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Cervical proprioceptive impairment in patients with rheumatoid arthritis

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Abstract

Rheumatoid arthritis (RA) involving the cervical spine can lead to various neurologic defects and impairment of proprioception is just one of them. The aim of this study was the assessment of cervical proprioception and its relation with radiographic, clinical, and functional characteristics of patients with RA. One hundred and six rheumatoid arthritis patients who diagnosed according to the 2010 American College of Rheumatology/European League Against Rheumatism criteria and age, gender, educational status matched one hundred and six healthy volunteers were enrolled in this study. Cervical joint position error test (CJPET) was applied to healthy volunteers and RA patients for cervical proprioception assessment. Fatigue, depression, balance, quality of life and balance scales were administered to all patients. Cervical radiography was used to assess cervical subluxations. Regression analysis was used for grading the factors which had relations with cervical proprioception. Mean age of patients and healthy volunteers was 51 ± 11.1 and 48.9 ± 9.2, respectively. Scores of CJPET were statistically significantly higher in RA group than healthy volunteers ($p = 0.001$). CJPET scores were negatively correlated with Berg balance scale findings in right rotation, left rotation, flexion and extension (rho = − 0.421, − 0.473, − 0.448, − 0.515). There was weak or not significant correlation between the scores of CJPET and fatigue, depression, and quality of life scales. Scores of CJPET in patients with atlantoaxial subluxations (AAS) were statistically significantly higher than those without AAS ($p < 0.05$). Regression analysis results showed that the AAS was related to impaired cervical proprioception on right and left rotations. There was no correlation between CJPET scores and functional parameters. Cervical proprioception impaired in RA patients. This impairment was related to the existence of AAS and balance problems.

Keywords Rheumatoid arthritis · Cervical proprioception · Proprioception · Atlantoaxial subluxation · Balance

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Introduction

Rheumatoid arthritis (RA) is a systemic autoimmune disease characterized by synovial inflammation that can involve the cervical spine. The atlantoaxial, atlantooccipital, facet and Luschka's joints that are synovial can be affected in RA. The absence of an intervertebral disc in atlantoaxial and atlantooccipital joints can also facilitate joint involvement in RA. Another structure that is essential in the stabilization of atlantoaxial joint is the transverse ligament. In RA, the transverse ligament is frequently involved secondarily to the spread of inflammation in the dens region, and tears can occur in the ligament. Due to a tear, cervical subluxations may occur and thereby promote neurologic complications [1, 2]. Cervical involvement occurs in 43–86% of RA patients [2–4]. The degree of cervical involvement is directly related to the activity and duration of the disease. Another important aspect is that half of the RA patients with cervical involvement are asymptomatic [5]. The clinical course of cervical involvement is quite variable, ranging from a chronic and insidious presentation to acute, severe neurologic deficits. It is important to diagnose cervical involvement in RA patients even when it is asymptomatic, because it may increase the risk of injury and neurologic deficit [3, 6, 7].

Cervical proprioception is supported by muscle spindles and mechanoreceptors in the joint. The receptors in these structures are of great importance for neck proprioception, and varying levels of disruption in neck proprioception are expected due to the degree of involvement [8]. The cervical joint position error test (CJPET), 3 Dimensional (3D) FASTRAK systems and ultrasound-assisted kinesthetic evaluation methods are used in the evaluation of neck proprioception [8].

Although there is no gold standard, most commonly used method in studies is CJPET [8]. The CJPET method can be performed with one laser head, one movable target and one eye patch. This test can be widely and easily used in clinical and research settings. There are few studies in the literature that evaluated neck proprioception [9–12]. To the best of our knowledge, there is no study that evaluated proprioception in rheumatic diseases. It is crucial to assess neck proprioception in RA, and this endeavor may direct us to diagnose and manage cervical involvement early.

Thus, the aim of this study was to evaluate the deterioration of cervical proprioception in RA. The relation of neck proprioception deterioration and functional parameters such as fatigue, depression and balance was also evaluated.

