

Impaired cervical proprioception and its relationship with intensity, frequency, and duration of headache in people with migraine

Makbule Ozel

makbuleozel195@gmail.com

Hacettepe University

Fatih Söke

University of Health Sciences

Yasemin Eren

University of Health Sciences

Cagri Gulsen

Eskişehir Osmangazi University

Oznur Tunca

Hacettepe University

Research Article

Keywords: Awareness, Migraine, Pain, Proprioception, Joint Position Sense

Posted Date: February 3rd, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-8749895/v1>

License:   This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Additional Declarations: No competing interests reported.

Abstract

Aim

Although loss of cervical position sense is common in neurological diseases and migraine especially affects the head and neck region of the body, cervical position sense has not comprehensively been assessed for people with migraine (PwM). Therefore, the primary aim was to compare cervical position sense between PwM and healthy people. The secondary aim was to investigate the relationship between cervical proprioception and headache intensity, frequency, and duration for PwM.

Materials and methods

This cross-sectional study included 68 PwM and 68 healthy people. Cervical proprioception was evaluated using the Joint Position Sense (JPS) test and Fremantle Neck Awareness Questionnaire (FreNAQ). Headache severity was assessed with the Numeric Pain Rating Scale (NPRS) and a structured form was used to evaluate headache frequency, and duration.

Results

Compared to healthy people, PwM had higher repositioning errors on the JPS in all directions (flexion, extension, right and left rotation) ($p < 0.001$) and had greater values in FreNAQ ($p < 0.001$). There was a fair correlation between cervical JPS and headache intensity, frequency, and duration in PwM ($p < 0.05$).

Conclusions

PwM had impaired cervical position sense. Impaired cervical position sense was also related to headache intensity, frequency, and duration. These findings suggest that evaluation of cervical position sense should be taken into consideration in the clinic of migraine.

1. INTRODUCTION

Migraine is a unilateral, throbbing headache with moderate to severe episodes, which can be accompanied by nausea, vomiting, phonophobia, photophobia or osmophobia (1). It affects approximately one billion people in the world and leads to serious loss of function negatively affecting quality of life (1, 2). People with migraine (PwM) experience a wide range of disorders especially in the head and neck region such as musculoskeletal dysfunction, and sensorimotor disturbance (3–5).

Proprioception allows our body to perceive its location and movement in space (6). Cervical position sense is the sense of the position of the head or the neck in space which makes interaction between the afferent and efferent receptors possible to view position and movement (7). A high amount of muscle

spindles in cervical muscles allows the cervical area to have a rich proprioceptive system (8). In particular, deep cervical flexor and suboccipital muscles contribute to the protection of cervical joint position. The deterioration in cervical afferent activity partially leads to impaired cervical position sense (8, 9). In addition, musculoskeletal system disorders, such as fibromyalgia and spondylosis seen in pathologies, which affect the head and neck area, can cause disturbances in the operation of the proprioceptive system (10, 11). Although PwM have commonly impairments in the cervical region, no study has comprehensively investigated cervical position sense in migraine.

Nociceptive stimulants are one of the important factors affecting cervical proprioception (12). Neck pain can commonly be seen in any phase of the attack and in periods between the attacks in migraine (13). The pain can occur in any part of the head and frequently affects the posterior cervical and trapezius areas for PwM (14). The pathophysiological connection between migraine and neck pain is explained with the union of afferent nociceptors from the trigeminal and upper cervical (C1–C3) nerves in the trigeminocervical nucleus (15, 16). Pain can affect the sensitivity of muscle spindle receptors and the response of the central nerve system to afferent inputs, in turn reducing joint position sense. However, the relationship between cervical proprioception and pain in migraine patients is still not clear.

Therefore, the primary aim of our study is to compare cervical position sense between migraine patients and healthy individuals. The secondary aim of the study is to analyze the relationship between cervical position sense and pain intensity, frequency and duration for PwM.

2. MATERIALS AND METHODS

2.1. Study Design

This cross-sectional study was performed at the Department of Neurology at Etlik City Hospital from May to December 2025 and approved by Etlik City Hospital Clinical Research Ethics Committee (AEŞŞH-BADEK-2024-050). The study was in compliance with the Declaration of Helsinki and informed consent forms were signed by the participants.

2.2. Participants

The sample size calculation was performed using G*Power 3.1.9.7 (17). Because no prior data were available on the differences in manual dexterity between PwM and healthy people, the sample size calculation was based on a medium effect size (Cohen's $d = 0.5$) (18). A sample size of 64 participants per group was required to detect a difference between the groups, with an effect size of 0.5, a two-sided significance level of 0.05, and a power of 0.80.

