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ORIGINAL ARTICLE

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Extensor/flexor ratio of neck muscle strength and electromyographic activity of individuals with migraine: a cross-sectional study

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Abstract

Purpose Neck pain is considered a common characteristic of migraine attacks. The relationship between neck pain and migraine can be explained by central sensitization of the trigeminocervical complex, where superior cervical afferents and the trigeminal nerve converge. However, few studies have evaluated motor control of cervical muscles in individuals with migraine. Thus, the purpose of the present study was to determine the extensor/flexor ratio of neck muscle strength and electromyographic activity during a test of maximal voluntary isometric contraction and craniocervical flexion in individuals with migraine and individuals without history of migraine or other headaches.

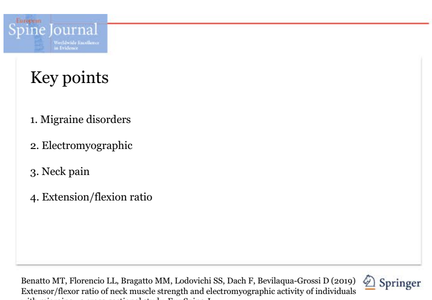
Methods Fifty-two women with the disease and 52 women with neither a history of migraine nor neck pain, between 18 and 55 years old, were included in the study. The electromyographic activities of the sternocleidomastoid, anterior scalene, splenius capitis, and upper trapezius muscles were evaluated during a test of maximal voluntary isometric contraction and craniocervical flexion.

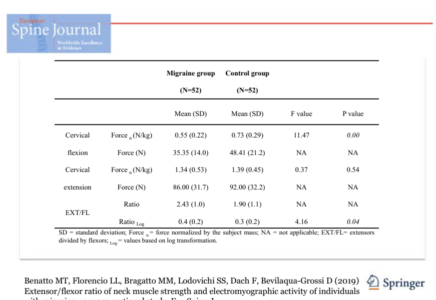
Results The migraine group presented lower flexor muscle strength and a higher extensor/flexor muscle strength ratio than the control group. In addition, the migraine group showed a reduced electromyographic extensor/flexor muscle ratio during maximal voluntary isometric contraction in flexion. The results demonstrated worse performance in the craniocervical flexion test of the migraine group and a lower electromyographic ratio of extensor/flexor neck muscles in the last stage of the test.

Conclusion Altogether, the migraine group presented an imbalance in cervical muscles verified not only during force production, but also during muscle activity.

Graphic abstract

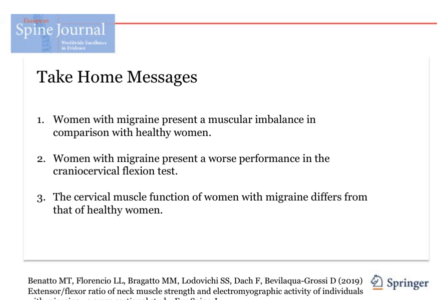
These slides can be retrieved under Electronic Supplementary Material.





		Migraine group (N=52)	Control group (N=52)		
		Mean (SD)	Mean (SD)	F value	P value
Cervical	$Force_n$ (N/kg)	0.55 (0.22)	0.73 (0.29)	11.47	*0.00*
flexion	Force (N)	35.35 (14.0)	48.41 (21.2)	NA	NA
Cervical	$Force_n$ (N/kg)	1.34 (0.53)	1.39 (0.45)	0.37	0.54
extension	Force (N)	86.00 (31.7)	92.00 (32.2)	NA	NA
EXT/FL	Ratio	2.43 (1.0)	1.90 (1.1)	NA	NA
	$Ratio_{Log}$	0.4 (0.2)	0.3 (0.2)	4.16	*0.04*

SD = standard deviation; $Force_n$ = force normalized by the subject mass; NA = not applicable; EXT/FL= extensors divided by flexors; $_{Log}$ = values based on log transformation.



Keywords Migraine disorders · Electromyographic · Neck pain · Extension/flexion ratio

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Introduction

Migraine is classified as a neurobiological [1], chronic [2], and disabling disease [3]. Neck pain is considered a common characteristic of migraine attacks [4] and is associated with worse prognosis of the disease [5]. The relationship between neck pain and migraine can be explained by central sensitization of the trigeminocervical complex, where superior cervical afferents and the trigeminal nerve converge [6].

