ISSN: 2651-4451 • e-ISSN: 2651-446X

Turkish Journal of Physiotherapy and Rehabilitation

2024 35(1)90-96

Hayriye YILMAZ, PT, MSc[1]
Gulsah OZSOY, PT, PhD[2*]
Mehmet Gürhan KARAKAYA, PT, PhD[3]

1 *İzmir Bozyaka Education and Research Hospital, Izmir, Turkey*
2 *Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Selcuk University, Konya, Turkey*
3 *Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Mugla Sıtkı Kocman University, Mugla, Turkey*

Correspondence (İletişim):

Gulsah OZSOY
Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Selcuk University, Konya, Turkey
fzt.gulsah@hotmail.com
ORCID: 0000-0001-5678-771X

Hayriye YILMAZ
E-mail: fzthayriyeyilmaz@yahoo.com
ORCID ID: 0000-0002-1151-7190

Mehmet Gürhan KARAKAYA
E-mail: karakaya70@yahoo.com
ORCID ID: 0000-0002-2395-649X

Received: *22.08.2022 (Geliş Tarihi)*
Accepted: *21.10.2023 (Kabul Tarihi)*

BALANCE PERFORMANCE IN DUAL TASK IN PATIENTS WITH CERVICAL DISC HERNIATION RELATED CHRONIC NECK PAIN: A COMPARATIVE STUDY

ORIGINAL ARTICLE

ABSTRACT

Purpose: The aim of the study was to compare balance performance in dual task between patients with cervical disc herniation (CDH) related chronic neck pain and asymptomatic controls.

Methods: Thirty-two patients with CDH related chronic neck pain and twenty-three age and sex-matched asymptomatic controls participated in this cross-sectional controlled study. The modified clinical test of sensory integration of balance (mCTSIB), athletic single leg test (ASLT), limits of stability (LOS), and fall risk assessment were performed with and without a cognitive task. Dual task interference (DTI) was assessed.

Results: According to our findings, the change in the mCTSIB values (except standing with eyes closed on a firm surface) and fall risk scores was greater in the CDH group compared to the control group ($p<0.05$). Additionally, the DTI of the mCTSIB values (except standing with eyes closed on a firm surface) and fall risk scores were higher in the CDH group than in the control group ($p < 0.05$).

Conclusions: The results of study suggest that patients with CDH related chronic neck pain have poorer postural control and increased fall risk under dual task conditions. Patients with CDH related chronic neck pain should participate in rehabilitation program to increase balance and postural control.

Key Words: Balance, Cervical Disc Herniation, Disability, Dual-Task, Postural Control

SERVİKAL DİSK HERNİASYONUYLA İLİŞKİLİ KRONİK BOYUN AĞRISI OLAN HASTALARDA İKİLİ GÖREVDE DENGE PERFORMANSI: KARŞILAŞTIRMALI BİR ÇALIŞMA

ARAŞTIRMA MAKALESİ

ÖZ

Amaç: Çalışmanın amacı, servikal disk herniasyonu (SDH) ile ilişkili kronik boyun ağrısı olan hastalar ve asemptomatik kontroller arasındaki ikili görevdeki denge performansını karşılaştırmaktı.

Yöntem: Bu kesitsel kontrollü çalışmaya SDH ile ilişkili kronik boyun ağrısı olan otuz iki hasta ve yaş/cinsiyet uyumlu yirmi üç asemptomatik kontrol katıldı. Modifiye Klinik Duyu Entegrasyon Testi (mKDET), atletik tek bacak testi (ATBT), stabilite limitleri (SL) ve düşme riski değerlendirmesi, bilişsel bir görevle ve bu görev olmadan gerçekleştirildi. İkili görev etkileşimi (İGE) değerlendirildi.

Sonuçlar: Bulgularımıza göre mKDET değerlerindeki değişim (gözler kapalı olarak sert bir zeminde ayakta durma dışında) ve düşme risk skorlarındaki değişim SDH grubunda kontrol grubuna göre daha fazlaydı ($p<0,05$). Ek olarak, mKDET değerlerinin İGE 'si (gözler kapalı bir zeminde ayakta durmak hariç) ve düşme riski skorları SDH grubunda kontrol grubuna göre daha yüksekti ($p <0,05$).