According to the criteria specified in the International Classification of Headache Disorders 3rd edition (ICHD-3), the people who were diagnosed with migraine by a neurologist were included in the study. The inclusion criterion was being between 18 and 65 years of age. The exclusion criteria were as follows: having other neurological disorders, having a systemic disease, receiving prophylactic treatment, and

having any disorder in the cervical area. A group of age and gender matched healthy people, who met the same exclusion criteria and did not experience neck pain, was included as the control group.

2.3. Procedures

The demographic and clinical characteristics of all participants were recorded using a form. The PwM were given a cervical Joint Position Sense (JPS) test, Fremantle Neck Awareness Questionnaire (FreNAQ), and Numeric Pain Rating Scale (NPRS). The healthy controls were only assessed with the JPS and FreNAQ.

The JPS is used to evaluate cervical position sense. Cervical JPS measures the ability of the musculoskeletal system to reposition the head in a neutral position after active movements in different motion planes. The test involves a laser pointer attached to the patient's head and a board with circles drawn 1 cm apart from each other. Participants are asked to sit on a chair with back support. The distance between the panel and the participant is set to 90 cm. A laser pointer is set on the center point. Participants are asked to close their eyes and keep this point in mind. Each participant is asked to memorize the neutral position at the start of each movement and to return to the neutral position after a submaximal active movement performed by the participant. They are asked to find the center point as accurately as possible for cervical flexion-extension and right-left rotation movements, in sequence, with their eyes closed (19). Each movement (flexion, extension, right and left rotation) joint position error testing was performed six times, and the mean error of these trials was recorded (20).

The FreNAQ assesses attention, proprioceptive sensation, neglect and shape/size perception of the neck. It is made up of 9 questions with each question rated from 0 to 4. The score range of the questionnaire is between 0 and 36 points. A higher score on the FreNAQ means that neck awareness is low. The FreNAQ is valid and reliable in individuals with chronic neck pain (21).

The Numeric Pain Rating Scale (NPRS) evaluates headache severity. This scale provides a rating of pain from 0 to 10 points on a vertical line. The pain felt by an individual is rated from "0: no pain at all" to "10: I feel very severe pain" (22).

2.4. Statistical Analysis

The SPSS 17.0 software (SPSS Inc, Chicago, Illinois) was used in the analysis of this study. Descriptive statistics were used to summarize the demographic characteristics of the participants. The normality of data was calculated using the Shapiro–Wilk test, and the homogeneity of variances was checked using Levene's test. Normally distributed variables were expressed as mean $\pm$ standard deviation, while non-normally distributed variables were expressed as median (interquartile range [IQR]). Categorical variables were presented in numbers (percentage).

The comparisons between groups were performed using independent t-test for the normally distributed variables, Mann–Whitney U test for the non-normally distributed variables, or chi-square test for the categorical variables. The correlation analyses for cervical JPS and FreNAQ with other outcome

measures were performed by using Pearson's (r) or Spearman's correlation coefficients (p) as appropriate. Correlation coefficients were classified as strong (0.76–1.00), moderate (0.51–0.75), fair (0.26–0.50), and poor (0–0.25) (23). The statistical significance level was set at 0.05.

3. RESULTS

In total, 68 PwM (9 males and 59 females) and 68 healthy people (11 males and 57 females) were recruited for this study. There were no significant differences in any demographic variables between patients with migraine and healthy people ($p > 0.05$). Demographic and clinical characteristics of the study participants are presented in Table 1.

Table 1
Demographic and clinical characteristics of participants.

Characteristics	Patients with migraine (n = 68)	Healthy people (n = 68)	p
Age, y			
Mean $\pm$ SD	31.18 $\pm$ 7.96	32.71 $\pm$ 6.12	0.211
Sex, n (%)			
Male	9 (13.2%)	11 (16.2%)	0.628
Female	59 (86.8%)	57 (83.8%)	
Weight, kg			
Mean $\pm$ SD	64.31 $\pm$ 11.27	66.19 $\pm$ 7.61	0.256
Height, cm			
Mean $\pm$ SD	165.22 $\pm$ 7.80	166.78 $\pm$ 5.36	0.177
Duration of headache, year			
Median (IQR)	10.00 (5.00-11.50)	NA	NA
Frequency of headache, days with headache/month			
Median (IQR)	8.00 (6.00–12.00)	NA	NA
Intensity of headache (NPRS)			
Median (IQR)	8.00 (8.00–9.00)	NA	NA
Intensity of Neck Pain (NPRS)			
Median (IQR)	5.00 (0.00–9.00)	0 (0–0)	0.234
cm: centimeter; kg: kilogram; SD: Standard deviation; NPRS: Numeric Pain Rating Scale;			
y: Year; NA: Not Applicable.			