Few studies have evaluated the cervical muscles in individuals with migraine, and to date, it is known that women with migraine present an increase in muscle coactivation during maximum efforts tasks, a decrease in muscle strength, a longer time to reach the force peak, and higher electromyographic activation during the craniocervical flexion test (CCFT) for cervical muscles. These musculoskeletal alterations are more evident in subjects who show higher frequency of migraine attacks [7, 8].

The muscular imbalance between the force of the extensors and flexors of the cervical spine can be negatively correlated with the stabilization of this region [9]. A feasible and practical measure to verify this imbalance is the ratio estimation of the cervical muscles, which can be calculated based on the strength or muscle activity. Individuals with tension-type headache have a lower strength ratio between extensor and flexor muscles than controls, suggesting a potential for disease chronification [10].

Although the extensor/flexor ratio is believed to be more informative than isolated muscle strength data and can be used to evaluate and treat patients more effectively, it is often neglected [11, 12]. To date, there have been no studies that have verified the strength or muscle activity ratio of cervical muscles in individuals with migraine.

Therefore, the aim of the present study was to compare the extensor/flexor cervical muscle ratio in subjects with migraine and in controls, based on the parameters of muscle strength and electromyographic activity, during maximal voluntary isometric contraction (MVIC) and CCFT. An additional aim was to verify the muscle performance of the deep flexors in both groups by CCFT.

Methods

Participants

The migraine group consisted of 52 women, aged from 18 to 55 years, who were diagnosed with migraine according to The International Classification of Headache Disorders, 3rd edition [13], by an experienced neurologist. The participants were selected in a tertiary hospital between August 2016 and June 2017. The exclusion criteria were: (1) diagnosis of another type of headache, associated or not with migraine, including medication overuse headache; (2) history of trauma in the cervical region or face; (3) pregnancy; (4) diagnosis of hernia or disk degeneration in the cervical region; and (5) systemic diseases or anesthetic block in the three months prior to the selection process. The control group was composed of 52 women from the same age range with no migraine history, any other headache, or self-reported neck pain. The same exclusion criteria used to define the migraine group were applied to the control group. The study was approved by the local ethics committee under process no. 6861/2016, and all the participants signed informed consent forms.

Clinical data

Demographic data, neck pain self-reports, and migraine-related information, such as frequency and intensity of attacks and duration of the disease, were collected. The questionnaires Neck Disability Index (NDI), Migraine Disability Assessment (MIDAS), and 12-item Allodynia Symptom Checklist (ASC-12) were applied. The NDI evaluates disability related to neck pain during daily activities [14]; it classifies patients as having no disability (0–4 points), mild disability (5–14 points), moderate disability (15–24 points), severe disability (25–35 points), or total disability (36 points or over) [14, 15]. The MIDAS test characterizes the disability caused by the migraine and categorizes patients as having no disability or little disability (0–5 points), mild disability (6–10 points), moderate disability (11–20 points), or severe disability (21 points or over) [16]. The ASC-12 rates cutaneous allodynia [17] according to the following grades: no allodynia (0–2 points), mild allodynia (3–5 points), moderate allodynia (6–8 points), and severe allodynia (9 points or over) [18]. Only demographic data were collected in the control group.

Instrumentation

Electromyographic data were collected with Trigno™ Wireless System wireless surface sensors (20–500 Hz, CMRR of 80 dB, input impedance exceeding 1000 Ω, Delsys Inc., Boston, MA), with eight channels used during the MVIC and CCFT. Each sensor had four parallel bars with 99.9% of Ag and a contact area of 50 mm^2 (5 × 1 mm and an interelectrode distance of 10 mm; US patent 6480731, 6238338; European patent EP 1070479). The set had two active and two stabilizing electrodes. After a proper skin preparation procedure, the sensors were firmly attached to the skin surface bilaterally with double-sided tape [8] on: (1) the distal portion of the sternocleidomastoid muscle belly [19]; (2) the belly of the splenius capitis muscle, located around C2–C3 between the sternocleidomastoid and upper trapezius muscles [20]; (3) the belly of the anterior scalene muscle, parallel to the clavicular head of the sternocleidomastoid muscle [19]; and (4) the upper trapezius muscle, located at the midpoint between the C7 spinous process and the acromion process [21]. The minimum distance between the centers of the different electrodes was 20 mm, and the total channel noise was < 0.45 μV pk-pk. Electromyographic signals were acquired by the EMGworks program (Delsys Inc., Boston, MA), amplified (gain = 300), and sampled at 4 kHz with a 16-bit high-definition A/D system.