Tartışma: Çalışmanın sonuçları, SDH ile ilişkili kronik boyun ağrısı olan hastaların, ikili görev koşulları altında daha zayıf postüral kontrole ve artan düşme riskine sahip olduğunu göstermektedir. SDH ile ilişkili kronik boyun ağrısı olan hastalar denge ve postüral kontrolü artırmak için rehabilitasyon programına katılmalıdır.

Anahtar Kelimeler: Denge, Servikal Disk Hernisi, Özürlülük, İkili Görev, Postüral Kontrol

INTRODUCTION

Dual-task is defined as doing more than one task at a time, and fail of this one or more simultaneous tasks is called as dual task interference (DTI) (1). The frontal lobe is responsible for higher cognitive functions such as memory, motor function, problem solving, and dual-tasking (2). Dysfunction of the frontal lobe may result in a consequent reduction in attentional capacity and this is thought to be the neurological background of DTI. (3). Therefore, in conditions such as aging and neurological diseases, DTI increases (1, 4). Chronic pain is another condition which is related with cognitive impairments and alters the structure of the brain, especially the frontal lobe (5, 6). Therefore, chronic pain may also increase the DTI (7).

Higher DTI during postural control increases risk of falls, disability and death (8, 9), and therefore, it is important to determine the effects of pain related disability on dual task performance. Intense pain and moderate disability are seen most patients with symptomatic cervical disc herniation (CDH) (10). Since neck pain and disability affect negatively neck motion and motor control (11), it is highly likely that patients with neck pain related disability would display DTI during postural control with a cognitive task. In addition, the cervical region, its rich proprioceptive content, the cervical afferents that form the basis of the vestibular reflex, and the visual sense perception associated with neck movements, affect all three mechanisms that are effective in providing postural control (12). A problem which might arise in cervical region can be lead to significant postural instability and fear of falling (13). Additionally, it is demonstrated that patients with neck pain have altered spatiotemporal parameters and neck and trunk kinematics during walking while performing concurrent head movements (14, 15).

As mentioned above, it is seen that the effects of neck pain and dual task are mostly emphasized. To the best our knowledge, there is no study directly investigating the relationship between CDH and dual task in the literature. However, CDH is a frequent reason for neck pain in adults (16). It is very important for patients with CDH to perform more than one task at the same time for many activities of daily living. However, considering the disruptions seen even in single tasks due to postural instability, it is possible that problems may arise in performing dual-task focused activities. Therefore, the aim of this study was to compare balance performance in dual task between patients with CDH related chronic neck pain and asymptomatic controls.

METHODS

Study design and participants

This study was designed cross-sectional controlled study (ClinicalTrials.gov Identifier: NCT05338788). Thirty-two patients with CDH related chronic neck pain and twenty-three age and sex-matched asymptomatic controls participated in this study.

Patients who aged 20–50 years, had neck pain for at least 12 weeks, having disc prolapse with neck pain symptom between C3 and C7, pathology confirmed by magnetic resonance imaging, no disease other than CDH that might affect balance, no vertebrobasilar insufficiency, no tumour, trauma, fracture pathology in the spinal region and no history of spine surgery were included. People with cognitive, orthopaedic or neurological diseases that could negatively affect the evaluations were excluded. Age- and sex-matched asymptomatic controls without any known disease diagnosis and health problems that would affect the evaluations were included.

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study protocol was approved by the local ethics committee of Izmir Bozyaka Education and Research Hospital (Report number and date = 08 and 08.05.2019). Informed consent was obtained from all participants included in the study.

Data collection

The Neck Disability Index (NDI): The patients' self-reported neck pain related disability was assessed with the NDI. It assesses the level of neck pain related disability during activities of daily liv-

ing. The NDI is 10-item questionnaire and evaluated between 0 and 50 points. Increasing score is associated with increased disability (17, 18).

