Analysis of dimensions, activation and median frequency of cervical flexor muscles in young women with migraine or tension-type headache

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ABSTRACT | Background: Central and peripheral mechanisms may be involved in migraine and tension-type headache pathogenesis, however the role of muscle disorders in their pathophysiological mechanisms remains unclear. **Objectives:** To assess the association between the presence of migraine or tension-type headache and changes in longus colli muscle dimensions and sternocleidomastoid muscle activity. **Method:** An observational study with 48 women comparing the following groups: migraine (n=21), tension-type headache (n=16), and control (n=11). The cross-sectional area, lateral and anteroposterior dimensions, and shape ratio of the longus colli muscle were measured using ultrasound. The activation of the sternocleidomastoid muscle was assessed by signal amplitude and the decline in median frequency using surface electromyographic analysis. **Results:** The dimensions of the longus colli muscle did not differ between groups (p>0.05). Post-test analysis showed lower sternocleidomastoid muscle activation on both sides, at the onset of contraction, in the group with tension-type headache when compared to the control group {right sternocleidomastoid [tension-type headache: 0.39 (0.30-0.49); control: 0.58 (0.42-0.76); p=0.026] and left sternocleidomastoid [tension-type headache: 0.39 (0.31-0.48); control: 0.60 (0.42-0.79); p=0.039], Tukey's post hoc test}. There was no difference between the three groups in sternocleidomastoid muscle activation, on both sides, at the end of contraction (p>0.05). Intergroup analysis showed no difference in the rate of decline in median frequency (p>0.05). **Conclusion:** The group with tension-type headache exhibited less activation at the onset of sternocleidomastoid muscle contraction. No association was observed between the presence of headache and alterations in longus colli muscle dimensions, median frequency, and sternocleidomastoid muscle activation at the end of contraction.

Keywords: migraine disorders; tension-type headache; neck muscles; ultrasonography; electromyography; movement.

Introduction

Migraine and tension-type headache are the most common source of pain in young workers and they have also been characterized as significant public health issues, with great socioeconomic impact[1-4]. These are primary headaches, and central and peripheral mechanisms may be involved in their pathogenesis[5,6].

A number of authors[6-10] have sought to elucidate the involvement of peripheral nociceptive stimuli in the pathogenesis of migraine and tension-type headache. However, the role of muscle alterations in the activation of the physiopathological process of these types of headache remains unclear[8-10].

A possible reason for the association between changes in craniocervical muscles in patients with migraine or tension-type headache is the activation of trigemino-cervical nucleus during migraine or tension-type headache attacks. In this nucleus, there is a convergence of cervical and trigeminal nociceptive afferents in the trigeminocervical complex, releasing vasoactive algogenic substances, which facilitate pain transmission to the brain and promote awareness of the central nervous system[4-5,11].

This is supported by other findings suggesting that individuals with migraine or tension-type headache are more likely to self-report neck pain and to report cervical muscles disorders, such as limited range of motion[11], changes in head and cervical posture[11], alterations in muscle dimensions[12-14], and muscle

fatigue and activation during contractions[7,15]. Several methods have been used to verify this association, including photogrammetry[11], electromyography[7,15-17], and ultrasonography[12-14].

Prior studies[7,15-17] have used electromyography to assess the relationship between headache and alterations in the superficial cervical activity of the sternocleidomastoid, splenius, and trapezius muscles. The results suggest that changes in activation[7,16,17] and fatigability[7,15] are more frequent in individuals with headache. However, previous assessments of neck muscle dimensions only included patients with chronic neck pain and did not include subjects with migraine.

Patients with chronic neck pain exhibited lower activation in deep neck muscles, such as the longus capitis and longus colli muscles[12-14], accompanied by increased sternocleidomastoid muscle activity[12] as a compensatory mechanism. In two studies[13,14], the ultrasonographic images of these muscles showed a reduction in thickness[13], cross-sectional area[13], and anteroposterior dimension in individuals with chronic neck pain. Other findings suggest the presence of atrophy and alterations in muscle recruitment[14].

In this respect, deep flexor muscles in the cervical region are essential to cervical spine postural control. Thus, imbalances between these muscles and superficial cervical muscles make the cervical spine less stable and more vulnerable to other forces involved in maintaining posture, causing overload in other muscles[18].