Methods

Participants

RA patients diagnosed with the American College of Rheumatology/European League Against Rheumatism 2010 criteria and age- and gender-matched healthy volunteers were included in the study [13]. Healthy volunteers had neither neck pain nor rheumatologic disorder. Ethical approval with informed consent was provided by all participants. Exclusion criteria were: a history of trauma to the neck area during the last year, physical therapy to the neck region within the previous year, cervical spinal fracture, cervical neurological deficits, vestibular disorder, visual problems, cognitive impairment, neurological disease (epilepsy, migraine, multiple sclerosis, Parkinson's disease and degenerative brain diseases), symptomatic cervical discopathy, spinal cord injury and polyneuropathies. We calculated the relevant sample size by computing the mean scores of the test and reference group in accordance to an initial report, using 80% power and a significance level of 0.05. The minimum sample size was calculated as 80 for each group [14].

Age, gender, marital status, occupation and educational status were noted as demographic features. Disease duration, comorbid disorders and existing laboratory measurements [sedimentation (ESR; mm/hour), complete blood count, C-reactive protein (CRP; mg/dl), rheumatoid factor and anti-cyclic citrullinated peptide (anti-CCP; unit/ml)] were recorded as clinical features. Disease activity score-28 (DAS-28) was used as a disease activity measure. Cervical range of motion, muscle spasm and trigger point presence were also analyzed. All cervical active range of motion (ROM) tests (neck flexion, extension and rotation) was performed with the patient in a seated, upright posture. Cervical ROM tests were measured with an inclinometer. Muscle spasms and trigger point evaluation were performed by palpating the subject. A trigger point represents a hyperirritable spot and a palpable nodule in the taut bands of the skeletal muscles' fascia. Palpating the muscles using manual pressure, direct compression or muscle contraction can elicit a jump sign, a local tenderness, a local twitch response and a referred pain which usually responds with a pain pattern distant from the spot [15].

All radiographic measurements were performed by analyzing the lateral view of the cervical X-ray image. The atlanto-dental distance (AADD) was measured on the lateral view at flexion, neutral and extension positions. Anterior atlantoaxial subluxation (AAS) was defined as an anterior AADD of greater than 3 mm. The measurement of AADD is made between the posteroinferior edge of the anterior arc of the atlas and the anterior surface of the odontoid. An AADD between 3 and 6 mm indicates early instability and transverse ligament damage, whereas more than 6 mm indicates that the alar ligament is damaged. Basilar invagination (BI) was analyzed with the Redlund-Johnell method. The McGregor line is the line between the posterosuperior part of the hard palate and the most caudal point of the occiput. The Redlund-Johnell method measures the distance between the McGregor line and the midpoint of the inferior edge of the C2 vertebral corpus. Normal values in men and women are greater than 34 and 29 mm, respectively. Subaxial subluxation (SAS) is defined as a shift of a vertebral corpus over another vertebral corpus by more than 3.5 mm. The cervical height index (CHI) was used to evaluate SAS; it is the distance between the sclerotic ring in the center of the C2 vertebra and the tip of the spinous process. This value is then divided by the distance between the sclerotic ring in the center of the C2 and the inferior edge of the C7 vertebra corpora. A value smaller than two is an indication that there may be a neurological deficit [3].

Functional measures

The following functional parameters were used in this study: CJPET for neck proprioception, Health Assessment Questionnaire (HAQ) and Neck Pain and Disability Index (NPAD) for disability and neck pain evaluation, Short Form-36 (SF-36) and European Quality of Life-5 Dimensions (EQ-5D) for quality of life evaluation, Berg Balance Scale (BBS) for balance, multidimensional assessment of fatigue (MAF) for fatigue evaluation and Beck Depression Inventory (BDI) for depression evaluation [16–22]. All of the questionnaires were validated in the Turkish population [23–30]. The CJPET is a test used to evaluate the cervical cephalic proprioception and neck position sensation. This test evaluates whether the head of the subject can return to the old neutral position after maximal rotation in the transverse and sagittal planes. The following equipment was utilized: a headlamp with a laser light source in the middle, an eye band, a target with a 40-cm diameter and trigonometric divisions, a metal and a magnetic apparatus used to adjust the target according to the neutral position of the patient's head.