Compared to healthy subjects, PwM had significantly higher cervical JPS in flexion, extension, rotation to the right side, and rotation to the left side ($p < 0.001$, $p < 0.001$, $p < 0.001$, and $p < 0.001$, respectively), and had also significantly FreNAQ values ($p < 0.001$). (Table 2).

Table 2
Comparison of cervical joint position sense and FreNAQ between PwM and healthy people.

Variable	Patients with migraine (n = 68)	Healthy people (n = 68)	p
JPS-Flexion global (cm) Mean $\pm$ SD	6.92 $\pm$ 1.89	3.87 $\pm$ 1.10	< 0.001
JPS-Extension (cm) Mean $\pm$ SD	6.48 $\pm$ 1.98	4.17 $\pm$ 1.29	< 0.001
JPS-Right rotation (cm) Median (IQR)	6.78 (5.50–8.25)	4.00 (2.86–4.78)	< 0.001
JPS-Left rotation (cm) Median (IQR)	6.34 (4.98–7.60)	4.00 (3.27–4.96)	< 0.001
FreNAQ Median (IQR)	6.00 (2.00-10.50)	2.00 (1.00–4.00)	< 0.001
IQR: Interquartile range; JPS: Joint Position Sense; FreNAQ: Fremantle Neck Awareness Questionnaire; SD: Standard deviation. * $p < 0.001$.			

In PwM, the intensity of headache in right and left rotation directions had a fair correlation with cervical position sense ($r = 0.255$; $p < 0.036$, $r = 0.271$; $p < 0.025$, respectively), the frequency of headache in all directions had a fair correlation with cervical joint position sense (r ranged from 0.287 to 0.424; $p < 0.05$), and duration of headache had a fair correlation with cervical joint position sense in flexion, right and left rotation directions ($r = 0.253$; $p = 0.038$, $r = 0.270$; $p = 0.026$, $r = 0.299$; $p = 0.013$, respectively). (Table 3).

Table 3
Outcome measures and their correlations with the JPS and FreNAQ in PwM.

	JPS-Flexion		JPS-Extension		JPS -Rotation: Right		JPS Rotation: Left	
	r_s	p	r_s	p	r_s	p	r_s	p
Intensity of headache (NPRS)	0.091	0.460	0.018	0.883	0.255	0.036*	0.271	0.025*
Frequency of headache	0.424	< 0.001**	0.287	0.018*	0.318	0.008**	0.314	0.009*
Duration of headache, year	0.253	0.038*	0.009	0.945	0.270	0.026*	0.299	0.013*
JPS, Joint Position Sense; NPRS, Numeric Pain Rating Scale; r_s , Spearman correlation coefficient.*p < 0.05; ** p < 0.01.								

4. DISCUSSION

This study examined cervical position sense and its relationship with intensity, frequency, and duration of headache in PwM. The loss of cervical position sense was found in migraine. In addition, cervical position sense was associated with the intensity, frequency, and duration of headache for PwM.

PwM showed impaired cervical position sense in all directions compared to healthy people. Deep cervical flexor and suboccipital muscles could maintain cervical proprioception. The deep cervical muscles are weakened in longus colli and longus cervicis muscles, and the myofascial trigger points especially trapezius, sternocleidomastoideus, suboccipital and splenius muscles appear in the head and neck region in migraine (24, 25). Thus, PwM showed a reduction in neck muscle strength and a dysfunction in the deep stabilizer muscles (26). Also, these disorders can contribute to postural disorders such as forward head posture and limited range of motion in the neck region (27). Such structural and functional changes in the cervical region can impair cervical position sense. In contrast to our results, previous studies have not reported impaired cervical position sense (28, 29). However, these studies had a small sample size and did not report treatment status (28, 29). In our study, PwM had not received prophylactic treatment known to have a positive effect on pain (30, 31). This can provide a more clear assessment of the effect of pain because chemically mediating substances during pain response can alter free nerve ending discharges following sensitization and impair proprioceptive input by inducing abnormal pain afferents in the gamma motor neuron and muscle spindle. These findings suggest that clinicians and researchers should add the assessment of cervical position sense in the clinic of migraine. Future studies should clarify the underlying mechanisms of impaired cervical position sense in migraine.