Despite the importance of deep and superficial cervical flexor muscles in stabilizing and maintaining cervical lordosis and indications that migraine and tension-type headache are associated with changes in neck muscles, there is still a lack of studies[7,15-17] that use non-invasive techniques to assess those muscles in individuals with migraine or tension-type headache not related to chronic neck pain.

Thus, the aim of the present study was to assess the association between the presence of migraine or tension-type headache and changes in the longus colli muscle dimensions and sternocleidomastoid muscle activity, using ultrasonography and surface electromyography.

● Method

This is an observational, cross-sectional type study comparing three groups. The sample size was not calculated because this is a pilot study. The study was approved by the Human Research Ethics Committee of the Health Sciences Center of *Universidade Federal de Pernambuco* (UFPE), Recife, PE, Brazil (CAAE 02219412.5.0000.5208). All participants gave their informed consent.

Data were collected from October/2012 to December/2013 in the Physical Therapy Department of UFPE.

Participants

The sample was composed of young adult women, aged between 20 and 30 years, to avoid biases due to the presence of muscle changes associated with biological aging. Only nulliparous women were included in order to prevent biases related to the relationship between hormones and the presence of headache[19]. Clinical diagnosis, established by a neurologist based on criteria proposed by The International Classification of Headache Disorders[20], was used to divide the sample into migraine, tension-type headache, and control groups.

The migraine group was composed of women diagnosed with episodic migraine (less than 15 days with headache per month), with following characteristics: pure migraine (with aura, without aura or both) or probable migraine (with aura and without aura or both). Participants who had probable migraine associated with tension-type headache or migraine associated with tension-type headache were also allocated to the migraine group[20]. The tension-type headache group was formed by women with episodic tension-type headache (less than 15 days with headache per month)[20]. The control group was composed of participants who had intermittent headache crises over their lifetime that were not associated with the characteristics of primary headaches and those who did not meet the diagnostic criteria of migraine or tension-type headache[20].

The exclusion criteria were as follows: 1) body mass index ≥30 as obesity can increase the risk of chronic migraine[19]; 2) chronic migraine, chronic tension-type headache or chronic neck pain due to the association between muscle alterations and chronification of headache and neck pain[7,16,17]; 3) diseases or dysfunctions such as myopathies, fibromyalgia, abnormalities, fractures or history of cervical spine or thoracic surgery, symptomatic spinal disc herniation, rheumatoid arthritis, and history of spinal tumors; 4) score ≥15 in the neck disability index[21], score ≥36 in the Beck depression inventory or score ≥30 in the Beck anxiety inventory[22] as neck disability, depression, and anxiety are disorders often comorbid with chronic migraine[19,20].

The neck disability index is a questionnaire adapted and validated for the Brazilian population that provides information about how neck pain affects the ability to perform activities of daily living. It consists of 10 sections, scored from 0 to 5 each. Scores ≥15 indicate moderate neck dysfunction[21].

The Beck depression and anxiety inventories are instruments for research of depressive and anxiety symptoms, translated and validated for the Brazilian population, and consists of 21 items. In the Beck depression inventory, the severity of symptoms varies from 0 to 3, with a maximum score of 63. Scores ≥36 indicate severe depression. In the Beck anxiety inventory, the sum of the items results in a total score that can range from 0 to 63, and scores ≥30 indicate severe anxiety[22].

Data collection procedure

An examiner, blinded to the diagnosis of headache, performed an ultrasonographic assessment of the longus colli muscle and surface electromyographic evaluation of the sternocleidomastoid muscle. During data collection, participants could not be menstruating or taking medication such as muscle relaxants, analgesics or anti-inflammatories, in the 48 hours before the examination.

To avoid measurement bias, the examiner was trained to perform the evaluations.

Ultrasonographic assessment of the longus colli muscle

B-mode ultrasonography (Aloka 1500 with 7.5 MHz linear transducer) was used to measure the cross-sectional area (cm^2), as well as the lateral (cm), anteroposterior (cm), and shape ratio dimensions of the muscle.

The cross-sectional area was considered the greatest distance between the inner edges of the margins of the muscle image, without including fascial contours[13]. The lateral and anteroposterior dimensions were considered the greatest distance between one margin and another of the image, in the lateral and anteroposterior direction, respectively[13]. The shape ratio was obtained by dividing lateral and anteroposterior dimension values[13].