The patient was seated in a chair with their eyes closed with their head in the neutral position; the target was positioned at a distance of 90 cm. The target was a circle with a 40-cm diameter and included five separate small circles to which the rating was applied. These small circles were named as 1 degree, 2 degrees, 3 degrees, 4.5 degrees and 6 degrees, nomenclature that allowed us to evaluate the deviation. The target was adjusted according to patient's height.

The headlamp was attached to the patient's head, and the laser was considered to be at the 0 point in the target when the head was in the neutral position. Maximal active flexion, extension and right and left rotation were performed by the patient with eyes closed. The participant was then asked to reposition their head to the neutral, starting position. The angle between where the point of the patient's head came and the starting point was evaluated by trigonometry, and the deviation from the center was called a global error (Fig. 1). As this global error increases, neck proprioception impairment increases [12]. The test took approximately 30 min. During test development, a global error ≤ 4.5 degrees was accepted as normal; the sensitivity was 86% and the specificity was 93% [10]. Test–retest reliability of CJPET assessed with intraclass correlation coefficient was between 0.35 and 0.90. The CJPET method has intra-rater reliability (ICC = 0.50–0.80) that ranges from medium to high, and the inter-rater reliability (ICC = 0.51–0.57) is moderate [31]. Concurrent validity correlated with reduced balance and smooth pursuit in whiplash-associated disorder [32].

The test application sequence was randomly determined by the closed envelope method and applied 10 times in each direction for flexion, extension, right rotation and left rotation. The first four applications in each direction were performed to allow the subject to learn the test, and thus they were not used in the calculations. The mean scores of the patients were calculated separately for each direction; we recorded whether these mean values were within normal ranges.

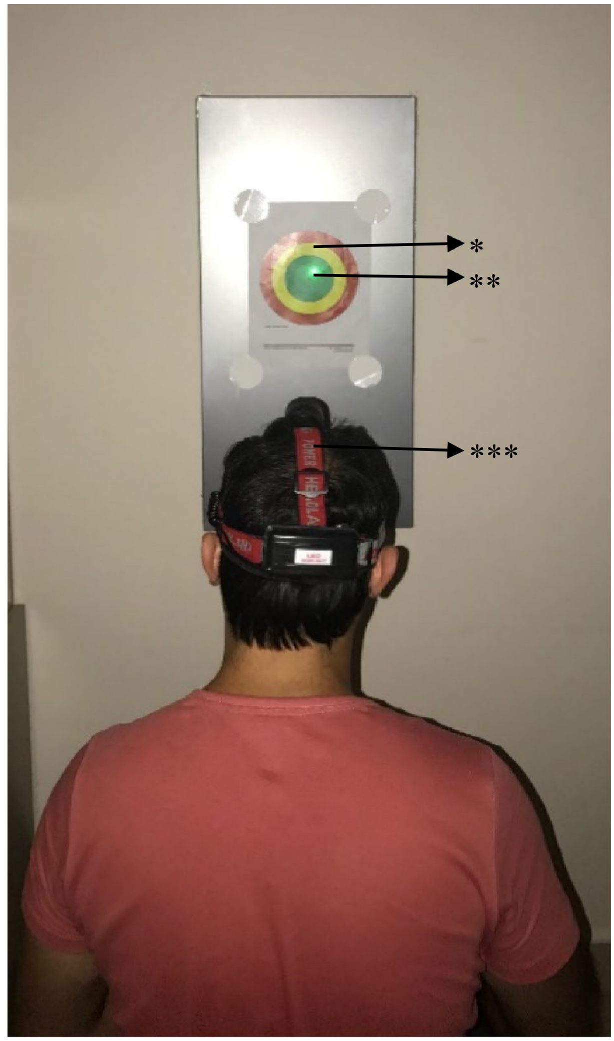

Fig. 1 Cervical joint position error test application.*Yellow and red circles named as 4.5 and 6 degrees, respectively.**Three green circles named as 1 degree, 2 degrees, 3 degrees, consecutively.***Laser headlamp

Statistical analyses

Data normality was analyzed with the Shapiro–Wilk test. Descriptive statistical analyses were performed. Continuous normally and non-normally distributed variables were evaluated with two-tailed independent sample Student's t test and Mann–Whitney U test, respectively. The Chi-squared test was used to compare categorical variables. Spearman's correlation coefficient was used to assess the relationship between continuous parameters. Correlation coefficients > 0.50, 0.35–0.50 and < 0.35 were considered strong, moderate and weak, respectively [33]. The logistic regression analysis (enter method) was performed to identify CJPET score determinants in RA patients. A p value less than 0.05 was considered as statistically significant.