Cervical position sense was associated with headache intensity, frequency, and duration for PwM. Consistent with our findings, it has been shown that increased cervical joint position errors was related

to higher pain intensity, frequency, and chronicity in different conditions such as cervical spondylosis (11), fibromyalgia (32), and chronic neck pain (33) affected the cervical region. Pain affects the sensitivity of muscle spindle receptors and the response of the central nerve system to afferent inputs (8). Thus, PwM can experience impaired cervical position sense due to chronic and severe pain causing changes in the firing of sensory receptors. Moreover, neck pain that is in the pathophysiological processes of headache as a symptom of migraine was reported by PwM in the present study. Previous studies showed that neck pain was associated with higher migraine attack frequency (34), higher migraine disability levels (35) and worse pharmacological treatment prognosis in migraine (30, 31). On the other hand, proprioceptive exercises can be used to reduce pain in chronic low back pain (36). Clinically, the features of headache can provide information about the ability of cervical position sense for PwM. Longitudinal studies can be designed to understand the effects of cervical proprioceptive training on headache in migraine.

The present study has several limitations. The study focused only on the angle in the measurement of cervical joint position sense, but several factors such as the quality and speed of cervical movements were not examined in this study. Since the study was cross-sectional, the interpretation of the cause-effect relationship between impaired cervical proprioception and migraine was limited. Prospective studies should be conducted to determine the role of impaired cervical proprioception in migraine. Psychological stress is among the various mechanisms, which may contribute to the impairment of neck proprioception. Therefore, the effect of pain behaviors of migraine patients and the psychological stress caused by these behaviors on cervical joint position sense should be evaluated in detail.

5. CONCLUSION

The results of this study showed that PwM had impaired cervical position sense compared to healthy people. Impaired cervical position sense was also associated with the clinical features of headache including intensity, frequency, and duration for PwM. These findings suggest that cervical position sense is a novel and important part of the assessment in migraine. Future studies should focus on developing rehabilitation strategies to improve cervical position sense and to explore the effects of cervical position sense on pain in PwM.

Declarations

Competing Interests and Funding

The authors declare that they have no conflict of interest. There is no funding source.

Author Contribution

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by [Makbule Özel], [Fatih Söke], [Yasemin Eren], [Cagri Gulsen] and [Oznur

Tunca]. The first draft of the manuscript was written by [Makbule Özel] and [Fatih Söke] and all authors commented on the previous versions of the manuscript. All authors read and approved the final manuscript.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

References

1. Puledda F, Silva EM, Suwanlaong K, Goadsby PJ. Migraine: from pathophysiology to treatment. *J Neurol*. 2023 Jul;270(7):3654–3666. doi: 10.1007/s00415-023-11706-1.
2. Charles A. The pathophysiology of migraine: implications for clinical management. *Lancet Neurol*. 2018 Feb;17(2):174–182. doi: [https://10.1016/S1474-4422\(17\)30435-0](https://doi.org/10.1016/S1474-4422(17)30435-0).
3. Luedtke K, Starke W, May A. Musculoskeletal dysfunction in migraine patients. *Cephalalgia*. 2018;38(5):865–875. doi: [https://10.1177/0333102417716934](https://doi.org/10.1177/0333102417716934).
4. Szikszay TM, Hoenick S, von Korn K, Meise R, Schwarz A, Starke W, Luedtke K. Which examination tests detect differences in cervical musculoskeletal impairments in people with migraine? A systematic review and meta-analysis. *Phys Ther*. 2019;99(5):549–569. doi: [https://10.1093/ptj/pzz007](https://doi.org/10.1093/ptj/pzz007).
5. Carvalho GF, Luedtke K, Bevilaqua-Grossi D. Balance disorders and migraine. *Musculoskelet Sci Pract*. 2023 Aug;66:102783. doi: [https://10.1016/j.msksp.2023.102783](https://doi.org/10.1016/j.msksp.2023.102783).
6. Sherrington, C. S. (1906). On the proprioceptive system, especially in its reflex aspect. *Brain: A Journal of Neurology*, 29, 467–482. <https://doi.org/10.1093/brain/29.4.467>
7. Strimpakos N. The assessment of the cervical spine. Part 1: Range of motion and proprioception. *J Bodyw Mov Ther*. 2011 Jan;15(1):114 – 24. doi: 10.1016/j.jbmt.2009.06.003.
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 Jun;10(1):143–164. doi: 10.1007/s40122-020-00230-z.
9. Ghamkhar L, Kahlaee AH. Are Ultrasonographic Measures of Cervical Flexor Muscles Correlated with Flexion Endurance in Chronic Neck Pain and Asymptomatic Participants? *Am J Phys Med Rehabil*. 2017 Dec;96(12):874–880. doi: 10.1097/PHM.0000000000000778.
10. Reddy RS, Tedla JS, Dixit S, Raizah A, Al-Otaibi ML, Gular K, Ahmad I, Sirajudeen MS. Cervical Joint Position Sense and Its Correlations with Postural Stability in Subjects with Fibromyalgia Syndrome. *Life (Basel)*. 2022 Nov 7;12(11):1817. doi: 10.3390/life12111817.
11. Reddy RS, Tedla JS, Dixit S, Abohashrh M. Cervical proprioception and its relationship with neck pain intensity in subjects with cervical spondylosis. *BMC Musculoskelet Disord*. 2019 Oct 15;20(1):447.