Participants were positioned in dorsal decubitus, knees flexed, arms along the body and head in midline position[14]. The transducer was placed longitudinally in the anterior region of the neck, parallel to the trachea, approximately five centimeters from the midline at the level of vertebrae C5 and C6. The longus colli muscle is bordered inferiorly and medially by the vertebral body, laterally by the carotid artery, and superiorly by the retropharyngeal space[13].

Three measurements of the muscle dimensions were taken at rest and during contraction, with a one-minute interval between them. In contraction, subjects were instructed to perform a cervical flexion, without removing their head and shoulders from the table, sustaining it for ten seconds[14]. The average of the three results for each measurement was used to compare intergroup dimensions.

Surface electromyography of the sternocleidomastoid muscle

The EMG device (model 410C, EMG System of Brazil Ltda.) was connected to a portable computer. The equipment has four channels, with pre-amplifiers, sample frequency per channel of 2000 Hz, Butterworth band-pass filter between 20 and 500 Hz, amplified 2000 times (common-mode rejection >120 dB), digitized with a frequency of 2 KHz per channel and amplitude range between −5 and +5 volts. After collection, the signal was digitized, converted to .txt format and analyzed using the software of the device itself.

Signal capture followed ISEK (International Society of Electrophysiology and Kinesiology) Standards for Reporting EMG Data[23]. Electromyographic signals were detected using two rectangular surface electrodes (Ag/AgCl, self-adhesive, bipolar) on the muscle, twenty millimeters apart[24].

Participants were placed in dorsal decubitus, knees flexed and feet resting on the table, arms flexed and hands above their head and resting on the table, in order to reduce the action of trunk and scapular waist muscles[25]. The electrodes were placed on the midpoint of the muscle belly, along the length of the muscle fibers[17], from a reference line running between the lower point of the mastoid process and the center of the sternal furcula. The reference electrode was fixed to the lateral epicondyle of the left humerus.

In the first five seconds of collection, participants remained at rest with their head at maximum rotation amplitude to the opposite side to that assessed and leaning toward the same side. Cervical flexion was then performed, up to maximum amplitude[25], maintaining the position in isometric contraction for twenty-five seconds, subjects not raising their shoulders from the table, followed by five seconds of rest. The sternocleidomastoid muscle was assessed unilaterally in order to minimize the cross-talk effect[26].

The electrical activities analyzed were median frequency (Hz) and signal amplitude (v), through a time window manually driven by the software of the device itself. One-second samples of the electromyographic recording were analyzed at the start of the rest period (between 2 and 3 seconds), at the onset of contraction (between 6 and 7 seconds), and at the end of contraction (between 28 and 29 seconds).

Median frequency was measured at the start and end of muscle contraction in order to analyze the rate of decline at the end of contraction[15]. Muscle activation was determined from the amplitude of the electromyographic signal quantified by root mean square (RMS) values. Data were normalized by subtracting RMS values at the start and end of contraction from baseline values[27]. The average of median frequency and normalized RMS values was used for intergroup comparison.

Processing and data analysis

The data bank was digitized into Microsoft Excel (2007) spreadsheets and exported to SPSS 20.0 for analysis. Data were presented as mean (confidence interval) and percentage. All variables exhibited normal distribution in the Kolmogorov-Smirnov test. To verify the association between variables, paired t-test, one-way ANOVA (for intergroup comparisons separately), repeated measures two-way ANOVA (for intra and intergroup comparisons performed simultaneously) and Tukey's post hoc test were performed. Statistical significance was set at the 95% confidence level (p<0.05).

● Results

A total of 52 participants were recruited, 4 of whom refused to take part in the study. Forty-eight women, aged on average 22.67 years (CI: 22.1-23.23), were allocated to the migraine (n=21), tension-type (n=16), and control (n=11) groups.

Of the participants with headache (n=37), 43% (n=16/37) suffered from episodic tension-type headache and 57% (n=21/37) migraine. Considering only the migraine group (n=21), we found the following frequency of subtypes: 67% (n=14/21) had migraine without aura; 14% (n=3/21) migraine without aura associated with episodic tension-type headache; 9% (n=2/21) migraine with aura; 5% (n=1/21) migraine with aura associated with episodic tension-type headache; and 5% (n=1/21) migraine with aura and without aura.

