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CERVICAL PROPRIOCEPTION AND VESTIBULAR FUNCTIONS IN PATIENTS WITH NECK PAIN AND CERVICOGENIC HEADACHE: A COMPARATIVE STUDY

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ABSTRACT

Objective: To investigate cervical proprioceptive input and vestibular system function in patients with cervicogenic headaches (CGH). In addition, this study aimed to determine whether abnormal proprioceptive or vestibular inputs are effective in the emergence of cervicogenic dizziness.

Materials and Methods: Thirty patients with CGH and 25 healthy individuals were included in this study. Participants were asked about their recent falls. A visual analog scale was used to evaluate headache severity. Furthermore, static posturography, dizziness handicap index (DHI), neck disability index, subjective visual vertical, cervical vestibular-evoked myogenic potentials (cVEMP), and cervical joint position error test (CJPET) were applied to the participants.

Results: Patients with CGH had more falls in the last year than the control group ($p<0.05$). DHI, standing with eyes closed on a foam surface, cVEMP, and CJPET scores were worse in patients with CGH than in healthy individuals ($p<0.05$). The CJPET score of patients with CGH who reported cervicogenic dizziness was worse than that of patients with CGH who did not report dizziness ($p<0.05$). However, no difference in cVEMP findings was observed between patients with CGH and those without dizziness ($p>0.05$).

Conclusion: It was determined that there were abnormalities in both cervical and vestibular inputs in patients with CGH. However, abnormal cervical proprioceptive inputs, not vestibular responses, were found to play a role in the mechanism of cervicogenic dizziness.

Keywords: Cervicogenic headache, neck pain, vestibular, balance, proprioception

INTRODUCTION

Problems occurring in the muscles, ligaments, discs, bursae, or joints in the cervical region may cause cervicogenic neck pain and secondary headache[1]. Cervicogenic headache (CGH) is a lateralized, non-throbbing headache caused by a nociceptive source in the cervical spine. CGH is the pain with the best understood mechanism among common headaches[2]. It generally results from the disorder of the structures innervated by the upper cervical nerves (C1-C3) and is considered a referred pain related to the trigeminal system[2]. CGH accounts for approximately one-fifth of chronic headache cases[3]. Chronic neck pain and CGH affect the upper extremity functions of individuals, limiting their daily living activities, reducing their quality of life, and causing psychiatric disorders such as stress, anxiety, and depression in individuals[4-6].

The vestibular, somatosensory, and visual input interaction provides balance and postural control. The upper cervical spine has more proprioceptive receptors than the caudal region of the spine[7-9]. Therefore, disorders in the upper cervical structures that cause CGH may affect the proprioceptive system more[10]. Also, abnormal proprioceptive input may cause cervicogenic dizziness in individuals [9,10]. Maintaining balance is important not only to maintain postural stability but also to perform activities of daily living safely. Therefore, abnormal balance is also the main risk factor for falls.

The vestibular and spinal systems interact with the lateral and medial vestibulospinal pathways. The lateral vestibulospinal

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pathway extends to the ipsilateral (mainly) spinal cord and modulates the α and γ motor neurons of intraspinal pathways and antigravity muscles[11]. It stimulates lower extensor motor neurons and suppresses flexor motor neurons. Thus, it plays an important role in maintaining balance by controlling muscle activity and maintaining posture against gravity. The medial vestibulospinal system terminates in the upper cervical regions of the spinal cord and is involved in the control of neck and eye movements, mainly about changes in head orientation[12].

As a result, cervical spinal disorders may affect the balance system through neck proprioception and the medial vestibulospinal tract[12]. However, to our knowledge, no study has investigated cervical proprioceptive inputs and the vestibular system in patients with CGH. This study aims to investigate cervical proprioceptive inputs and the vestibular system in patients with CGH. It also aimed to examine whether abnormal proprioceptive or abnormal vestibular inputs are effective in the emergence of cervicogenic dizziness.