doi: 10.1186/s12891-019-2846-z.

12. Ashina M, Hansen JM, Do TP, Melo-Carrillo A, Burstein R, Moskowitz MA. Migraine and the trigeminovascular system-40 years and counting. *Lancet Neurol*. 2019 Aug;18(8):795–804. doi: 10.1016/S1474-4422(19)30185-1. Epub 2019 May 31. PMID: 31160203; PMCID: PMC7164539.
13. Rees TA, Doukhi D, Wang VS, et al. Neck pain in migraine: A narrative review and steps to correct evaluation and treatment. *Cephalalgia*. 2025;45(10). doi:10.1177/03331024251387449.
14. Calandre EP, Hidalgo J, García-Leiva JM, Rico-Villademoros F. Trigger point evaluation in migraine patients: an indication of peripheral sensitization linked to migraine predisposition? *Eur J Neurol*. 2006 Mar;13(3):244-9. doi: 10.1111/j.1468-1331.2006.01181.x.
15. Jull G, Amiri M, Bullock-Saxton J, Darnell R, Lander C. Cervical Musculoskeletal Impairment in Frequent Intermittent Headache. Part 1: Subjects With Single Headaches. *Cephalalgia*. 2007;27(7):793–802. doi:10.1111/j.1468-2982.2007.01345.x.
16. Bogduk N. The neck and headaches. *Neurol Clin*. 2014 May;32(2):471 – 87. doi: 10.1016/j.ncl.2013.11.005.
17. Faul F, Erdfelder E, Buchner A et al (2009) Statistical power analyses using G* Power 3.1: Tests for correlation and regression analyses. *Behav Res Methods* 41(4):1149–1160. <https://doi.org/10.3758/BRM.41.4.1149>.
18. Cohen J (2013) Statistical power analysis for the behavioral sciences. Routledge.
19. Revel M, Andre-Deshays C, Minguet M. Cervicocephalic kinesthetic sensibility in patients with cervical pain. *Arch Phys Med Rehabil*. 1991 Apr;72(5):288 – 91.
20. de Vries J, Ischebeck BK, Voogt LP, van der Geest JN, Janssen M, Frens MA, Kleinrensink GJ. Joint position sense error in people with neck pain: A systematic review. *Man Ther*. 2015 Dec;20(6):736 – 44. doi: 10.1016/j.math.2015.04.015.
21. Onan D, Gokmen D, Ulger O. The Fremantle Neck Awareness Questionnaire in Chronic Neck Pain Patients: Turkish Version, Validity and Reliability Study. *Spine (Phila Pa 1976)*. 2020 Feb 1;45(3):E163-E169. doi: 10.1097/BRS.0000000000003207.
22. Atisook R, Euasobhon P, Saengsanon A, Jensen MP. Validity and Utility of Four Pain Intensity Measures for Use in International Research. *J Pain Res*. 2021 Apr 21;14:1129–1139. doi: 10.2147/JPR.S303305.
23. Portney, L. G., & Watkins, M. P. (2009). Foundations of clinical research: applications to practice (Vol. 892, pp. 11–15). Upper Saddle River, NJ: Pearson/Prentice Hall.
24. Castien RF, van der Wouden JC, De Hertogh W. Pressure pain thresholds over the cranio-cervical region in headache: a systematic review and meta-analysis. *J Headache Pain*. 2018 Jan 26;19(1):9. doi: 10.1186/s10194-018-0833-7.
25. Rodrigues A, Bigal LM, Bragatto MM, Dach F, Bevilaqua-Grossi D, Bigal ME, Fernández-de-Las-Peñas C, Florencio LL. Cervical muscle parameters and allodynia in migraine and cervical pain-A controlled study. *Eur J Pain*. 2024 Apr;28(4):565–577. doi: 10.1002/ejp.2200.