There was no intergroup difference (p>0.05) in age, height, weight or body mass index. The scores for the Neck disability index were statistically significant in the intergroup analysis (p=0.01; one-way ANOVA). Post-test analysis showed higher scores in the migraine group than in the control group (p<0.01); and higher scores in tension-type headache than in the control group (p=0.08). The Beck depression inventory scores and the Beck anxiety inventory scores did not differ between groups (p>0.05; Table 1).

Regarding participants with headache in Table 1, there was no difference between groups in the time

Table 1. General characteristics of sample.

	Groups			
	Control (n=11)	**Migraine (n=21)**	**TTH (n=16)**	**p***
Age (years)	21.64 (21.02-22.26)	23.1 (22.12-24.07)	22.81 (21.73-23.9)	0.123
Weight (kg)	57.26 (53.03-61.49)	58.67 (55.22-62.12)	57.34 (54.06-60.63)	0.794
Height (m)	1.64 (1.61-1.66)	1.64 (1.62-1.67)	1.62 (1.6-1.64)	0.263
BMI (kg/m²)	21.31 (19.38-23.23)	21.43 (20.24-22.63)	21.86 (20.69-23.03)	0.824
NDI	3.18 (1.72-4.88)	8.86 (6.06-10.23)	6.4 (4.87-9.25)	0.01†
BDI	4.80 (1.88-7.72)	7.71 (3.96-11.47)	4.0 (2.37-5.63)	0.16
BAI	6.50 (1.61-11.39)	6.52 (3.56-9.48)	5.50 (2.79-8.21)	0.88
Time with headache (years)	-	8.71 (6.80-10.63)	8.0 (6.03-9.97)	0.59
Headache frequency (days/6 months)	-	24.48 (11.75-37.20)	6.50 (2.68-10.32)	0.01**
Headache duration (hours)	-	6.62 (5.03-8.21)	7.44 (1.31-13.57)	0.21

*One-way ANOVA. † Tukey's post-hoc test (control *vs* migraine group: p†<0.01; control *vs* tension-type headache group: p†=0.08; migraine *vs* tension-type group: p†=0.128). **p<0.05. Data are shown as mean and confidence interval. TTH: tension-type headache; n: number; BMI: Body mass index; NDI: Neck disability index; BDI: Beck depression inventory; BAI: Beck anxiety inventory.

with headache (p=0.59) and headache duration (p=0.21). However, headache frequency was higher in the migraine group than in the tension-type headache group (p=0.01).

Ultrasonographic analysis of the left and right longus colli muscle during rest and contraction revealed no intergroup difference in cross-sectional area or lateral, anteroposterior, and shape ratio dimensions (Table 2).

There was a statistically significant intergroup difference in right and left sternocleidomastoid muscle activation at the onset of contraction (p<0.05; repeated measures two-way ANOVA). Post-test analysis showed less sternocleidomastoid muscle activation on both sides at the start of contraction in the group with tension-type

headache when compared to the control group {right sternocleidomastoid [tension-type headache: 0.39 (0.30-0.49); control: 0.58 (0.42-0.76); p=0.026] and left sternocleidomastoid [tension-type headache: 0.39 (0.31-0.48); control: 0.60 (0.42-0.79); p=0.039], Tukey's post-hoc test}. There was no difference between the three groups in sternocleidomastoid muscle activation, on either side, at the end of contraction (p>0.05; repeated measures two-way ANOVA; Table 3).

In intragroup analysis, there was a significant difference (p<0.05; repeated measures two-way ANOVA) in median frequency variation between the start and end of sternocleidomastoid muscle contraction, indicating a decline in median frequency at the end of

Table 2. Intergroup analysis of ultrasonography of the longus colli muscle during rest and contraction.