MATERIALS AND METHODS

Participants

This study was conducted on patients referred to the neurosurgery clinic who complained of neck pain and headaches for at least three months. Detailed anamnesis was taken from the patients, and according to the clinical examination and magnetic resonance imaging results, 30 patients who developed CGH due to neck problems that did not require surgery were included in the study. The duration of the patient's headache and neck pain symptoms was recorded. Twenty-five healthy individuals, similar to the patients in terms of age and gender, were included in the study as a control group. Participants were excluded if they had a traumatic neck injury/surgery, true vertigo (benign paroxysmal positional vertigo, vestibular neuritis or Meniere's disease), hearing loss (pure tone average >25 dB) neurological and uncontrollable systemic disease, visual impairment, and musculoskeletal injury/diseases that may affect balance.

Written and verbal consent was obtained from all individuals included in the study. Permission for the study was obtained from the Karabük University Non-invasive Ethics Committee (approval number: 2023/1464, date: 07.11.2023) and the hospital (approvel number: 2023/61), and the study was conducted by the Declaration of Helsinki.

All participants were referred to the hearing and balance clinic for evaluations. Otoscopic evaluation and pure tone audiometry test were applied to the participants, and their falls in the last year were asked and noted. Neck disability index (NDI), static posturography test, dizziness handicap inventory (DHI), head impulse test (HIT), cervical vestibular evoked myogenic potential (cVEMP), subjective visual vertical (SVV), and cervical joint position error test (CJPET) were applied to the participants.

Data Collection

Neck Pain and Headache

The severity of neck pain was evaluated with the Turkish version of the NDI[13]. The index consists of a total of 10 questions, and each question is scored between 0 and 5. An increase in the total index score indicates that the neck problem is increasing. CGH severity in individuals was evaluated with visual analog scale (VAS). The starting point of a 10 cm straight line drawn on paper was 0 (no CGH), and the ending was 10 (excessive CGH). Individuals were asked to mark the point on the line corresponding to the pain intensity. Headache scores were determined by measuring this point with a ruler.

Balance

The balance skills of the participants were evaluated with static posturography. The test was applied in 4 different situations with a Bertech (Bertech Corporation, Ohio, USA) force platform. These situations are as follows: eyes open firm surface, eyes closed firm surface, eyes open foam surface, and eyes closed foam surface. Participants were asked to get on the platform and stand in the desired position for 10 seconds without moving.

Participants' psychometric balance complaints were evaluated with the Turkish version of the DHI[14]. DHI consists of a total of 25 questions. The answers to the questions can be no (score: 0), sometimes (score: 2), and yes (score: 4). An increase in the total score means that the balance problem increases.

Cervical Proprioception

The participants' cervical proprioception sense was evaluated with CJPET. A (target) point was marked on the wall. A straight line was drawn 90 cm from the wall. Patients were asked to stand on the line and were fitted with a laser headband. Patients were asked to place the laser light on the target and close their eyes. Then, he was asked to turn his head left-right/up-down ten times (approximately 45 degrees) with his eyes closed. After his command was carried out, he was asked to guess the target. The distance between the estimated and the target was measured with tape. If the difference was >4.5°, cervical proprioception input was considered abnormal[15].

Vestibular System

The vestibular system was evaluated with HIT, SVV, and cVEMP. For HIT, the patient was asked to look at the clinician's nose, and the head was turned left and right unexpectedly. Observed overt saccades were noted.

The bucket test evaluated SVV. A white vertical line was drawn in the middle of a black bucket. The middle of the bucket was pierced, and a rope passed through the hole. A weight was attached to the end of the string, and a goniometer was attached to the back of the bucket. Participants were asked to look inside the bucket and position the white line vertically. The verticality angle of the line was measured from the back of the bucket.