Results

We included 106 RA patients and 106 age-, gender-matched healthy controls into the study. The results of the Shapiro–Wilk test showed that the distribution of age of the patients was normal. Demographic features of the patient and control group are presented in Table 1.

Mean duration of disease in RA patients was 96 ± 85.7 months with a range of 3–480 months. Mean DAS-28 score was calculated as 3.26 ± 0.97 with a range of 1.82–5.85.

In the neck proprioception evaluation, the scores of CJPET were found significantly impaired in all directions (right rotation, left rotation, flexion, and extension) in RA group compared to control group ($p = 0.001$). The descriptive features and comparison of CJPET scores in both groups are shown in Table 2.

The relationship between the results of CJPET and demographic, clinical, functional and radiological findings in RA patients was investigated. The correlation between age and scores of right (rho = 0.24, $p = 0.01$) and left rotation (rho = 0.23, $p = 0.02$) in CJPET was weakly positive. There was no relation between CJPET scores and other demographic features.

There was moderate correlation between BBS and right rotation, left rotation, flexion, and extension of neck proprioception tested by CJPET (rho = − 0.42, $p = 0.001$; rho = − 0.47 $p = 0.001$; rho = − 0.45, $p = 0.001$; rho = − 0.52, $p = 0.001$) in RA patients. Correlation of functional parameters with the CJPET global error scores in RA patients presented in Table 3.

Cervical radiographic evaluation was performed in 85 of 106 RA patients included in the study. While AAS was detected in 23 (27.1%) of these patients, AAS was not observed in 62 (72.9%) patients. Only one patient had BI,

Table 1 Demographic features of the participants

	RA group ($n = 106$) Mean + SD	Control group ($n = 106$) Mean + SD	Significance level (p value)
Age (years)	50.97 ± 11.10	48.89 ± 9.23	0.08*
	N (%)	*N* (%)	
Gender			
Female	89 (84%)	89 (84%)	0.57**
Male	17 (16%)	17 (16%)	
Marital status			
Married	95 (89.6%)	87 (82%)	0.22**
Single	11 (10.4%)	19 (18%)	
Education			0.27**
Primary	72 (67.9%)	65 (61.4%)	
Secondary	10 (9.4%)	13 (12.2%)	
High school	17 (16%)	19 (17.9%)	
College	2 (1.9%)	1 (0.9%)	
University	5 (4.7%)	8 (7.5%)	
Occupation			0.0005**
Unemployed	79 (74.5%)	23 (21.6%)	
Civil servant	3 (2.8%)	16 (15.1%)	
Laborer	10 (9.5%)	67 (63.2%)	
Self-employed	14 (13.2%)	0 (0%)	

$p < 0.05$ accepted as significant

RA rheumatoid arthritis, *n* number

*Student independent samples t test, **Chi Squared Test

Table 2 Comparison of neck proprioception between RA patients and control group

		RA ($n=106$)	Control ($n=106$)	Significance (p value)
	Min–Max	Mean ± SD	Mean ± SD	
CJPET				
Right rotation (1–6)	1.66–6.00	4.55 ± 1.30	3.03 ± 0.81	0.001*
Left rotation (1–6)	1.50–6.00	4.52 ± 1.37	3.07 ± 0.95	0.001*
Flexion (1–6)	1.00–6.00	4.46 ± 1.35	2.98 ± 0.89	0.001*
Extension (1–6)	1.50–6.00	4.57 ± 1.29	3.00 ± 0.93	0.001*

$p < 0.05$ accepted as significant

RA rheumatoid arthritis, *N* number, *CJPET* cervical joint position error test, *SD* standard deviation

*Mann–Whitney U test

while 3 patients had SAS. The mean values of neck proprioception in patients with and without AAS are summarized in Table 4.