Tests

All tests were performed during the interictal period for the migraine group. To measure the isometric force of the cervical muscles, a protocol established by Florencio et al. (2015) [8] was applied. As indicated in the protocol, the test was conducted by a trained physical therapist. The instrument used was a manual isometric dynamometer (Lafayette Instrument Company®, model 2201163, Lafayette, IN, USA), which remained attached to a non-elastic belt to prevent the influence of external forces. Three repetitions were monitored for both muscle groups, each lasting three seconds; a 20-second interval between repetitions and a three-minute interval between each type of movement were allowed for the participants to rest. For flexion, subjects were in the supine position and Velcro® (VELCRO B.V., Manchester, NH, USA) belts stabilized the pelvic and thoracic regions (Fig. 1). During the extension MVIC, subjects were in the prone position, also with pelvic and thoracic stabilization (Fig. 2).

The subjects executed the CCFT in the supine position, keeping the lower limbs relaxed and the neck in the neutral position [22]. The Stabilizer Pressure Biofeedback® pressure device (Chattanooga, Hixson, TN, USA) was positioned in the posterior region of the back and initially inflated at 20 mmHg. The task was to increase the pressure by 2 mmHg in each stage, totaling five stages (30 mmHg), and to maintain the pressure for 10 s without compensations [22]. To ensure that the subjects could see the mark for which they had to maintain the pressure, a support was created to allow the pressure device to be adjusted according to each subject's height (Fig. 3).

Fig. 1 Position for strength measurement in maximal voluntary isometric contraction at cervical flexion

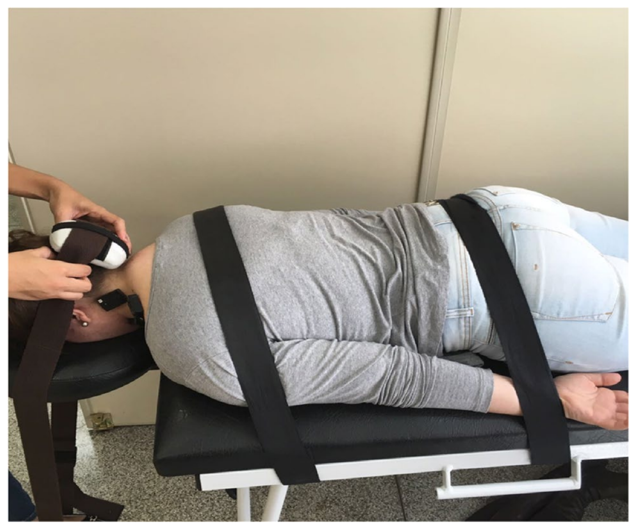

Fig. 2 Position for strength measurement in maximal voluntary isometric contraction at cervical extension

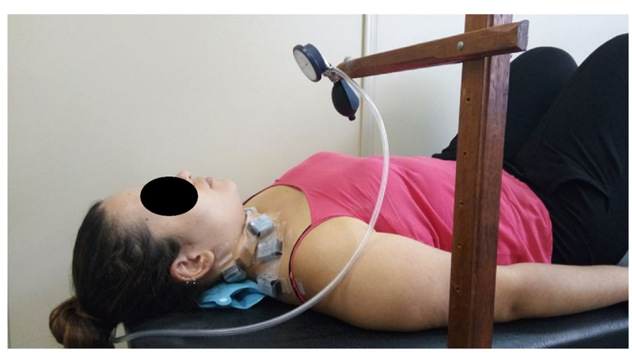

Fig. 3 Position for the craniocervical flexion test

Electromyographic data processing

A MATLAB® custom routine (The MathWorks™, Natick, MA, USA) was used to process the raw electromyographic signals and filter them at a frequency of 20–500 Hz (fourth-order Butterworth). In the MVIC, the root mean square (RMS) was calculated based on a 2-s window for each repetition. For the calculation of the electromyographic ratio, the mean for repetitions and sides of each muscle was obtained, followed by the sum of the RMS of the flexor muscles and the sum of the RMS of the extensor muscles. Last, the sum of the extensor muscles was divided by the sum of the flexor muscles. In the CCFT, the RMS was calculated based on a central 5-s window. Using these values, the mean between the sides was obtained, and the sum of the RMS for the flexors and extensors was carried out separately. The final step was to divide the sum of the RMS of the extensor muscles by the sum of the RMS of the flexor muscles.