The Biodex Balance System (BBS; Biodex Medical Systems, Shirley, New York, USA) was used to assess postural control. This system allows individuals to measure their stability limits. It also examines the control of the center of gravity on the support surface and balance abilities when trying to move it. The evaluated parameters of this system are presented below:

-The modified Clinical Test of Sensory Integration of Balance (mCTSIB): The mCTSIB was used to assess individuals' capability to use sensory inputs for balance. Four conditions (standing with eyes open or closed on a firm or foam surface) were assessed. An increasing score indicates impaired postural control (19).

-Athletic Single Leg Test (ASLT): The evaluation was made with eyes open and closed on one leg (dominant limb) on a firm floor on the balance device platform. Each test lasted 10 seconds and with 3 repetitions. The average of 3 measurements was recorded as the 'Athletic Single Leg Test' score. As the score increases, the balance deteriorates (20).

-Limits of Stability (LOS): This test is the best test that measures dynamic control among the standard sway tests. It is a test with a total of nine goals by standing on the platform and hitting the targets in one centre and eight different directions on the screen (21). As the score increases, dynamic control deteriorates.

-Fall risk assessment: The pre-test platform level was adjusted so that the starting position was 12 and the ending position was 8. A test protocol was created, consisting of three tests (20 seconds each) for a total of 60 seconds, and a 10-second rest period was given between each test. The mean of these three tests was accepted as the fall risk index score. The higher the score is associated with the higher the risk of falling (22).

Measurement procedure

In order to avoid the order bias of postural control measurements during "Single-task" and "Dual-task" for each case, the order of the measurements was determined by randomization on the first day by using sealed envelope method. After single/double task randomization was made, the order of tests was also randomized by using sealed envelopes containing two different orders (1-mCTSIB, 2-ASLT, 3-Fall test, 4-LOS and 1- LOS, 2- Fall test, 3- ASLT, 4-mCTSIB).

Before starting the evaluations, the participants were informed about the tests. Considering methodological bias, the same investigator performed all assessments and all participants received standardized and identical instructions.

Single and dual task measurements were made as follows:

Single task measurements involved the measurement of balance parameters by using Biodex Balance System without any additional cognitive task. For assessment of dual task performance, the participants were asked to perform an additional cognitive task (counting backwards from 200 by three or seven) during measurements (23).

DTI values were calculated for all balance parameters using the formulas below (24):

DTI %= (Dual Task-Single Task)/Single Task*100

Sample size

A previous study has shown that the balance is disturbed with dual task ($p<0.05$) (25). Based on the findings of that study, the minimum required sample size for an analysis was calculated as 31 participants for the probability level of 0.05; the anticipated effect size as 0.458; and a statistical power level of 80% when using G*Power Software (version 3.1.9.2).

Data analysis

The data was analysed by using the IBM® SPSS® Statistics for Windows software (ver. 22.0; IBM Corp., NY, USA). Shapiro–Wilk test and histograms were used to check normality. To compare the independent groups, independent samples t-test, Mann-Whitney U Test or chi-square test were used. The paired sample t-test was used to assess the mean difference between single and dual tasks within the groups. Two-way repeated measures analysis of variance was used to compare 'condition' and 'group*condition' interaction between the groups.

Table 1. Characteristics of the Participants

	CDH Group (n =32)	Asymptomatic Group (n=23)	p
Age (year)	41.09±5.68	39.61±3.60	0.275[a]
Gender (Female, n (%))	19 (59.4)	12 (52.2)	0.595[b]
Height (cm)	168.69±9.24	172.48±9.46	0.143[a]
Weight (kg)	75.09±13.10	70.30±11.47	0.165[a]
Body mass index (kg/m²)	26.35±3.94	23.52±2.39	0.004[a]
Neck Disability Index	12.88±4.77		
Cervical pain duration (months)	36.00 (12.00-72.00)		
Disc herniation level			
One level disc herniation (n (%))	16 (50.0)		
Two level disc herniation (n (%))	15 (46.9)		
Three level disc herniation (n (%))	1 (3.1)		
Disc herniation stages			
Bulging (n (%))	8 (25.0)		
Protrusion (n (%))	15 (49.6)		
Bulging+ Protrusion (n (%))	9 (28.1)		

a: Student t Test, b: Chi-square Test.
Values are expressed as mean±standard deviation for continuous variables and 'n' were reported for categorical variables.

