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ARTICLE

Muscle strength, balance and upper extremity function are not predictors of cervical proprioception in healthy young subjects

Anıl Özüdoğru[a], Mehmet Canlı[a], Şafak Kuzu[a], Mensure Aslan[a], İsmail Ceylan[a] and Halil Alkan[b]

[a]School of Physical Therapy and Rehabilitation, Kırşehir Ahi Evran University, Kırşehir, Turkey; [b]Department of Physiotherapy and Rehabilitation, Muş Alparslan University, Muş, Turkey

ABSTRACT

Purpose/Aim: The aim of this study is to examine the relationship between cervical proprioception sense and balance, hand grip strength, cervical region muscle strength and upper extremity functionality in healthy young subjects.

Methods: A total of 200 people with a mean age of 20.8 ± 1.8 participated in the study. Cervical proprioception sense of the participants was evaluated with Cervical Joint Position Error Test (CJPET), balance with Biodex Stability System, hand grip strength with hand dynamometer, and upper extremity functionality with Perdue Pegboard test. The relationship of variables with cervical proprioception was evaluated with Pearson Correlation analysis.

Results: According to this study results, there was no significant relationship between CJPET (extension, left rotation, right rotation) and sub-parameters of dynamic balance (anteroposterior, mediolateral, overall), cervical muscle strength and hand grip strength ($p > 0.05$). There was a significant correlation between CJPET flexion and static balance variables ($p < 0.05$).

Conclusion: According to this study, there is no relationship between cervical proprioception and balance, hand grip muscle strength, cervical region muscle strength and upper extremity functionality in healthy young subjects.

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KEYWORDS
Cervical proprioception; upper extremity function; healthy young subjects

1. Introduction

The proprioceptive system determines the position and movement of the body in space with the information transmitted by the afferent receptors in the muscles, joints and ligaments to the central nervous system (Newcomer et al. 2000). In this way, it contributes to basic protective reflexes, coordination and stability of movement patterns (Chen and Treleaven 2013). Kinaesthesia and joint position sense participate in the sense of proprioception. The proprioception sense, together with the vestibular system and the visuomotor system, forms the sensorimotor control that provides all afferent and efferent organisation (Bogduk and Mercer 2000). Its deficiency results in loss of motor control (Proske and Gandevia 2012). The sense of proprioception is carried from the muscles, joints and skin. Cervical proprioception sense is important for the longitudinal position and orientation of the head in the spine (Revel et al. 1991). Cervical muscles have abundant muscle spindle density reflecting a rich proprioceptive system (Lee et al. 2008). The muscle spindle provides the sense of intramuscular proprioception. Decreased muscle strength and increased muscle fatigue can alter the firing of sensory receptors, thereby affecting afferent inputs, and causing a change in proprioceptive input (Pedersen et al. 1998). Decreased proprioception sensation alters the sensation of tension on the muscle spindle and the threshold of muscle activation (Proske and Gandevia 2012). In this way, it can affect muscle activation and muscle strength. Cervical position sense is important in maintaining joint stability under static and dynamic conditions (Lee et al. 2008). Joint stability is vital for motor control and balance proximally and extremity functions distally.

The spatial position of the head must be perceived correctly to maintain proper balance and posture. Cervical proprioception coordinates the vestibular and visual systems by adjusting the position of the head in relation to the trunk and plays an important role in posture and balance control (Treleaven 2008). The balance and sensorimotor system consists of multiple subsystems that contribute to motor control; proprioception and kinaesthesia are responsible for the sense of head orientation, the vestibular system is responsible for postural balance and spatial orientation, and the visuomotor system processes visual information used for head and neck movements (Bogduk and Mercer 2000). The cervical region and the upper extremity are affected by each other due to their close anatomical relationships. Decreased proximal region stabilisation leads to delayed muscle activation and impaired motor control in the distal joints. The correct sense of location is important in the activities of individuals. In daily life activities, it ensures that the movement is purposeful in various exercises (Han et al. 2016). Cervical proprioception disorder negatively affects this entire interaction and

CONTACT Anıl Özüdoğru aozudogru@hotmail.com Kirsehir Ahi Evran University, School of Physical Therapy and Rehabilitation, Kırşehir 40100, Turkey
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causes deterioration of joint stability and function (Falla and Farina 2008).