Neuro-Audio (Neurosoft, Ivanovo, Russia, Version 1.0.104.1) auditory evoked potentials device was used for cVEMP. The test was performed with the patient in a sitting position. Electrode areas were cleaned with abrasive gel. It was obtained by placing the active electrode on the upper 1/3 of the SCM, the reference electrode on the sternoclavicular joint, and the ground electrode on the forehead. Electrode impedances were checked, and the <10-ohm requirement was met for all electrodes. Participants were asked to turn their necks contralateral to the recorded ear and maintain the level of muscle contraction in the desired region by looking at the computer screen. A 500 Hz tone burst stimulus at 100 dB was used in the test.

Beck Anxiety Inventory (BAI)

The Turkish version of the BAI was used to measure the anxiety symptoms level of the participants. The BAI is a 21-item questionnaire to reflect the severity of somatic and cognitive anxiety symptoms during the previous week. Items are scored on a 4-point scale (0-3), and the total score ranges from 0 to 63[16].

Statistical Analysis

IBM SPSS 21 (SPSS Chicago, IL, USA) program was used for statistical analysis. Shappiro-Wilk was used for normality testing. Normally distributed variables were evaluated with a t-test, One-Way analysis of variance, or Pearson's correlation test. The Mann-Whitney U, Kruskal-Wallis, or Spearman's correlation test evaluated variables that did not show normal distribution. Variables with normal distribution are presented as mean ± standard deviation, and variables that do not show normal distribution are presented as median (minimum-maximum). p<0.05 was accepted as the significance level in all statistical analyses.

RESULTS

In the CGH group, 21 (70.0%) of the patients were female, 9 (30.0%) were male, and the average age was 39.23±9.08 (18-52). 14 (56.0%) of the individuals in the control group were female, 11 (44.0%) were male, and the average age was 35.80±8.47 (22-50). There was no difference between the groups regarding age and gender (p=0.116, p=0.283, respectively).

The median headache duration of CGH patients was 30 (3-96) months, the average NDI score was 21.70±8.97, and the average headache severity (VAS) was 5.93±2.49.

Patients with CGH had more falls in the last year compared to the control group [p<0.05, odds ratio: 0.500 (0.379-0.660)]. 15 (50%) of CGH patients had dizziness symptoms compared to 1 (4%) of healthy individuals (p<0.001). There was no difference between the groups regarding eyes open firm surface, eyes closed firm surface, and eyes open foam surface balance scores (p>0.05). However, the eyes-closed foam surface balance score of the CGH group was worse than that of healthy individuals (p<0.05). Also, the DHI score of the CGH group was significantly higher or lower than that of healthy 160 individuals (p<0.05). Fall history, static posturography scores, and DHI scores according to groups are presented in Table 1. The CGH group had no relationship between NDI and DHI and eyes-closed foam surface balance score (p=0.561, p=0.239, respectively). However, there was a negative relationship between the eyes closed foam surface balance score and headache severity and headache duration (p=0.008, r=-0.35; p=0.025, r=-0.30, respectively); there was a positive relationship between DHI and headache severity and headache duration (p<0.001, r=0.62; p=0.002, r=0.40, respectively).

The CJPET score of the CGH group was worse than that of healthy individuals (p<0.05). CJPET score according to groups is presented in Figure 1. There was no relationship between CJPET and headache severity, duration, and NDI (p=0.200, p=0.083, p=0.274, respectively). The mean CJPET score of CGH patients with dizziness symptoms (n=15) was 9.50±6.93, and the CJPET mean score of CGH patients without dizziness symptoms was 4.86±3.67. The CJPET score of CGH patients with dizziness symptoms was worse (0.030) than that of CGH patients without dizziness symptoms.