RESULTS

Based on the data obtained from thirty-two patients with CDH related chronic neck pain (59.4 % female) and twenty-three controls (52.2 % female) were analysed. The demographic characteristics (age, sex, height, weight) except body mass index of the two groups were similar (p > 0.05, Table 1). The clinic characteristics (neck disability level, cervical pain duration, disc herniation level, disc herni-

Table 2. Comparison of Outcomes

Outcome Measures	CDH Group (n =32)		p[1]	Asymptomatic Group (n=23)		p[1]	p[2]	
	Single Task	Dual Task		Single Task	Dual Task		Condition	Group* Condition
mCTSIB								
EO-Firm sway index (score)	0.47±0.13	0.70±0.20	**<0.001**	0.54±0.12	0.58±0.17	0.265	**<0.001 (0.215)**	**0.009 (0.121)**
EC-Firm sway index (score)	0.70±0.20	0.81±0.27	0.065	0.83±0.36	0.91±0.29	0.224	**0.034 (0.082)**	0.654 (0.004)
EO-Foam sway index (score)	0.68±0.20	1.06±0.36	**<0.001**	0.87±0.48	0.93±0.26	0.618	**0.002 (0.169)**	**0.023 (0.094)**
EC-Foam sway index (score)	1.35±0.47	1.66±0.45	**0.003**	1.82±0.26	1.85±0.21	0.727	**0.013 (0.111)**	**0.034 (0.082)**
ASLT								
Overall (score)	0.78±0.23	0.94±0.47	0.051	0.62±0.15	0.66±0.19	0.291	**0.046 (0.073)**	0.261 (0.024)
AP (score)	0.50±0.14	0.64±0.39	0.065	0.47±0.15	0.50±0.12	0.295	0.059 (0.066)	0.261 (0.024)
ML (score)	0.50±0.23	0.57±0.26	0.183	0.45±0.12	0.46±0.11	0.517	0.182 (0.033)	0.424 (0.012)
LOS								
Overall (score)	44.13±9.04	46.50±12.07	0.263	42.74±8.77	44.87±7.07	0.225	0.120 (0.045)	0.932 (< 0.001)
Time (sn)	47.66±8.81	49.47±13.09	0.367	53.35±11.28	54.61±6.76	0.534	0.292 (0.021)	0.849 (0.001)
Fall risk assessment								
Fall risk (score)	1.30±0.33	1.71±0.36	**<0.001**	1.43±0.45	1.49±0.35	0.570	**<0.001 (0.220)**	**0.006 (0.136)**

mCTSIB: Modified Clinical Test for Sensory Integration of Balance, ASLT: Athletic Single Leg Test, AP: Anteroposterior, ML: mediolateral, EO: Eyes open, EC: Eyes closed, Firm: Firm surface, Foam: Foam surface, LOS: Limits of Stability.
Note: p1, paired sample t-test; p2, two-way repeated measures analysis of variance. Values are expressed as mean ± standard deviation. Figures in parentheses are effect sizes.

Table 3. Comparison of Dual-Task Interference

	CDH Group (n =32)	Asymptomatic Group (n=23)	p
mCTSIB			
DTI EO-Firm sway index %	39.95 (0.39-80.44)	5.55 (-11.76-14.03)	**0.007**
DTI EC-Firm sway index %	19.64 (-9.01-54.22)	8.75 (-10.71-42.85)	0.726
DTI EO-Foam sway index %	54.88 (12.57-91.64)	27.58 (0.00-61.76)	**0.022**
DTI EC-Foam sway index %	18.12 (-2.01-58.86)	2.23 (-6.63-11.79)	**0.024**
ASLT			
DTI Overall %	18.33 (-12.15-48.21)	0.00 (-16.66-20.00)	0.146
DTI AP %	0.00 (-20.00-75.00)	0.00 (-12.50-25.00)	0.869
DTI ML %	22.50 (0.00-44.09)	0.00 (-14.28-25.00)	0.199
LOS			
DTI Overall %	3.08 (-14.45-20.78)	3.70 (-4.25-10.86)	0.865
DTI Time %	0.34 (-12.79-12.54)	3.50 (-10.76-13.33)	0.959
Fall risk assessment			
DTI Fall risk %	26.78 (1.92-55.82)	10.00 (-9.52-25.00)	**0.019**