Studies have shown that proprioception sense, joint movement, and muscle strength are negatively affected in individuals with neck pathology and neck pain (Prushansky et al. 2005). However, there is no study examining the relationship between cervical proprioception sense and muscle strength, balance and upper extremity functions in healthy individuals. In this context, the aim of this study is to investigate the relationship between cervical proprioception and balance, hand grip strength, upper extremity functionality and cervical region muscle strength in healthy subjects.

2. Methods

2.1. Design and participants

This research was planned as a cross-sectional study. The study was conducted between October and December 2022 in Kırşehir Ahi Evran University Physiotherapy and Rehabilitation Department. A total of 200 people, 144 women and 56 men, aged between 18 and 25 were included in the study. The study was conducted in accordance with the Declaration of Helsinki, and written and verbal consent was obtained from the participants. It was decided by the Clinical Research Ethics Committee of Kırşehir Ahi Evran University that there was no ethical objection to the implementation of the study (Decision no: 2022–16/144).

A screening questionnaire was used to determine the eligibility of the participants. Participants between the ages of 18–25 years were included in the study. The exclusion criteria from the study were the presence of spine or shoulder pathology within the past 12 months, cervical pain, a history of cervical surgery, vertigo, osteoporosis, trigger points in the sternocleidomasteideus muscle and pregnancy.

2.2. Measures

Participants' age, heights, gender body weights, and body mass indexes were recorded. Then the clinical evaluations were performed.

2.2.1. Cervical joint position error test

The Cervical Joint Position Error Test (CJPET) is used to evaluate cervical region proprioception. CJPET assesses cervical proprioception in four positions (flexion, extension, left rotation, and right rotation). It is based on the principle of finding a point while the eyes are closed. 10 repetitions for each position were done. The first four measurements are trials and the average of the last six measurements gives us the joint position error (Hillier et al. 2015; Ulutatar et al. 2019).

2.2.2. Balance

The "Biodex Balance System" (Biodex, Inc., Shirley, New York) device, which has been shown to be valid and reliable, was used for balance assessment. This device consists of a multi-axial platform and a system that reflects the centre of gravity of the person on the screen as a representative point. Dynamic and static postural control of the participants were evaluated with the device (Cachupe et al. 2001).

2.2.3. Hand grip strength

A hand dynamometer (The Jamar J. A. Preston Corporation, Clifton, NJ, USA) was used to assess hand grip strength. Subjects were asked to squeeze the dynamometer vigorously while sitting upright in a standard chair, elbows flexed to 90 degrees, and forearm and wrist in neutral position. The process was repeated on the right and left sides and the averages were recorded in kg (Mathiowetz et al. 1984).

2.2.4. Perdue Pegboard test

The Perdue Pegboard test is used to evaluate upper extremity functionality. The test has five more subtests. While one of them involves mathematical addition, in the other tests the person does the tasks actively. While scoring the test, the pins, washers and nuts inserted in the given time are counted (Thammachai et al. 2022).

2.2.5. Cervical muscle strength

Flexor and extensor muscle strength of the cervical region was measured with a digital hand dynamometer (Lafayette Instrument Company, USA). For the evaluation position, the fine muscle test positions and method defined by Lovett were taken as a basis. While evaluating the cervical flexors, participants were asked to flex their heads while lying in the supine position in the hook position, and the resistance was given from the frontal region. While evaluating the cervical extensors, participants were asked to extend their heads in the prone position with the arms at their sides, the resistance was given from the occipital region. All measurements were repeated three times and the highest value was recorded in kg (Lovett and Martin 1916; Sarig et al. 2015).