The values of CJPET during right rotation, left rotation, flexion and extension of patients with AAS were significantly higher than those without AAS ($p=0.003$; $p=0.002$; $p=0.045$; $p=0.012$). There were no significant differences in CJPET scores during right rotation, left rotation, flexion and extension between the RA patients with SAS and without SAS ($p=0.34$, $p=0.12$, $p=0.79$, $p=0.08$).

The logistic regression analysis with enter method was performed to find out the determinants of CJPET scores in RA patients (Table 5). There was no weighted variable. In this analysis, being an RA patient was associated with an increase in the risk of impaired neck proprioception (elevated CJPET global error scores) by 12–22 folds (Odds Ratio: 12.96–22.85, $p < 0.001$ with a confidence interval of 95%). No factors were found to be associated with CJPET extension according to regression analysis ($p > 0.05$). The results of the logistic regression analyses are depicted in Table 5.

Discussion

Cervical spine involvement in RA may lead to neurological complications or even death [2]. Cervical spine involvement in RA is of great importance and occurs in the first 2 years of disease duration [34]. While proprioceptive exercises constitute one of the main treatment modalities when the lower extremities are involved, evaluation of the cervical spine proprioceptive status and the formation of a treatment program for it are often ignored [8].

Cervical involvement occurs as RA progresses, and clinically significant subluxations might be diagnosed by imaging techniques [2]. The receptors in these structures are of great importance for neck proprioception, and varying levels of disturbance in neck proprioception are expected due to the degree of involvement [8]. Treleaven et al. demonstrated that neck proprioception impairment in patients with a whiplash injury is associated with deterioration in all dimensions of balance [12]. Fatigue and visual and hearing problems are also associated with impaired neck proprioception [11, 12]. There are many methods to evaluate neck proprioception. Although there is no gold standard method, the CJPET is most commonly used in studies [8]. Humphreys et al. compared the tests used to evaluate the neck position sense, and no test exhibited a clear advantage over another. The same study reported that the use of 3D-FASTRAK (Colchester, Vermont) which evaluates neck proprioception using an electromagnetic tracking system, or the Zebris CMS20 (Zebris Meditechnic GmbH, Isny, Germany), an ultrasound-based software with a coordinate measuring system for neck proprioception assessment, is unnecessary [35–37]. On the other hand, the CJPET can be widely and easily used in a clinical setting, and it may allow multicenter studies that involve in large patient groups [35]. Thus, we preferred to use the CJPET method for the measurement of neck proprioception in RA patients.

To the best of our knowledge, there is no study in the literature that evaluated neck proprioception impairments in RA patients. Additionally, there are limited studies that show the relationship between neck proprioception impairment and functional parameters such as fatigue, depression and balance.

In our study, neck proprioception of 106 RA patients was compared with the results from 106 healthy volunteers. This study included more subjects compared to other reports that examined neck proprioception. Age, educational level and fatigue levels that might affect neck proprioception were similar in the RA and control groups, because these variables might affect neck proprioception [8].

According to the CJPET results, neck proprioception was significantly impaired in RA patients compared to the control group. Further, neck proprioception in all directions (right rotation, left rotation, flexion, extension) of the

Table 3 The Spearman's rank correlation of the CJPET with other outcome measures in RA patients ($n = 106$)

