

Approval from the institutional ethics committee was obtained before the start of the study, reference number INTI-IU/FHLS-RC/BPHTI/1NY12022/029.

References

1. Kumari S, Kumar R, Sharma D. Text neck syndrome: the pain of modern era. Int J Health Sci Res 2021;11:161–5.
2. David D, Giannini C, Chiarelli F, Mohn A. Text neck syndrome in children and adolescents. Int J Environ Res Public Health 2021;18:1565.
3. Devi Uma A, Anumula SK, Suhail A. Effect of thoracic manipulation on pain and postural sway in chronic mechanical neck pain patients: a quasi-experimental study. J Clin Diagn Res 2021;15.

4. Ruhe A, Fejer R, Walker B. Altered postural sway in patients suffering from non-specific neck pain and whiplash associated disorder-A systematic review of the literature. Chiropr Man Therap 2011;19:1–11.
5. Gielen AC, Bachman G, Badaki-Makun O, Johnson RM, McDonald E, Omaki E, et al. National survey of home injuries during the time of COVID-19: who is at risk? Inj Epidemiol 2020;7:1–4.
6. Pashine AA, Jethani S, Chourasia S. Does smartphone use really impact cervical rotation and cervical proprioception in asymptomatic individuals? Cureus 2023;15.
7. Savić D. COVID-19 and work from home: Digital transformation of the workforce. TGJ 2020;16:101–4.
8. Peng B, Yang L, Li Y, Liu T, Liu Y. Cervical proprioception impairment in neck pain-pathophysiology, clinical evaluation, and management: a narrative review. Pain Ther 2021;10:143–64.
9. Sasaki H, Polus BI. Can neck muscle spindle afferents activate fusimotor neurons of the lower limb? Muscle Nerve 2012;45:376-84.
10. Mamet J, Baron A, Lazdunski M, Voilley N. Proinflammatory mediators, stimulators of sensory neuron excitability via the expression of acid-sensing ion channels. J Neurosci 2002;22:10662-70.
11. Vargas AM, Bisi A, Chiappa AS, Versteeg C, Miller LE, Mathis A. Task-driven neural network models predict neural dynamics of proprioception. Cell 2024;187:1745-61.
12. ıqbal K, Hafeez K, Rashad A, Lodhi AA. Prevalence of neck pain and its association with smartphone use among university students. J Health Rehabil Res 2024;4:96-101.
13. Kim E, Song D, Park D, Kim H, Shin G. Reflexive response of neck muscle to sudden perturbation after prolonged smartphone use. Proceedings of the Human Factors and Ergonomics Society Annual Meeting. Los Angeles: SAGE Publications; 2021;65;1250-3.
14. Torkamani MH, Mokhtarinia HR, Vahedi M, Gabel CP. Relationships between cervical sagittal posture, muscle endurance, joint position sense, range of motion and level of smartphone addiction. BMC Musculoskelet Disord 2023;24:61.
15. Humphreys BK. Cervical outcome measures: testing for postural stability and balance. J Manipulative Physiol Ther 2008;31:540–6.
16. Röijezon U, Jull G, Blandford C, Daniels A, Michaelson P, Karvelis P, et al. Proprioceptive disturbance in chronic neck pain: Discriminate validity and reliability of performance of the clinical cervical movement sense test. Front Pain Res 2022;3:908414.
17. Paleti ST, Inuganti R, Krishna SVG, Islam R. A cross-sectional study to estimate the prevalence of text neck syndrome among medical students in a tertiary care teaching hospital in Andhra Pradesh. MRIMS J Health Sci 2024;10–4103.
18. Sahu PK. Cervical proprioception and dynamic balance in computer users: a comparison between male and female healthy adults. Indian J Public Health Res Dev 2020;11:263–9.
19. Kaewkaen K, Uthama S, Ruengsirarak W, Puntumetakul R. Validity and reliability of the wii balance board for static balance assessment in healthy young adults. Malays J Med Sci 2019;26:114.
20. Vishal K, Walkay A, Huixin T, Raghava Neelapala YV, Bhat VS. Influence of duration of pain on postural sway in individuals with mechanical neck pain. Muscles, Ligaments Tendons J 2019;9:442–5.
21. Röijezon U, Björklund M, Djupsjöbacka M. The slow and fast components of postural sway in chronic neck pain. Man Ther 2011;16:273–8.
22. Sremakaew M, Treleaven J, Jull G, Vongvaivanichakul P, Uthaikhup S. Altered neuromuscular activity and postural stability during standing balance tasks in persons with non-specific neck pain. J Electromyogr Kinesiol 2021;61:102608.
23. Hirosawa M, Takehara I, Moriyama Y, Amimoto K. Effects of unilateral neck muscle vibration on standing postural orientation and spatial perception in healthy subjects based on stimulus duration and simultaneous stimulation of trunk muscles. PLoS One 2023;18:1–11.
24. Portelli A, Reid SA. Cervical proprioception in a young population who spend long periods on mobile devices: A 2-group comparative observational study. J Manipulative Physiol Ther 2018;41:123–8.
25. Hsu WL, Chen CPC, Nikkhoo M, Lin CF, Ching CTS, Niu CC, et al. Fatigue changes neck muscle control and deteriorates postural stability during arm movement perturbations in patients with chronic neck pain. Spine J 2020;20:530–7.
26. Wint SY, Hiruntrakul A. Correlation between deep cervical muscle endurance, cervical proprioception, and chronic neck pain: a cross-sectional analysis study. Int J Hum Mov Sports Sci 2022;10:138-44.
27. Namwongsa S, Puntumetakul R, Boucaut R. Effect of neck flexion angles on neck muscle activity among smartphone users with and without neck pain. Ergonomics. 2019;62:1524–33.