mCTSIB: Modified Clinical Test for Sensory Integration of Balance, ASLT: Athletic Single Leg Test, AP: Anterior-posterior, ML: mediolateral, EO: Eyes open, EC: Eyes closed, Firm: Firm surface, Foam: Foam surface, LOS: Limits of Stability.
Note: Mann-Whitney U Test Values are expressed as median (25-75 quartiles)

ation stages) of the patients are presented in Table 1.

According to our findings, the change in the mCTSIB values (except standing with eyes closed on a firm surface) and fall risk scores was less than in the control group compared to the CDH group ($p<0.05$, Table 2). Additionally, the ASLT and the LOS scores were similar between the groups (group × condition interactions) ($p>0.05$, Table 2).

The DTI of the mCTSIB values (except standing with eyes closed on a firm surface) and fall risk scores were higher in the CDH group than in the control group ($p < 0.05$, Table 3). There was no significant difference in DTI in the ASLT and the LOS tests between the two groups ($p>0.05$, Table 3).

DISCUSSION

The primary finding of the study reported that the impairment in postural control performance and increased risk of falling throughout dual task was more prominent in patients with CDH related chronic neck pain than in asymptomatic controls.

Postural control is of vital importance for the maintenance of activities of daily living (26). It has been reported that deterioration in postural control is increased in patients with chronic neck pain compared to healthy individuals (27). The postural control problems increase risk of fall and mortality (28). Also, a previous review noted the negative effects of dual tasks on postural stability (9). The DTI is a consequences of frontal lobe dysfunction (2). Additionally, chronic pain alters the structure of the brain especially frontal lobe (6). Hamacher et al. showed that chronic pain increases the DTI by decreasing motor-cognitive dual-task performance capacity (7). A previous study has shown that patients with chronic neck pain have more severe impairments in postural control of different sensory and dual-task conditions. (14). A systematic review postulated that neck proprioception is deteriorated in people with neck pain compared to healthy controls (29). Neck pain has been shown to impair input from cervical mechanoreceptors and it has been claimed that impaired cervical input may be the reason for poorer balance in people with neck pain (29, 30). When the studies in the literature are examined, it is seen that the effects of neck pain and dual task are mostly emphasized. To the best our knowledge, there is no study directly investigating the relationship between CDH and dual task in the literature. As you know, cervical

disc herniation is a frequent reason for neck pain in adults (16). Our study suggests that patients with CDH related chronic neck pain have poorer postural control under concurrent dual tasks condition. All the three mechanisms which are influential in maintaining postural control are influenced by the cervical region, its rich proprioceptive content, the cervical afferents which create the basis of the vestibular reflex, and the perception of visual sense linked with neck movements (12). Additionally, chronic pain which alters the structure of the brain, especially the frontal lobe, increase the DTI (5). For these reasons, a situation that will affect the cervical region such as pain can explain cause of deterioration of postural control during dual task conditions in patients with CDH.

Dual-task testing is a widely used method of evaluating the relationship between cognition and mobility. Additionally, the DTI is associated with future fall risk, and this association is stronger than that for single-task conditions (31). Chronic pain has been shown to decrease the ability to complete motor-cognitive dual tasks. These effects are generated by central mechanisms in which pain impairs executive functioning, potentially increasing the chance of falling (7). Additionally, dual-task measures were more predictive of falls than single-task measures (32). The gap in performance between dual-task and single-task walking trials has been shown to be important to discriminate between falls (33). Our study suggests that patients with CDH related chronic neck pain have increased fall risk compared controls under concurrent dual tasks condition.