The HIT result of individuals in both groups was normal. There was no difference in terms of SVV between the groups (p>0.05). In the CGH group, cVEMP could not be obtained unilaterally in 4 patients (13.3%) and bilaterally in 1 patient (3.3%). Bilateral cVEMP was obtained in all participants in the control group. Abnormal cVEMP in the CGH group was higher than in the control group (p=0.041). The cVEMP result of 2 (13.3%) of the CGH patients (n=15) with dizziness symptoms was abnormal, and the cVEMP result of 3 (20%) of the CGH patients without dizziness symptoms was abnormal. There was no difference in terms of cVEMP between CGH patients with and without symptoms of dizziness (p=0.500). There was no difference between the groups regarding normally obtained VEMP latency, amplitude, and asymmetry rate (p>0.05). SVV, VEMP latency, amplitude, and asymmetry rate according to groups are

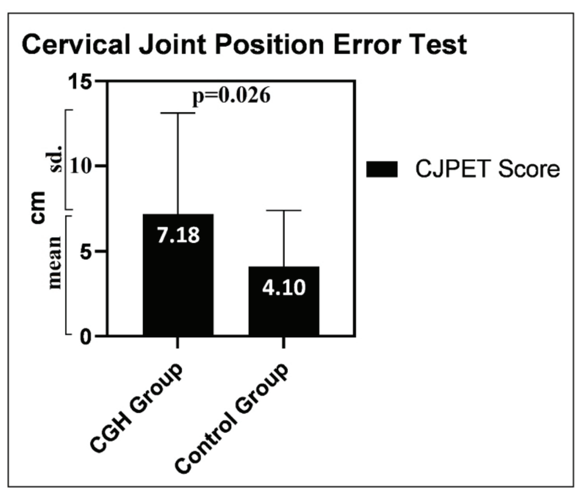

Figure 1. Comparison of cervical joint position error test score according to groups

CJPET: Cervical joint position error test, CGH: Cervicogenic headache

Table 1. Comparison of falls, static posturography and DHI scores according to groups

	CGH group (n=30)	Control group (n=25)	p-value
Falls, n	5 (%16.7)	0 (0.0%)	0.041[a]
Firm surface-eyes open	92.5 (77.8-96.8)	92.9 (74.5-95.9)	0.660[b]
Firm surface-eyes closed	90.4 (43.5-96.7)	91.0 (81.1-95.6)	0.504[b]
Foam surface-eyes open	88.3 (75.1-92.5)	89.4 (62.5-96.2)	0.735[b]
Foam surface-eyes closed	90.9±6.0	85.8 (58.0-92.1)	0.020[b]
DHI	2 (0-86)	0 (0-12)	<0.001[b]

[a]: Fisher's exact test, [b]: Mann-Whitney U test, DHI: Dizziness handicap Inventory, CGH: Cervicogenic headache

Table 2. Comparison of SVV, VEMP latency, amplitude, and asymmetry rate according to groups

	CGH group (n=30)	Control group (n=25)	p-value
SVV, cm	0.0 (-3.0-3.5)	0.0 (-1.0-1.0)	0.558[a]
Asymmetry ratio, %	1.81±18.92	-4.74±18.75	0.305[b]
Right ear			
P1, msec.	14.62±1.11	14.40 (11.20-15.90)	0.754[a]
N1, msec.	21.70 (19.20-25.00)	22.30 (19.30-24.60)	0.095[a]
Amplitude, μV	90.20 (75.00-114.20)	92.80 (76.20-109.20)	0.145[a]
Left ear			
P1, msec.	15.50 (13.00-15.90)	15.00 (13.10-15.80)	0.455[a]
N1, msec.	22.47±1.85	22.40 (19.10-25.70)	0.985[a]
Amplitude, μV	90.50 (44.20-110.40)	90.60 (80.00-99.60)	0.685[a]

[a]: Mann-Whitney U test, [b]: Student's t-test, SVV: Subjective visual vertical, msec.: Millisecond, CGH: Cervicogenic headache, VEMP: Vestibular-evoked myogenic potentials

presented in Table 2.