	Longus colli muscle							
	Left				Right			
	Groups							
Measures	Control (n=11)	Migraine (n=21)	TTH (n=16)	p*	Control (n=11)	Migraine (n=21)	TTH (n=16)	p*
CSA rest	0.60(0.49-0.70)	0.58(0.51-0.64)	0.60(0.46-0.75)	0.899	0.61(0.51-0.72)	0.62(0.55-0.68)	0.63(0.45-0.80)	0.985
CSA contraction	0.57(0.43-0.71)	0.51(0.45-0.56)	0.52(0.38-0.65)	0.677	0.56(0.42-0.60)	0.55(0.47-0.63)	0.56(0.41-0.72)	0.988
LL rest	1.31(1.11-1.51)	1.34(1.26-1.42)	1.27(1.09-1.45)	0.708	1.32(1.15-1.49)	1.39(1.28-1.49)	1.30(1.10-1.49)	0.598
LL contraction	1.29(1.07-1.51)	1.31(1.22-1.39)	1.25(1.08-1.42)	0.817	1.31(1.08-1.55)	1.37(1.26-1.49)	1.28(1.06-1.49)	0.673
AP rest	0.58(0.53-0.63)	0.55(0.51-0.58)	0.59(0.52-0.65)	0.377	0.57(0.53-0.61)	0.56(0.53-0.65)	0.57(0.50-0.65)	0.905
AP contraction	0.53(0.47-0.59)	0.51(0.48-0.54)	0.53(0.47-0.59)	0.788	0.52(0.47-0.57)	0.53(0.49-0.56)	0.55(0.48-0.61)	0.766
SR rest	2.28(1.90-2.65)	2.47(2.31-2.63)	2.15(1.93-2.36)	0.076	2.26(20.1-2.50)	2.46(2.23-2.70)	2.23(2.00-2.47)	0.274
SR contraction	2.44(2.07-2.81)	2.55(2.38-2.72)	2.33(2.17-2.49)	0.262	2.48(2.10-2.87)	2.61(2.38-2.85)	2.31(2.04-2.58)	0.232

*One-way ANOVA. Data are shown as mean and confidence interval. TTH: tension-type Headache; n: number; CSA: cross sectional area, cm^2; LL: lateral measure, cm; AP: anteroposterior measure, cm; SR: shape ratio.

Table 3. Intergroup analysis of the means of normalized root mean square values of the sternocleidomastoid muscle.

	Root mean square Sternocleidomastoid muscle			
	Left		Right	
Groups	Beginning of contraction (6-7s)	End of contraction (28-29s)	Beginning of contraction (6-7s)	End of contraction (28-29s)
Migraine (n=21)	0.53 (0.44-0.63)	0.42 (0.35-0.48)	0.46 (0.39-0.53)	0.39 (0.34-0.44)
Control (n=11)	0.60 (0.42-0.79)	0.49 (0.37-0.62)	0.58 (0.42-0.76)	0.44 (0.32-0.58)
	p†=0.039		p†=0.026	
TTH (n=16)	0.39 (0.31-0.48)	0.38 (0.30-0.47)	0.39 (0.30-0.49)	0.35 (0.27-0.45)
p*	0.038**	0.188	0.033**	0.369

*Repeated measures two-way ANOVA. † Tukey's post-hoc test (difference between the migraine and control groups). **p<0.05. Data are shown as mean and confidence interval. TTH: tension-type headache; n: number; s: seconds.

contraction in all groups. However, the difference in the rate of median frequency decline, from the start to the end of sternocleidomastoid muscle contraction, was not significant between groups (p=0.092 on the left side and p=0.97 on the right side; repeated measures two-way ANOVA; Table 4).

Discussion

The hypothesis that women with migraine or tension-type headache have a shorter longus colli muscle and increased sternocleidomastoid muscle activity, when compared to women without headache, was not confirmed. On the other hand, the present study is innovative in that it assesses muscles with important stabilization and postural alignment functions in the cervical region in a young population with migraine or episodic tension-type headache.

Since muscle alterations may be more associated with biological aging and chronification of headache and neck pain[7,16,17] than with episodic headache in a younger population (15 to 24 years), the present study avoided a confusion factor in the association between muscle modifications and the emergence of headaches. Therefore, differences between our results and those reported in the literature[7,16,17] may be due to the different characteristics and age groups of the populations analyzed.

In this study, there was less activation at the onset of sternocleidomastoid muscle contraction in the group with tension-type headache, when compared to participants without headache. Corroborating our findings, other authors have also observed less activation and more prolonged sternocleidomastoid muscle relaxation in participants with chronic neck pain associated with headache[16].