	CJPET: right rotation	CJPET: left rotation	CJPET: flexion	CJPET: extension
NPAD				
rho	0.147	0.149	0.134	**0.216**
p	0.134	0.128	0.170	0.026
HAQ				
rho	0.027	0.031	0.053	– 0.012
p	0.783	0.757	0.589	0.905
EQ-5D				
rho	– 0.029	– 0.044	– 0.036	– 0.049
p	0.771	0.657	0.714	0.618
SF-36 physical functioning				
rho	– 0.087	– 0.069	– 0.057	– 0.070
p	0.374	0.485	0.562	0.475
SF-36 role-physical				
rho	0.076	0.052	0.021	– 0.004
p	0.442	0.597	0.828	0.969
SF-36 role-emotional				
rho	0.118	– 0.028	0.051	0.159
p	0.227	0.779	0.606	0.103
SF-36 energy/fatigue				
rho	– 0.025	0.032	0.057	– 0.030
p	0.802	0.745	0.565	0.761
SF-36 emotional well-being				
rho	– 0.044	0.092	0.048	– 0.054
p	0.652	0.350	0.627	0.580
SF- 36 social Functioning				
rho	– 0.135	0.036	– 0.056	– 0.118
p	0.167	0.713	0.570	0.229
SF-36 pain				
rho	– 0.132	– 0.082	– 0.156	– 0.175
p	0.176	0.404	0.110	0.074
SF-36 general health				
rho	– 0.057	– 0.007	0.17	– 0.037
p	0.564	0.946	0.860	0.704
BBS				
rho	**– 0.421**	**– 0.473**	**– 0.448**	**– 0.515**
p	0.001	0.001	0.001	0.001
MAF				
rho	**0.219**	**0.225**	0.155	0.156
p	0.024	0.021	0.112	0.110
BDI				
rho	0.163	0.167	0.013	0.021
p	0.095	0.088	0.895	0.833

$p < 0.05$ accepted as significant; bold values were significant

CJPET cervical joint position error test, *RA* rheumatoid arthritis, *N* number, *NPAD* Neck Pain and Disability Scale, *HAQ* Health Assessment Questionnaire, *EQ-5D* European Quality of Life-5 Dimensions, *SF-36* Short Form-36, *BBS* Berg Balance Scale, *MAF* multidimensional assessment of fatigue, *BDI* Beck Depression Inventory

Table 4 The relation of CJPET scores with existence of atlantoaxial subluxation in RA patients ($n = 106$)

	AAS	N	Mean ± SD	Significance level (p)
CJPET: right rotation	Not present	62	4.29 ± 1.37	**0.03***
	Present	23	5.21 ± 1.05	
CJPET: left rotation	Not present	62	4.27 ± 1.37	**0.02***
	Present	23	5.17 ± 1.23	
CJPET: flexion	Not present	62	4.30 ± 1.33	**0.04***
	Present	23	4.93 ± 1.14	
CJPET: extension	Not present	62	4.40 ± 1.27	**0.01***
	Present	23	5.13 ± 1.22	

$p < 0.05$ accepted as significant; bold values were significant

CJPET cervical joint position error test, *RA* rheumatoid arthritis, *N* number, *AAS* atlantoaxial subluxation, *SD* standard deviation

*Mann–Whitney U test

patients was higher than the normal values reported in the literature. These data suggest that neck proprioception is impaired in RA patients.

While AAS was observed in 23 (27%) of 85 RA patients who had a cervical radiographic evaluation, SAS was only observed in three patients and BI in only one patient. Although the AAS results are similar to the literature, SAS and BI rates were lower than previously reported [3]. While radiographically BI patients were included in our study, BI patients who were symptomatic with neurological findings were excluded. Neck proprioception impairment was significantly higher in AAS compared to non-AAS patients. In patients with AAS, neck proprioception was worse in all directions compared to non-AAS patients; there was significantly greater deterioration in right and left rotation directions compared to flexion and extension.

Increases in the severity of cervical involvement might elevate neck proprioception impairment. The patients with AAS demonstrated profoundly impaired neck proprioception in rotation directions and this finding shows that the atlantoaxial joint controls neck rotation. There was no association between SAS, BI and neck proprioception impairment. The findings suggested that neck proprioception impairment in RA patients was secondary to atlantoaxial joint involvement. However, the low number of patients with SAS and BI does not allow us to definitively draw this conclusion.

Similar to the literature, there was no difference in CJPET scores between genders in our study [38]. Fatigue level and neck proprioception values in two directions were weakly correlated in our study similar to the literature. Previous studies demonstrated that proprioception is impaired in the ankle, knee, hip, shoulder and elbow joints as fatigue levels increased, and this relationship is associated with damage caused by fatigue in muscle fibers [11].