The BAI scores of the CGH and control groups were 11.10±4.52 and 5.68±2.39, respectively. The mean BAI of the CGH group was statistically higher than the control (p<0.01).

DISCUSSION

The first aim of this study is to investigate cervical proprioceptive inputs and vestibular systems in patients with CGH. The second is to investigate whether abnormal proprioceptive or vestibular inputs are effective in developing dizziness symptoms (cervicogenic dizziness) in patients with CGH. This study showed that patients with CGH had worse postural balance and more abnormal vestibular and proprioceptive inputs than healthy individuals. This study showed that patients with CGH had worse postural balance, more abnormal vestibular and proprioceptive inputs and higher levels of depression than healthy individuals.

Individuals with cervical disorders such as flattening of cervical lordosis or cervical disc herniation may develop imbalance (or dizziness), disorientation, neck pain, limited cervical range of motion, and CGH. Although the mechanism of CGH and neck pain is well known, the mechanism of cervicogenic dizziness is not fully known. It is thought that faulty afferent proprioceptive inputs from the upper cervical region cause incorrect depiction of head and neck orientation in space and cause dizziness[17]. It has been stated that another factor may be pain[18]. Neck pain can cause maladaptive strategies and alter neck muscle coordination. Additionally, neck pain may change the cortical representation and modulation of cervical afferent input[19]. It has been stated that these patients (patients with neck pain and CGH) successfully maintain balance on hard surfaces but have difficulty in difficult conditions[10]. Sremakaew et al.[10] investigated the balance skills of patients with CGH and reported that the balance skills of these patients were worse. It has also been reported that patients with CGH have increased anterior-posterior sway, and they attributed this to faulty cervical proprioceptive input[10]. Similarly, patients with CGH were included in this study. Consistent with the literature, the CGH group's balance skills in challenging static conditions were worse than the asymptomatic group. Also, patients with CGH had a higher risk of falling. In maintaining balance on the foam surface with eyes closed, proprioceptive input is reduced, and visual input is prevented. To maintain balance, reduced proprioceptive inputs must be provided correctly, and the vestibular system must be intact. Therefore, the reason why patients with CGH cannot maintain balance with eyes closed on the foam surface may be abnormal cervical inputs and vestibular abnormalities. In our study, there was no relationship between the eyes-closed balance score and NDI on the foam surface. However, there was a relationship between CGH intensity and duration and DHI and eyes-closed balance score on the foam surface. This shows that as the severity of headaches increases, the perception of psychometric dizziness and postural instability increases. This relationship between headache and balance supports the hypothesis that cervicogenic dizziness may occur due to pain.

Proprioceptive inputs, defined as awareness of the sense of joint position and joint movement, are one of the primary systems that provide balance. To maintain balance, proprioceptive input is relied on by 70%, visual input by 10%, and vestibular input by 20% on hard ground[20]. Therefore, proprioceptive input is the most important input for balance. Impairment of cervical proprioception due to cervical pathology and pain is an expected situation in patients with CGH. The results of this study support this finding. Our study's main finding is that patients reporting cervicogenic dizziness have more impaired cervical proprioceptive input. Therefore, our study supports the hypothesis that cervicogenic dizziness occurs due to faulty cervical proprioceptive input.