2.3. Sample size

The smallest sample size to participate in the study was calculated based on the study of Ulutatar et al. With the G*POWER program (G*Power, Ver. 3.1), it was found that the total number of participants should be at least 191 to obtain 99% power at an effect size of 0.29. An amount of 5% was added to the sample size considering the possibility of any dropouts and then number of participants was determined as 200 (12).

2.3.1. Statistical analysis

Statistical analyzes were performed using "IBM SPSS 24 software". The conformity of numerical variables to the normal distribution was performed using visual (histogram and probability graphs) and analytical methods (Kolmogorov–Smirnov). While descriptive statistics for normally distributed numerical variables are given with mean and standard deviation; Descriptive statistics of categorical variables were given using numbers and percentages. Relationships between variables were calculated with Pearson correlation test in normally distributed data. The degree of correlation was interpreted as low correlation between 0.05–0.4, moderate correlation between 0.4–0.7 and high correlation between 0.7–.0 according to the correlation coefficient (Schober et al. 2018). Statistical significance level was accepted as $p < 0.05$.

3. Results

The data on the descriptive characteristics of the individuals included in the study are shown in Table 1. According to this table, it was observed that the mean age of the individuals included in the study was 20.8%, 72% were female, and 89.5% had the right dominant side.

The relationship between CJPET (flexion, extension, left rotation, right rotation) and Biodex Stability Index, hand grip strength, cervical muscle strength, and Perdue Pegboard test of the individuals included in the study are given in Table 2.

A positive and low statistical correlation was found between CJPET flexion score and Static Stability Index (anteroposterior, mediolateral and overall) ($p < 0.05$). No statistical relationship was found between CJPET (flexion, extension, left rotation, right rotation) and other variables ($p > 0.05$).

4. Discussion

This is the first study to examine factors associated with cervical proprioception in healthy young adults. According to this study results, there was no relationship between cervical proprioception and balance, upper extremity muscle strength, cervical muscle strength, upper extremity functionality in healthy young subjects.

Proprioception is a complex system involving both peripheral and central processes. The source for the proprioceptive receptor is muscle afferent input, particularly from the muscle spindle. These receptors are special fibres that sense the change in muscle length, as well as the rate of muscle contraction (or movement of the body part as the first derivative of length, i.e. the rate of change in length). Muscle spindle detects muscle fibre shortening as well as speed (Hillier et al. 2015). Studies have shown that the sense of cervical position has an important role in maintaining joint stability and that impaired proprioception can cause pain. Impaired position sense alters muscle and nerve control in the cervical region, disrupts muscle strength balance, and a risk of trauma may occur in the joint (Reddy et al. 2019).

Cervical proprioceptive system consists of mechanoreceptors of cervical intervertebral joints, mechanoreceptors of cervical muscles, and muscle spindles of cervical region muscles and plays an important role in maintaining body balance. The cervical proprioceptive system is connected to the vestibular nuclei *via* tractus spinovestibularis (Grgić 2006). The study of Gucmen et al. in patients with fibromyalgia, found that the sense of cervical proprioception and body balance are related, and that body balance and sense of cervical proprioception decrease in patients with fibromyalgia compared to healthy individuals. (Gucmen et al. 2022). In order to maintain balance and posture, the position of the head in space must be perceived correctly. Treleaven stated that the receptors in the cervical spine are associated with the vestibular and visual systems as well as the central nervous system. They stated that disorders in the cervical region alter the dysfunction of cervical receptors, altering the afferent input by changing the timing of integration of sensory-motor control. Therefore, they concluded that cervical joint position sense and postural stability are related (Treleaven 2008). Contrary to the literature, in this study, no significant relationship was found between the sense of cervical proprioception and most of the body balance variables. We think that there is no significant relationship because this study population consists of healthy young adults. One of the results of this study was that there was a significant relationship between proprioception in the flexion direction and static balance. While there is no relationship between proprioception and balance in other directions (extension, right and left rotation), it is noteworthy that there is a relationship in the flexion direction. The lack of sufficient research on this situation has made it difficult to interpret the results. The more frequent use of flexion movement in the cervical region in daily life (Choi 2021) may have resulted in better proprioception sensation in the flexor direction in healthy individuals. As a matter of fact, in our results, cervical proprioception in the flexion direction was better than in other directions.