Statistical analysis

An effect size of 0.55, a probability error of $\alpha = 0.05$, and a power of 0.80 were used to estimate the sample based on ratio of peak muscle strength of extensors in relation to flexors. For intergroup comparison, data normality was verified with the Shapiro–Wilk test and dispersion graphs. The Mann–Whitney *U* test was applied to compare ages between the groups. Given the statistical difference, the analysis of covariance (ANCOVA) test was run using age as a covariable to compare the migraine and control groups regarding the variables muscle strength, electromyographic data, and ratios of muscle strength and electromyographic data. To analyze the distribution of the groups in stages of the CCFT, a Chi-square (χ^2) test was carried out followed by a post hoc comparison test for proportions. The calculations were run using SPSS version 20.0, and a level of significance of 0.05 was adopted.

Results

The mean age in years was 33.8 (SD 10.6) in the migraine group and 28.9 (SD 8.3) in the control group ($p = 0.02$). The mean weight (kg) and height (m) were 66.5 (SD 14.2) and 1.62 (SD 5.3), respectively, in the migraine group and 65.5 (SD 12.7) and 1.63 (SD 0.07) in the control group ($p > 0.05$). The migraine group presented a mean of 11.9 (SD 8.8) days with headache per month, with a mean intensity of 7.8 (SD 1.9), on a scale from 0 to 10. All patients with migraine were under tailored pharmacological treatment. Additionally, more than half of this group presented severe disability (54.9%) and cutaneous allodynia (55.8%). Self-reported neck pain was prevalent (82.7%). However, the disability caused by the neck pain was mild (44.2%) (Table 1).

Group comparison of the measurement of muscle strength revealed that the migraine group showed a decrease in the strength of the cervical flexor muscles ($F = 11.47$; $p = 0.00$) and a lower extensor/flexor neck muscle strength ratio ($F = 4.16$; $p = 0.04$) when compared to the control group (Table 2). The electromyographic ratio of the extensor/flexor muscles during the measurement of muscle strength in extension did not show statistically significant differences between the groups. The mean value was 2.8 (SD 1.0) for the migraine group ($F = 0.32$; $p = 0.57$) and 3.0 (SD 2.5) for the control group. Nevertheless, an increase in the extensor/flexor electromyographic ratio obtained for the measurement of muscle strength in flexion was observed in the control group ($F = 6.45$; $p = 0.01$), which presented a mean value of 0.4 (SD 0.2) compared to the migraine group value of 0.3 (SD 0.2) (Table 3).

Analysis of the distribution of the groups in the stages of the CCFT showed that the control group presented better

Table 1 The characteristics of migraine

	Migraine group ($N = 52$) Mean (SD)
Years with migraine	17.4 (10.7)
Frequency of attacks (days/month)	11.9 (8.8)
Headache intensity (NPRS)	7.8 (1.9)
Self-report of neck pain (*n* [%])	
Yes	43 (82.7%)
No	9 (17.3%)
Questionnaires (*n* [%])	
NDI	
None	11 (21.2%)
Mild	23 (44.2%)
Moderate	15 (28.8%)
Severe	3 (5.8%)
MIDAS	
None	7 (13.7%)
Mild	5 (9.9%)
Moderate	11 (21.5%)
Severe	28 (54.9%)
ASC-12/Brazil	
None	4 (7.7%)
Mild	10 (19.2%)
Moderate	9 (17.3%)
Severe	29 (55.8%)

SD standard deviation, *NPRS* Numeric Pain Rating Scale, *NDI* Neck Disability Index, *MIDAS* Migraine Disability Assessment, *ASC-12/Brazil* 12-item Allodynia Symptom Checklist/Brazil

Table 2 Strength of cervical muscles and extensor/flexor muscle strength ratio in the migraine and control groups