The medial vestibulospinal reflex, which terminates in the motor neurons of the sternocleidomastoid muscle (SCM), originates from the saccule, and extends to the vestibular nuclei via the inferior vestibular nerve[21]. High-intensity sound stimulates the saccule, and this stimulus is recorded from the medial vestibulospinal tract and SCM in the cVEMP test. Therefore, neck problems can affect saccule function and cVEMP testing. Shi et al.[12] investigated cVEMP findings in patients with cervical vertigo. As a result, it has been reported that patients with cervical vertigo have more abnormal cVEMP responses than healthy individuals, and as the severity of cervical vertigo increases, the abnormal cVEMP response also increases[12]. In this study, patients with CGH had more abnormal cVEMP responses than healthy individuals. However, unlike the study by Shi et al.[12] there was no difference in terms of cVEMP findings between CGH patients with and without cervicogenic dizziness. This finding indicates that the vestibular system (cVEMP) is affected in patients with CGH, but abnormal cVEMP responses do not produce dizziness symptoms. The vestibular system has a compensation mechanism, and acutely developing vestibular pathologies heal spontaneously over time[22]. In slowly developing pathologies, patients may not feel any vestibular symptoms. Therefore, abnormal vestibular system function in patients with CGH may not have caused symptoms of dizziness. On the other hand, even if vestibular compensation develops in these patients, they may experience loss of balance, especially under challenging conditions such as complex visual stimuli (optokinetic)[23]. Therefore, even if cVEMPs do not affect the occurrence of dizziness symptoms in patients with CGH, abnormal vestibular functions may pose a fall risk for patients, especially in challenging conditions. Falls can cause fatal fractures and injuries, permanent disabilities, and fear of falling in individuals. Therefore, balance and vestibular exercises can be added to cervical region rehabilitation to reduce the risk of falling and improve the quality of life in patients with neck pain and CGH.

Causes of CGH include neck muscle tension, spinal disc problems, and joint dysfunction[24]. Increased anxiety levels can also contribute to an increase in headaches. Previous studies have shown that high anxiety levels can cause CGH to occur more frequently and more intensely[24]. This can also affect individuals' daily life activities and result in increased disability symptoms. This study also showed that patients with CGHs have higher depression levels, parallel to the literature. Therefore, it is important to evaluate the relationship between CGH and depression, which are bidirectionally related, during the clinical follow-up process[25].

CONCLUSION

The results show that there are abnormalities in both cervical proprioceptive inputs and vestibular inputs in patients with CGH. Therefore, patients with CGH have a higher risk of falling than asymptomatic individuals. However, it has been determined that only cervical proprioceptive inputs play a role in the cervicogenic dizziness mechanism. Therefore, evaluating these systems in patients with CGH and applying appropriate rehabilitative approaches is important.

Ethics

Ethics Committee Approval: Permission for the study was obtained from the Karabük University Non-invasive Ethics Committee (approval number: 2023/1464, date: 07.11.2023) and the hospital (approvel number: 2023/61), and the study was conducted by the Declaration of Helsinki.

Informed Consent: Written and verbal consent was obtained from all individuals included in the study.

Authorship Contributions

Surgical and Medical Practices: A.S.A., E.S., Concept: A.S.A., E.S., M.G., T.G.S., Z.K.A., Design: A.S.A., E.S., T.G.S., Z.K.A., Data Collection or Processing: A.S.A., M.G., Analysis or Interpretation: A.S.A., T.G.S., Z.K.A., Literature Search: A.S.A., E.S., M.G., T.G.S., Z.K.A., Writing: A.S.A., E.S., M.G., T.G.S.

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REFERENCES

1. Jull G. Management of cervical headache. Man Ther. 1997;2:182-90.
2. Bogduk N, Govind J. Cervicogenic headache: an assessment of the evidence on clinical diagnosis, invasive tests, and treatment. Lancet Neurol. 2009;8:959-68.
3. Verma S, Tripathi M, Chandra PS. Cervicogenic headache: current perspectives. Neurol India. 2021;69:S194-8.
4. Ünlüer NÖ, Ateş Y. An investigation of neck pain in older adults, and its relation with shoulder position sense and upper extremity function. Somatosens Mot Res. 2021;38:333-8.
5. Ortego G, Villafañe JH, Doménech-García V, Berjano P, Bertozzi L, Herrero P. Is there a relationship between psychological stress or anxiety and chronic nonspecific neck-arm pain in adults? A systematic review and meta-analysis. J Psychosom Res. 2016;90:70-81.