26. Benatto MT, Florencio LL, Bragatto MM, Lodovichi SS, Dach F, Bevilaqua-Grossi D. Extensor/flexor ratio of neck muscle strength and electromyographic activity of individuals with migraine: a cross-sectional study. *Eur Spine J*. 2019 Oct;28(10):2311–2318. doi: 10.1007/s00586-019-06097-9.
27. Pensri C, Liang Z, Treleaven J, Jull G, Thomas L. Cervical musculoskeletal impairments in migraine and tension-type headache and relationship to pain related factors: An updated systematic review and meta-analysis. *Musculoskelet Sci Pract*. 2025 Apr;76:103251. doi: 10.1016/j.msksp.2024.103251.
28. Jull G, Amiri M, Bullock-Saxton J, Darnell R, Lander C. Cervical musculoskeletal impairment in frequent intermittent headache. Part 1: Subjects with single headaches. *Cephalalgia*. 2007 Jul;27(7):793–802. doi: 10.1111/j.1468-2982.2007.01345.x.
29. Liang Z, Galea O, Thomas L, Jull G, Treleaven J. Cervical musculoskeletal impairments in migraine and tension type headache: A systematic review and meta-analysis. *Musculoskelet Sci Pract*. 2019 Jul;42:67–83. doi: 10.1016/j.msksp.2019.04.007.
30. Maarrawi J, Abdel Hay J, Kobaiter-Maarrawi S, Tabet P, Peyron R, Garcia-Larrea L. Randomized double-blind controlled study of bedtime low-dose amitriptyline in chronic neck pain. *Eur J Pain*. 2018 Jul;22(6):1180–1187. doi: 10.1002/ejp.1206.
31. Onan D, Bentivegna E, Martelletti P. OnabotulinumtoxinA Treatment in Chronic Migraine: Investigation of Its Effects on Disability, Headache and Neck Pain Intensity. *Toxins (Basel)*. 2022 Dec 30;15(1):29. doi: 10.3390/toxins15010029.
32. Reddy RS, Tedla JS, Dixit S, Raizah A, Al-Otaibi ML, Gular K, Ahmad I, Sirajudeen MS. Cervical Joint Position Sense and Its Correlations with Postural Stability in Subjects with Fibromyalgia Syndrome. *Life (Basel)*. 2022 Nov 7;12(11):1817. doi: 10.3390/life12111817.
33. Raizah A, Reddy RS, Alshahrani MS, Gautam AP, Alkhamis BA, Kakaraparthi VN, Ahmad I, Kandakurti PK, ALMohiza MA. A Cross-Sectional Study on Mediating Effect of Chronic Pain on the Relationship between Cervical Proprioception and Functional Balance in Elderly Individuals with Chronic Neck Pain: Mediation Analysis Study. *J Clin Med*. 2023 Apr 26;12(9):3140. doi: 10.3390/jcm12093140.
34. Florencio LL, Chaves TC, Carvalho GF, Gonçalves MC, Casimiro EC, Dach F, Bigal ME, Bevilaqua-Grossi D. Neck pain disability is related to the frequency of migraine attacks: a cross-sectional study. *Headache*. 2014 Jul-Aug;54(7):1203-10. doi: 10.1111/head.12393.
35. Di Antonio S, Arendt-Nielsen L, Ponzano M, Bovis F, Torelli P, Pelosin E, Finocchi C, Castaldo M. Migraine patients with and without neck pain: Differences in clinical characteristics, sensitization, musculoskeletal impairments, and psychological burden. *Musculoskelet Sci Pract*. 2023 Aug;66:102800. doi: 10.1016/j.msksp.2023.102800.
36. Ghamkhar L, Kahlaee AH. Pain and Pain-Related Disability Associated with Proprioceptive Impairment in Chronic Low Back Pain Patients: A Systematic Review. *J Manipulative Physiol Ther*. 2019 Mar-Apr;42(3):210–217. doi: 10.1016/j.jmpt.2018.10.004.