Proprioception is essential for motor control and joint stability during daily activities and sports practices (Riemann

Table 1. Descriptive characteristics of the individuals included in the study.

		($N = 200$)	
		Mean ± SD	
Age (years)		20.8 ± 1.8	
Height (m)		167.9 ± 9.5	
Weight (kg)		64.3 ± 15.1	
BMI (kg/m^2)		22.6 ± 4.0	
		N	(%)
Gender	Male	56	28.0
	Female	144	72.0
Dominant side	Right	179	89.5
	Left	21	10.5
Cjpet	Flexion (score)	1.58 ± 0.48	
	Extension (score)	1.69 ± 0.55	
	Right rotation (score)	1.69 ± 0.53	
	Left rotation (score)	1.72 ± 0.51	
Dynamic stability index	Anteroposterior (score)	0.74 ± 0.52	
	Mediolateral (score)	0.52 ± 0.35	
	Overall (score)	0.98 ± 0.63	
Static stability index	Anteroposterior (score)	0.76 ± 0.62	
	Mediolateral (score)	0.81 ± 0.75	
	Overall (score)	1.21 ± 0.93	
Hand grip strength	Right (kg)	31.04 ± 11.18	
	Left (kg)	28.91 ± 10.53	
Cervical muscle strength	Flexion (kg)	6.98 ± 2.29	
	Extension (kg)	9.62 ± 5.29	
Perdue pegboard test	Dominant hand (score)	14.84 ± 1.82	
	Non-dominant hand (score)	13.78 ± 1.79	
	Both hands (score)	11.22 ± 1.43	
	Right + left + both hands (score)	39.87 ± 4.14	
	Assembly (score)	30.30 ± 6.66	

BMI: Body mass index; SD: Standard deviation; CJPET: Cervical joint position error test.

Table 2. The relationship between the CJPET scores of the individuals included in the study and balance, hand grip strength, cervical muscle strength and Perdue Pegboard test.

			CJPET ($n = 200$)			
			CJPET Flexion	CJPET Ekstension	CJPET Right Rotation	CJPET Left Rotation
Biodex balance system	Dynamic anteroposterior	r	0.030	0.043	−0.035	0.015
		p	0.671	0.547	0.626	0.836
	Dynamic mediolateral	r	0.038	0.042	0.026	0.009
		p	0.591	0.555	0.715	0.894
	Dynamic overall	r	0.010	0.061	0.022	0.013
		p	0.893	0.389	0.757	0.853
	Static anteroposterior	r	0.140	−0.057	−0.001	0.035
		p	**0.048***	0.426	0.990	0.626
	Static mediolateral	r	0.140	0.006	0.042	0.071
		p	**0.048***	0.934	0.558	0.316
	Static overall	r	0.160	−0.014	0.040	0.061
		p	**0.024***	0.839	0.579	0.390
Hand grip strength	Right	r	0.013	0.028	−0.066	−0.045
		p	0.857	0.697	0.355	0.523
	Left	r	0.022	0.044	−0.062	−0.043
		p	0.755	0.540	0.387	0.541
Cervical muscle strength	Flexion	r	0.001	−0.030	−0.049	−0.069
		p	0.984	0.672	0.495	0.331
	Extension	r	0.016	−0.024	−0.064	−0.084
		p	0.822	0.738	0.370	0.236
Perdue pegboard test	Dominant hand	r	−0.025	−0.213	−0.046	−0.002
		p	0.730	0.628	0.515	0.983
	Non-dominant hand	r	−0.107	−0.080	−0.099	−0.113
		p	0.132	0.262	0.163	0.112
	Both hands	r	−0.068	−0.154	−0.024	−0.049
		p	0.338	0.215	0.736	0.488
	Right + Left + Both hands	r	−0.085	−0.183	−0.075	−0.071
		p	0.233	0.364	0.293	0.315
	Assembly	r	−0.095	−0.102	−0.041	−0.102
		p	0.181	0.149	0.564	0.149