6. Cuenca-Martínez F, Bartrina-Rodríguez I, Suso-Martí L, La Touche R, Ferrer-Peña R. Association between somatosensory, motor and psychological variables by levels of disability in patients with cervicogenic dizziness. Somatosens Mot Res. 2018;35:247-52.
7. Banks RW. An allometric analysis of the number of muscle spindles in mammalian skeletal muscles. J Anat. 2006;208:753-68.
8. Kulkarni V, Chandy MJ, Babu KS. Quantitative study of muscle spindles in suboccipital muscles of human foetuses. Neurol India. 2001;49:355-9.
9. Liu JX, Thornell LE, Pedrosa-Domellöf F. Muscle spindles in the deep muscles of the human neck: A morphological and immunocytochemical study. J Histochem Cytochem. 2003;51:175-86.
10. Sremakaew M, Sungkarat S, Treleaven J, Uthaikhup S. Impaired Standing Balance in Individuals with Cervicogenic Headache and Migraine. J Oral Facial Pain Headache. 2018;32:321-8.
11. MacKinnon CD. Sensorimotor anatomy of gait, balance, and falls. Handb Clin Neurol. 2018;159:3-26.
12. Shi F, Song WH, Liu CW, Liang KH, Ma RJ, Wang ZA. [Correlation between cervical vertigo and vestibular function evaluated by vestibular evoked myogenic potentials]. Zhongguo Gu Shang. 2022;35:148-52.
13. Kesiktas N, Ozcan E, Vernon H. Clinimetric properties of the Turkish translation of a modified neck disability index. BMC Musculoskelet Disord. 2012;13:25.
14. Canbal M, Cebeci S, Duyan GÇ, Kurtaran H, Arslan I. A study of reliability and validity for the Turkish version of dizziness handicap inventory. TJFM&PC. 2016;10:19-24.
15. Quartey J, Ernst M, Bello A, Oppong-Yeboah B, Bonney E, Acquaah K, et al. Comparative joint position error in patients with non-specific neck disorders and asymptomatic age-matched individuals. S Afr J Physiother. 2019;75:568.
16. Ulusoy M, Şahin NH, Erkmen H. Turkish version of the Beck anxiety inventory: psychometric properties. J Cogn Psychother. 1998;12:163-72.
17. Kristjansson E, Treleaven J. Sensorimotor function and dizziness in neck pain: implications for assessment and management. J Orthop Sports Phys Ther. 2009;39:364-77.
18. Morinaka S. Musculoskeletal diseases as a causal factor of cervical vertigo. Auris Nasus Larynx. 2009;36:649-54.
19. Treleaven J. Sensorimotor disturbances in neck disorders affecting postural stability, head and eye movement control. Man Ther. 2008;13:2-11.
20. Horak FB. Postural orientation and equilibrium: what do we need to know about neural control of balance to prevent falls? Age Ageing. 2006;35 Suppl 2:ii7-11.
21. Colebatch JG, Halmagyi GM. Vestibular evoked potentials in human neck muscles before and after unilateral vestibular deafferentation. Neurology. 1992;42:1635-6.
22. Lacour M, Helmchen C, Vidal PP. Vestibular compensation: the neuro-otologist's best friend. J Neurol. 2016;263 Suppl 1:S54-64.
23. Lacour M, Tardivet L, Thiry A. Posture deficits and recovery after unilateral vestibular loss: early rehabilitation and degree of hypofunction matter. Front Hum Neurosci. 2022;15:776970.
24. Jull G, Trott P, Potter H, Zito G, Niere K, Shirley D, et al. A randomized controlled trial of exercise and manipulative therapy for cervicogenic headache. Spine (Phila Pa 1976). 2002;27:1835-43.
25. Farina S, Granella F, Malferrari G, Manzoni G. Headache and neck pain: Chronic cervicogenic headache. Headache: The Journal of Head and Face Pain. 2004;44:732-8.