		Migraine group ($N=52$) Mean (SD)	Control group ($N=52$) Mean (SD)	*F* value	*p* value
Cervical flexion	$Force_n$ (N/kg)	0.55 (0.22)	0.73 (0.29)	11.47	*0.00*
	Force (N)	35.35 (14.0)	48.41 (21.2)	NA	NA
Cervical extension	$Force_n$ (N/kg)	1.34 (0.53)	1.39 (0.45)	0.37	0.54
	Force (N)	86.00 (31.7)	92.00 (32.2)	NA	NA
EXT/FL	Ratio	2.43 (1.0)	1.90 (1.1)	NA	NA
	$Ratio_{Log}$	0.4 (0.2)	0.3 (0.2)	4.16	*0.04*

SD standard deviation, $Force_n$ force normalized by the subject mass, *NA* not applicable, *EXT/FL* extensors divided by flexors, *Log* values based on log transformation

Table 3 Ratio of the electromyographic activity of the extensor/flexor cervical muscles in the MVIC in the migraine and control groups

	Migraine group ($N=52$) Mean (SD)	Control group ($N=52$) Mean (SD)	*F* value	*p* value
MIVC in flexion	0.3 (0.2)	0.4 (0.2)	6.45	*0.01*
MIVC in extension	2.8 (1.0)	3.0 (2.5)	0.32	0.57

SD standard deviation, *MIVC* maximal isometric voluntary contraction

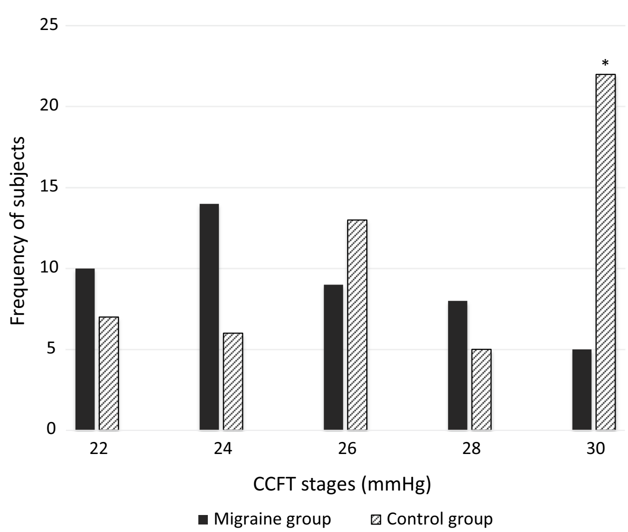

Fig. 4 Distribution of migraine and control groups during the craniocervical flexion test. *$p<0.05$

muscle performance when compared to the migraine group ($p<0.00$) (Fig. 4). The post hoc test for proportions revealed that the difference between the groups occurred at the pressure of 30 mmHg, or the fifth stage ($p<0.00$). Comparison of the CCFT electromyographic ratio between groups demonstrated that for only the pressure of 30 mmHg the control group showed a lower ratio than the migraine group ($F=4.05$; $p=0.047$) (Table 4).

Discussion

The results of the present study revealed worse performance of the cervical muscles in women with migraine in comparison with women in the control group. During the MVIC task, decreased force in the cervical muscles was observed, as well as a higher extensor/flexor muscle ratio and lower electromyographic activity ratio. In the CCFT, women with migraine showed worse performance

Table 4 Ratio of the electromyographic activity of the extensor/flexor cervical muscles in the five stages of the CCFT in the migraine and control groups

Pressure	Migraine group ($N=52$) $Mean_{Log}$ (SD)	Control group ($N=52$) $Mean_{Log}$ (SD)	*F* value	*p* value
22 mmHg	− 0.35 (0.23)	− 0.40 (0.26)	0.78	0.37
24 mmHg	− 0.37 (0.23)	− 0.45 (0.30)	1.74	0.19
26 mmHg	− 0.47 (0.24)	− 0.37 (0.33)	2.42	0.12
28 mmHg	− 0.40 (0.27)	− 0.49 (0.32)	1.85	0.17
30 mmHg	− 0.37 (0.27)	− 0.51 (0.33)	4.04	*0.047**

CCFT craniocervical flexion test, *SD* standard deviation, $_{Log}$values based on log transformation; *$p<0.05$

and a higher electromyographic extensor/flexor muscle ratio in the last stage of the test. From a clinical perspective, it should be highlighted that these findings of altered cervical muscle performance may be generalized only to women with migraine with similar characteristics to the current sample, for example, a mean frequency of 12 days with headache per month.