*:$p<0.05$, r: Pearson correlation test, CJPET: Cervical joint position error test.

and Lephart 2002a, 2002b). Studies have shown that strength training improves muscle strength and neuromuscular control (Dover and Powers 2003; Riemann and Lephart 2002a, 2002b). While the debate continues over the precise contributions of specific mechanoreceptors, proprioception as a whole is a necessary component for controlling the activation of dynamic constraints and motor control. It is argued that enhanced muscle stiffness, of which muscle spindles are a crucial element, is an important feature of dynamic joint stability (Riemann and Lephart 2002b). Muscle spindles have sensory connections as well as efferent motor connections. Swanik et al. stated that shoulder strength training not only increases muscle strength but also affects proprioception by making the proprioceptive spindles more sensitive. (Swanik et al. 2002). In another study, Song et al. reported that ankle proprioception sense was associated with lower extremity muscle strength in older adults (Song et al. 2021). In this study, no correlation was found between hand grip strength and cervical region muscle strength, which gives the general status of upper extremity muscle strength, and cervical proprioception sense. The participants in this study consisted of a group with no pain in the cervical region and a young average age group. In addition, the grip and cervical muscle strength of our participants were in good condition. For this reason, it can be thought that the muscle spindles extending together with the extrafusal muscle fibres of our participants were also physiologically healthy, and therefore our muscle strength results were not related to the sense of cervical proprioception. In addition, proprioceptors are located not only inside the muscle, but also outside the muscle. So we could say that other proprioceptors outside the muscle also contribute to the formation of the proprioceptive sense.

A disorder in the neck region also affects the upper extremity due to its close anatomical relationships (Falla et al. 2004). Deep and superficial neck muscles that contribute to the upper extremity movements cause a decrease in motor control and functionality as a result of delayed muscle activation due to the disorder in the neck region (Falla and Farina 2008). Changes in motor activity also affect afferent sensory proprioceptive impulses (Revel et al. 1991). For example; upper extremity position sense is very important in many activities of daily living, including abduction and flexion of the shoulder, especially when reaching for a shelf (Sakaguchi and Yamasaki 2021). Unluer et al. reported that neck pain caused a decrease in upper extremity functionality and upper extremity proprioception in elderly people with neck pain. (Ünlüer and Ateş 2021). Dos Santos et al. stated that there are deficiencies in the sense of proprioception during shoulder flexion and abduction in hemiparetic patients. (dos Santos et al. 2015). In this study, no correlation was found between Perdue Pegboard test, which evaluates upper extremity functionality, and cervical proprioception sense.

5. Study limitation

This study has several limitations. One of them was that this study was conducted in a narrow and young age range. Another limitation is that it was performed in healthy individuals and predominantly in female population, this may reduce the generalizability of the study. We think that the factors associated with cervical proprioception in different age groups and diseases should be examined in future studies.

6. Conclusion

In conclusion, there is no relationship between cervical proprioception sense and balance, hand grip strength, cervical region muscle strength and upper extremity functionality in healthy young subjects.

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ORCID

Anıl Özüdoğru http://orcid.org/0000-0002-7507-9863
Mehmet Canlı http://orcid.org/0000-0002-8868-9599
Şafak Kuzu http://orcid.org/0000-0003-0145-3565
Mensure Aslan http://orcid.org/0000-0001-6290-8135
İsmail Ceylan http://orcid.org/0000-0002-6465-0243
Halil Alkan http://orcid.org/0000-0001-6895-2495

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