28. Lee DH, Jeon HJ. The effect of the use of smartphone while walking on the electromyography activity of the lower extremity in young students. J Exerc Rehabil 2021;17:138–44.
29. Fouda KZ, Abdelsalam MS. Effect of cervical exercises with corrective instructions on neck pain and disability in smartphone addicted users. Physiotherapy Quarterly 2022;30:1-6.
30. Alshahrani A, Samy Abdrabo M, Aly SM, Alshahrani MS, Alqhtani RS, Asiri F, et al. Effect of smartphone usage on neck muscle endurance, hand grip and pinch strength among healthy college students: A cross-sectional study. Int J Environ Res Public Health 2021;18:4–11.
31. Ghamkhar L, Kahlaee AH, Nourbakhsh MR, Ahmadi A, Arab AM. Relationship between proprioception and endurance functionality of the cervical flexor muscles in chronic neck pain and asymptomatic participants. J Manipulative Physiol Ther 2018;41:129–36.
32. Reddy RS, Meziat-Filho N, Ferreira AS, Tedla JS, Kandakurti PK, Kakaraparthi VN. Comparison of neck extensor muscle endurance and cervical proprioception between asymptomatic individuals and patients with chronic neck pain. J Bodyw Mov Ther 2021;26:180–6.
33. Fercho J, Krakowiak M, Yuser R, Szmuda T, Zieliñski P, Szarek D, et al. Kinematic analysis of the forward head posture associated with smartphone use. Symmetry (Basel) 2023;15:667.
34. Cetin H, Turkmen C, Bal GA, Tekerlek H, Bilgin S, Köse N. Factors affecting the performance of the deep cervical flexors in young people using smartphones. Cranio 2023;41:380-8.
35. Majcen Rosker Z, Vodicar M, Kristjansson E. Relationship between cervicocephalic kinesthetic sensibility measured during dynamic unpredictable head movements and eye movement control or postural balance in neck pain patients. Int J Environ Res Public Health 2022;19:8405.
36. Rosker ZM, Kristjansson E, Vodicar M, Rosker J. Postural balance and oculomotor control are influenced by neck kinaesthetic functions in elite ice hockey players. Gait Posture 2021;85:145–50.
37. Fernandes TM, Méndez-Sánchez R, Puente-González AS, Martín-Vallejo FJ, Falla D, Carolina VC. A randomized controlled trial on the effects of "global postural re-education" versus neck specific exercise on pain, disability, postural control, and neuromuscular features in women with chronic non-specific neck pain. Eur J Phys Rehabil Med 2023;59:42.
38. Avaghade R-R, Shinde SB, Dhane SB. Effectiveness of McKenzie approach and segmental spinal stabilization exercises on neck pain in individuals with cervical postural syndrome: an experimental study. J Educ Health Promot 2023;12:225.
39. Fernandes TM, Méndez-Sánchez R, Puente-González AS, Martín-Vallejo FJ, Falla D, Carolina VC. A randomized controlled trial on the effects of "Global Postural Re-education" versus neck specific exercise on pain, disability, postural control, and neuromuscular features in women with chronic non-specific neck pain. Eur J Phys Rehabil Med 2023;59:42.
40. Avaghade RR, Shinde SB, Dhane SB. Effectiveness of McKenzie approach and segmental spinal stabilization exercises on neck pain in individuals with cervical postural syndrome: an experimental study. J Educ Health Promot 2023;12:225.