Previous studies have not found differences in strength of the cervical muscles between subjects with episodic migraine and controls [8, 23]. However, a significant reduction in the force of cervical extensor muscles was reported for women with chronic migraine [8]. Contradicting these results, our data revealed a significant reduction in the force of the cervical flexor muscles in women with migraine in comparison with women in the control group, corroborating the results obtained for subjects with pain and postural alterations in the cervical region [11].

The main contribution of our study was the data on the extensor/flexor ratio for the strength of the cervical muscles, given that this variable had not been explored previously in subjects with migraine. The weakness in cervical flexor muscles observed in subjects with migraine was confirmed by the data on the extensor/flexor force ratio, which also differed between the groups. The force ratio is a parameter that allows a better knowledge of muscle function [12] and reveals muscle dysfunctions and imbalances that could go unnoticed in the evaluation of the isolated isometric force [11].

Additionally, the ratio of neck muscle activity has never been reported despite several reports about the surface electromyography of the cervical muscles in subjects with headache [7, 8, 23]. According to current results, the migraine group showed a lower electromyographic ratio for the extensor/flexor muscles during the flexion MVIC, which reinforces an alteration in the balance of cervical muscle activity when compared to that expected for healthy subjects.

Musculoskeletal changes in the cervical region are known to affect subjects with migraine [7, 8]. However, the clinical performance of the deep flexor muscles during the CCFT was described in only one study that examined subjects with chronic tension headache [24]. Until the present study, the score on this test had never been reported in subjects with migraine. These pioneering findings reinforce the fact that women with migraine show poorer muscle performance in the cervical region.

Our results found no differences between the activation of the muscles examined separately, but a difference in the electromyographic ratio between the groups during the last stage of the CCFT was observed. The higher electromyographic ratio verified in the migraine group at the pressure of 30 mmHg during the CCFT may reflect greater activation of the extensor muscles in these subjects and highlight alteration in the motor control of the cervical region in comparison with controls.

The main contribution of the present study is that it was the first to analyze and describe differences in the ratio of strength and electromyographic activity in tasks that require maximal and submaximal effort. It pioneered in showing worse performance of the deep flexor muscles in women with migraine than in women in the control group. The results allow the conclusion that women with migraine may have a muscular imbalance in the cervical region and that the ratio, whether of force or electromyographic data, must be taken into account in future studies. Due to our study design, we can only conclude that these changes in cervical muscle performance are associated with migraine but cannot infer causality. There are several potential causes for this altered performance, i.e., coping, the high rates of neck pain, kinesiophobia, or even altered motor coordination related to the migraine itself [7, 8, 25, 26]. However, causality can only be verified in studies with longitudinal designs.

Despite the relevance of the findings, some limitations must be considered. First, the sample was made up exclusively of women who were selected in a tertiary hospital so the results cannot be extended to men and may not be applicable to all women from the general population. The association demonstrated here may be related not only to the disease itself in women, but also to more frequent episodes of migraine, considering our sample and our mean headache frequency of 11.9 days per month. Second, it is known that the CCFT is not representative of daily activities, although it is the most indicated test to assess the performance of the cervical muscles, mainly in subjects with neck pain [27]. Third, head and neck postures were not assessed. Altered spine alignment has the potential to biomechanically influence the force production considering the mechanical disadvantage of neck muscle [28] and has also been related to sarcopenia in elderly women [29]. Finally, the isometric force from other segments was not measured, so we cannot discard sarcopenia, which affects mainly elderly individuals but also has been reported in about 10% of women aged over 40 years [30]. However, as there is no evidence that head and cervical posture are altered in migraine patients, [31] in addition to the absence of an influence of age in our results, we believe that the potential influence of both uncontrolled variables is equally distributed in both groups.

Conclusion

Women with migraine present a muscular imbalance when compared to women in the control group. This imbalance was assessed by the ratios of muscle strength and electromyographic data of the cervical extensor/flexor muscles, and a worse performance in the CCFT. Ultimately, the cervical muscle function of women with migraine differs from that of healthy women in both force production and muscle activity.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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