On the other hand, studies that showed greater activation and fatigability in cervical muscles, such as the sternocleidomastoid, splenius[17], frontal and temporal[7], assessed participants with chronic tension-type headache[7,17]. Thus, the increase in muscle activation and fatigability may be a consequence of the motor control reorganization strategy in subjects with chronic headache[17], generating muscle overload and fatigue, increased nociception[17], and changes in the type of muscle fiber[7].

Therefore, the reduced muscle activation values observed in the group with tension-type headache may be related to the increased basal tonus in the sternocleidomastoid muscle and smaller amount of fast fibers. The reduction in type II fibers can be associated with lower speed of contraction, reducing the muscle activation in the tension-type group[7]. Similarly, the absence of a difference in sternocleidomastoid muscle activation in the group with migraine suggests that these individuals may have another type of muscle fiber.

The neck disability index scores were higher in the migraine and tension-type headache groups than in the control group, suggesting that neck pain adds significantly to the overall disability of individuals with migraine or tension-type headache. Neck pain-related disability can be associated with changes in body posture[28] and seems to increase as the frequency of migraine attacks increases[29]. Furthermore, this

Table 4. Intra and inter-group analysis of the variation in median frequency between the beginning and the end of the contraction of the sternocleidomastoid muscle.

| | Median frequency Sternocleidomastoid muscle | | | | | |
| | Left | | | Right | | |
Groups	Beginning of contraction (6-7s)	End of contraction (28-29s)	p*	Beginning of contraction (6-7s)	End of contraction (28-29s)	p*
Control (n=11)	75.99 (69.31-82.66)	66.40 (58.88-73.91)	0.010	76.70 (70.24-83.15)	64.98 (55.42-74.53)	0.008
Migraine (n=21)	87.23 (80.69-93.77)	75.70 (70.09-81.30)	<0.001	85.74 (78.71-92.78)	74.77 (67.81-81.73)	<0.001
TTH (n=16)	82.75 (76.57-88.94)	66.40 (60.71-72.08)	<0.001	78.85 (71.28-86.42)	67.86 (61.84-73.89)	<0.001
p†	0.092			0.974		

*Paired t-test; †repeated measures two-way ANOVA. Data are shown as mean and confidence interval. TTH: tension-type headache; n: number; s: seconds.

disability may be a functional consequence of changes in craniocervical posture in migraine patients[29].

With respect to the analysis of deep cervical muscles, one study[10] showed that people with chronic neck pain exhibited imbalance between deep and superficial cervical flexor muscles, such as the longus colli and sternocleidomastoid muscles. In our study, similar results were expected in groups with migraine or tension-type headache. However, given that they are deep muscles in the cervical region, alterations in this structure may only be perceived when there is prolonged accumulation of nociceptive stimuli, as in chronic neck pain[12,14].

Moreover, there are also reports of reduced thickness[14], cross-sectional area, and anteroposterior dimension[13] in the longus colli muscle of individuals with chronic neck pain. However, it is important to underscore that chronic neck pain may be linked to muscle atrophy and alterations in muscle dimension and recruitment[14], justifying the discrepancies in the findings of the present study. Thus, alterations in cervical muscles are most likely correlated to pain chronification, as occurs in the aging process or in conditions such as chronic migraine, cervicogenic headache and chronic neck pain, than to the pathogenesis of headache[7,16,17,19].

One of the limitations of the present study was that it is not a longitudinal study and does not involve a long-term follow-up of participants to establish a more accurate association between alterations in cervical muscles and the presence of headache. Additionally, the need to control some factors that possibly trigger the headache and the higher prevalence of migraine compared with tension-type headache and women without primary headache limited our ability to obtain a larger sample, especially for the control group.

The clinical importance of our study is that the knowledge of changes in muscle function will be important to guide physical therapy treatment in patients with headache. The decreased activation in the sternocleidomastoid muscle at the onset of contraction in the tension-type headache group suggests the importance of more muscle assessments in patients with headache. Furthermore, patients with headache benefited from the Neck disability index evaluation, because in our study they were more likely to report neck disability than the control group, suggesting that the prevalence of neck pain is higher in patients with headache.

Conclusion

In the present study, the group with tension-type headache showed less sternocleidomastoid muscle activation at the onset of contraction. No association was observed between the presence of headache and alterations in the dimensions of the longus colli muscle, median frequency, and sternocleidomastoid muscle activation at the end of contraction.

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