This study had some limitations. First, the patients with cervical disc herniation related chronic neck pain had mild neck pain related disability (NDI score=12.88±4.77). The results may be different, especially in patients with high disability due to neck pain. Second, this study had a cross-sectional design. Making inferences concerning the causality relationship among the variables is impossible due to the study's cross-sectional design. Third, only motor effects were evaluated with the cognitive task given as dual task in our study. However, in these patients, cognitive impairment may be observed in addition to motor impairment during the dual task. Future studies can be conducted with a design to evaluate both impairments.

The results of study suggest that patients with CDH related chronic neck pain have poorer postural control and increased fall risk under dual task conditions. Patients with CDH related chronic neck pain should participate in rehabilitation program to increase balance and postural control.

Sources of support: None

Conflict of Interest: No potential conflict of interest was reported by the authors.

Author Contributions: HY: Conceptualization, Methodology, Investigation, Writing-Original draft preparation, Visualization. GO: Conceptualization, Methodology, Formal Analysis, Writing-Original draft preparation, Visualization. MGK: Conceptualization, Methodology, Writing- Reviewing and Editing, Project administration, Supervision.

Explanations: This study has been never presented or published in a scientific platform.

Acknowledgments: Authors thank the participants.

REFERENCES

1. Smith E, Cusack T, Cunningham C, Blake C. The Influence of a Cognitive Dual Task on the Gait Parameters of Healthy Older Adults: A Systematic Review and Meta-Analysis. J Aging Phys Act. 2017;25(4):671-86.
2. Fuster JM. Frontal lobe and cognitive development. J Neurocytol. 2002;31(3-5):373-85.
3. Al-Yahya E, Dawes H, Smith L, Dennis A, Howells K, Cockburn J. Cognitive motor interference while walking: a systematic review and meta-analysis. Neurosci Biobehav Rev. 2011;35(3):715-28.
4. Kahya M, Moon S, Ranchet M, Vukas RR, Lyons KE, Pahwa R, et al. Brain activity during dual task gait and balance in aging and age-related neurodegenerative conditions: A systematic review. Exp Gerontol. 2019;128:110756.
5. Spindler M, Koch K, Borisov E, Özyurt J, Sörös P, Thiel C, et al. The Influence of Chronic Pain and Cognitive Function on Spatial-Numerical Processing. Front Behav Neurosci. 2018;12:165.
6. May A. Chronic pain alters the structure of the brain. Schmerz. 2009;23(6):569-75.
7. Hamacher D, Hamacher D, Schega L. A cognitive dual task affects gait variability in patients suffering from chronic low back pain. Exp Brain Res. 2014;232(11):3509-13.
8. Kressig RW, Herrmann FR, Grandjean R, Michel JP, Beauchet O. Gait variability while dual-tasking: fall predictor in older inpatients? Aging Clin Exp Res. 2008;20(2):123-30.
9. Ghai S, Ghai I, Effenberg AO. Effects of dual tasks and dual-task training on postural stability: a systematic review and meta-analysis. Clin Interv Aging. 2017;12:557-77.
10. Wong JJ, Côté P, Quesnele JJ, Stern PJ, Mior SA. The course and prognostic factors of symptomatic cervical disc herniation with radiculopathy: a systematic review of the literature. Spine J. 2014;14(8):1781-89.
11. Meisingset I, Stensdotter AK, Woodhouse A, Vasseljen O. Neck