In this study, the relationships between the number of tender joints, number of swollen joints, DAS-28, SF-36, EQ-5D, HAQ, CRP and ESR values and the CJPET scores in RA patients were evaluated. Although many functional parameters were correlated with each other and with clinical parameters, none were associated with impaired neck proprioception. These data show that there was no relationship between neck proprioception deterioration and clinical and functional variables that decline as a result of increased RA activity and progression. Early development of impaired neck proprioception due to neck involvement during the first 2 years of RA may explain the lack of correlation with the functional deterioration that will develop in the long term [34].

We also found no correlation between neck proprioception and neck pain. The CJPET scores and NPAD and VAS-neck were not correlated. There is no study in the literature that directly compares these data. Considering that neck involvement in RA is generally asymptomatic, it is expected that neck proprioception will deteriorate independently of pain.

Table 5 Odds ratios (OR) and 95% confidence intervals (CI) of logistic regression analysis (enter method) showing affecting factors of CJPET in rheumatoid arthritis patients ($N = 106$)

Variables	CJPET: right rotation		CJPET: left rotation		CJPET: flexion		CJPET: extension	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
AAS existence	**5.427***	**1.309–22.511**	**3.602***	**1.068–12.146**	2.061	0.591–7.195	1.907	0.478–7.612
Age	0.988	0.947–1.032	1.017	0.975–1.060	1.003	0.961–1.047	1.014	0.967–1.063
Educational status	0.901	0.755–1.075	0.911	0.765–1.085	0.933	0.782–1.114	0.968	0.799–1.174
VAS fatigue	1.185	0.950–1.477	1.070	0.869–1.318	**1.267***	**1.008–1.592**	1.057	0.832–1.344
MAF	0.992	0.934–1.053	1.005	0.950–1.064	0.970	0.913–1.032	1.042	0.978–1.111
BBS	1.039	0.983–1.098	1.002	0.950–1.057	1.023	0.968–1.081	0.993	0.933–1.056

CJPET cervical joint position error test, *N* number, *AAS* atlantoaxial subluxation, *VAS* Visual Analog Scale, *MAF* multidimensional assessment of fatigue, *BBS* Berg Balance Scale

*$p < 0.05$ accepted as significant; bold values were significant

We did find a correlation between neck proprioception disruption and impaired balance. In all directions, there was a moderate correlation between neck proprioception impairment and the BBS. As balance deteriorates, neck proprioception disturbance becomes more prominent. Treleaven et al. investigated the relationship between neck proprioception disturbances and balance disorders. In that study, there was a weak correlation between balance and left rotation ($r = 0.36$) and a strong correlation with right rotation ($r = 0.61$), data that support our results [12]. Additionally, BBS values in patients with AAS were profoundly impaired, but the impairment was statistically insignificant ($p = 0.06$). Body balance is ensured by the coordination of visual, vestibular and proprioceptive systems. Cervical receptors include vestibular, visual and postural control mechanisms with central and reflex connections, and they have an important role in providing postural balance. The neck muscles, especially deep occipital muscles contain a large number of muscle spindles, and they are involved in balance regulation. Thus, disorders in the neck area cause disturbances in balance [39].

The strengths of this study were the adequate number of participants, and the evaluation of the relationship between neck proprioception impairment and clinical, functional and radiological parameters. The weakness of the study was that a computer-assisted balance device was not used to allow a more detailed examination of the relationship between neck proprioception and balance.

In conclusion, neck proprioception was significantly impaired in RA patients. AAS caused neck proprioception deterioration, especially during right and left rotations. Neck proprioception deterioration in RA patients was independent of clinical and functional parameters. Further studies that examine the relationship between neck proprioception and balance with computerized systems are recommended.

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Authors contribution FU: Designing the study, collecting, analyzing the data, writing the manuscript; CU: Analyzing the data, writing the manuscript; MTD: Designing the study, analyzing the data and coordinating the study. All co-authors of the study take full responsibility for the integrity of the final version of the manuscript.

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Compliance with ethical standards

Conflict of interest: All authors declare that there is no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee (Marmara University School of Medicine Ethical Committee with a reference number of 09.2016.013) and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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