motion, motor control, pain and disability: A longitudinal study of associations in neck pain patients in physiotherapy treatment. Man Ther. 2016;22:94-100.
12. Kristjansson E, Treleaven J. Sensorimotor function and dizziness in neck pain: implications for assessment and management. J Orthop Sports Phys Ther. 2009;39(5):364-77.
13. Franchignoni F, Horak F, Godi M, Nardone A, Giordano A. Using psychometric techniques to improve the Balance Evaluation Systems Test: the mini-BESTest. J Rehabil Med. 2010;42(4):323-31.
14. Kirmizi M, Yalcinkaya G, Sengul YS, Kalemci O, Angin S. Investigation of balance performance under different sensory and dual-task conditions in patients with chronic neck pain. Musculoskelet Sci Pract. 2021;56:102449.
15. Alsultan F, De Nunzio AM, Rushton A, Heneghan NR, Falla D. Variability of neck and trunk movement during single- and dual-task gait in people with chronic neck pain. Clin Biomech (Bristol, Avon). 2020;72:31-6.
16. Kuijper B, Tans JT, Schimsheimer RJ, van der Kallen BF, Beelen A, Nollet F, et al. Degenerative cervical radiculopathy: diagnosis and conservative treatment. A review. Eur J Neurol. 2009;16(1):15-20.
17. Vernon H. The Neck Disability Index: state-of-the-art, 1991-2008. J Manipulative Physiol Ther. 2008;31(7):491-502.
18. Telci EA, Karaduman A, Yakut Y, Aras B, Simsek IE, Yagli N. The cultural adaptation, reliability, and validity of neck disability index in patients with neck pain: a Turkish version study. Spine (Phila Pa 1976). 2009;34(16):1732-5.
19. Wrisley DM, Whitney SL. The effect of foot position on the modified clinical test of sensory interaction and balance. Arch Phys Med Rehabil. 2004;85(2):335-8.
20. Maribo T, Iversen E, Andersen NT, Stengaard-Pedersen K, Schiøttz-Christensen B. Intra-observer and interobserver reliability of One Leg Stand Test as a measure of postural balance in low back pain patients. J Int Musculoskelet Med. 2009;31(4):172-7.
21. Sung ES, Kim JH. The influence of ovulation on postural stability (Biodex Balance System) in young female. J Exerc Rehabil. 2018;14(4):638-42.
22. Prometti P, Olivares A, Gaia G, Bonometti G, Comini L, Scalvini S. Biodex Fall Risk Assessment in the Elderly With Ataxia: A New Age-Dependent Derived Index in Rehabilitation: An Observational Study. Medicine (Baltimore). 2016;95(10):e2977.
23. Negahban H, Mofateh R, Arastoo AA, Mazaheri M, Yazdi MJ, Salavati M, et al. The effects of cognitive loading on balance control in patients with multiple sclerosis. Gait Posture. 2011;34(4):479-84.
24. Plummer P, Eskes G. Measuring treatment effects on dual-task performance: a framework for research and clinical practice. Front Hum Neurosci. 2015;9:225.
25. Resch JE, May B, Tomporowski PD, Ferrara MS. Balance performance with a cognitive task: a continuation of the dual-task testing paradigm. J Athl Train. 2011;46(2):170-5.
26. Haddad JM, Rietdyk S, Claxton LJ, Huber JE. Task-dependent postural control throughout the lifespan. Exerc Sport Sci Rev. 2013;41(2):123-32.
27. Saadat M, Salehi R, Negahban H, Shaterzadeh MJ, Mehravar M, Hessam M. Postural stability in patients with non-specific chronic neck pain: A comparative study with healthy people. Med J Islam Repub Iran. 2018;32:33.
28. Johansson J, Nordström A, Gustafson Y, Westling G, Nordström P. Increased postural sway during quiet stance as a risk factor for prospective falls in community-dwelling elderly individuals. Age Ageing. 2017;46(6):964-70.
29. Stanton TR, Leake HB, Chalmers KJ, Moseley GL. Evidence of Impaired Proprioception in Chronic, Idiopathic Neck Pain: Systematic Review and Meta-Analysis. Phys Ther. 2016;96(6):876-87.
30. Quek J, Treleaven J, Clark RA, Brauer SG. An exploratory study examining factors underpinning postural instability in older adults with idiopathic neck pain. Gait Posture. 2018;60:93-8.
31. Muir-Hunter SW, Wittwer JE. Dual-task testing to predict falls in community-dwelling older adults: a systematic review. Physiotherapy. 2016;102(1):29-40.
32. Tsang CSL, Miller T, Pang MYC. Association between fall risk and assessments of single-task and dual-task walking among community-dwelling individuals with chronic stroke: A prospective cohort study. Gait Posture. 2022;93:113-8.
33. Commandeur D, Klimstra MD, MacDonald S, Inouye K, Cox M, Chan D, et al. Difference scores between single-task and dual-task gait measures are better than clinical measures for detection of fall-risk in community-dwelling older adults. Gait Posture. 2018;66:155-9.