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Strength of scapular elevation in women with TMD and asymptomatic women - a cross-sectional study

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Temporomandibular disorder (TMD) is recognized for its high prevalence, presenting characteristic signs and symptoms. Cervical spine pain is present in 70% of diagnosed TMD cases. **Aim:** To verify if women with TMD present changes in isometric muscle strength in the scapula elevation. **Methods:** This is an observational, cross-sectional study. Thirty-five women, aged 22.89±2.04 years, were divided into the TMD group (TMDG), diagnosed with TMD according to the DC/TMD, and control group (CG), with asymptomatic individuals. The volunteers accessed a online link by the smartphone in order to answer questions on personal data, the Fonseca Anamnestic Index (FAI), Neck Disability Index (NDI), and Masticatory preference. In all participants, evaluation of the force of the scapula elevation muscles was performed, using a load cell model MM-100 (Kratos® SP, Brazil). Data were analyzed descriptively using the maximum, mean, and standard deviation and a two-way ANCOVA test was applied for all variables. A significance level of 5% was considered. **Results:** There were no statistically significant differences between the TMDG and CG for the maximal and mean muscle strength of scapular elevation. There were statistically significant differences in FAI ($p < 0.001$*) between the CG and the TMDG. **Conclusion:** Based on the results, it was not possible to confirm the hypothesis that women diagnosed with TMD present lower isometric strength during scapular elevation (right/left).

Keywords: Temporomandibular joint. Isometric contraction. Muscle strength.

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Introduction

Temporomandibular Disorder (TMD) is recognized by the American Academy of Orofacial Pain (AAOP) as a group of musculoskeletal and neuromuscular conditions involving the temporomandibular joint (TMJ), masticatory muscles[1], and all other associated craniocervical structures[2,3].

The clinical signs and symptoms present in individuals with TMD can be listed as muscle and/or joint pain, TMJ sounds or noises (in cases of disc displacement and/or degenerative dysfunction), restrictions, limitations, and deviations during mouth opening and/or closing[2]. Moreover, pain in the cervical region is present in 70% of cases of TMD[4-6].

The prevalence of TMD ranged from 21.1% to 73.3% with the occurrence of painful TMD signs/symptoms varying from 3.4% to 65.7%, and non-painful signs/symptoms between 3.1% and 40.8%[7]. According to Silveira et al. (2015)[5], the presence of signs and symptoms in the cervical region of patients diagnosed with TMD, as well as the presence of painful points in the cervical region, are very common. The presence of signs and symptoms in the cervical region was confirmed on palpation, with 23 to 67% of patients with TMD presenting muscle tenderness (presence of tender points) in the sternocleidomastoid and upper trapezius muscles[5]. Muscle tension in the cervical and mandibular regions is associated with high levels of disability, according to the Neck Disability Index (NDI)[8].

The cervical spine and TMJ present a neuro-anatomical and functional relationship[5,6]. In addition, alterations in the cervical posture can be related to patients with TMD and vice versa. High rates are reported for the coexistence of TMD and cervical spine abnormalities. According to Armijo-Olivo et al.[9], the prevalence of neck pain in their sample of subjects with TMD was high; approximately 88% of subjects with mixed TMD had self-reported neck pain.

Several studies demonstrate correlations and associations between TMD and signs and symptoms of cervical dysfunctions and despite increasing evidence, this is still explained by the intimate anatomical connections[10,11], neurophysiological mechanisms that connect these two regions[12-14], and pain[15].

The work of Truong Quang Dang et al.[16], investigated the relationship between dental occlusion and arm strength; in particular, jaw imbalance could cause a loss or decrease in upper limb strength. During functioning, mechanical loads on the scapula are transferred to the shoulder and cervical spine, through the double orientation of the musculature (upper trapezius and scapular elevation)[17-19], and this may be altered in patients with cervical dysfunction[20], in addition to being frequently cited for involvement in myofascial neck pain[21].

Based on the literature cited above, the current study hypothesized that women with TMD would present decreased isometric strength generation of scapular elevation in the orthostatic position when compared with asymptomatic women. Measurements of the function and strength of scapular elevation were not found in the existing literature, especially when related to patients with TMD. This information may help to elucidate the functionality of this structure in patients with TMD, using an inexpensive, simple, and objective evaluation method. The possibility of correlations between muscle strength in scapula elevation and subjects with TMD could bring elements that are easy to access for the clinical evaluation of these subjects in the future. Thus, the current study aimed to verify if there is a difference in developing the strength of scapular elevation between women with TMD and asymptomatic women.

Methods

Study design

This is an observational, cross-sectional study. The study was approved by the Research Ethics Committee of the University (CAAE 65444417.1.0000.5507) and led by LARET (Therapeutic Resources Laboratory) from UNIMEP (Methodist University of Piracicaba).

Sample size

A sample size calculation was performed, based on a pilot study comparing the groups, composed of 6 volunteers in each group. The measure used was the movement of scapular elevation strength. The mean and standard deviation values of the Control Group (CG) and the Temporomandibular Disorder Group (TMDG) were, respectively, 23.23±6.38 Kgf and 43.98±6.91 Kgf. According to the variables, for an effect size of 0.32, power of 80%, and 20% alpha, following the analysis of the results, 15 volunteers were required per group. The sample size calculation was performed using GPower® software, version 3.1.9.2.

Inclusion criteria

For inclusion in the TMDG, volunteers were required to be female university students, aged between 18 and 40 years, with a body mass index (BMI) ≤25kg/m², and a diagnosis of TMD according to the Diagnostic Criteria for Temporomandibular Disorders (DC/TMD)[22]. The diagnoses accepted in this study were myalgia, local myalgia, myofascial pain with spreading, myofascial pain with referral, disc displacement with reduction, disc displacement with reduction and with intermittent locking, disc displacement without reduction and with a limited opening, disc displacement without reduction and limited opening, degenerative joint disease, and arthralgia.

For inclusion in the CG, the subjects were required to be female university students aged between 18 and 40 years, with a BMI<25kg/m², and no diagnosis of TMD according to the DC/TMD.

Exclusion criteria

In the TMD group, volunteers that did not present a TMD diagnosis or presented a diagnosis of degenerative joint diseases in the TMJ were excluded. For both groups (TMD and Control) the following exclusion criteria were considered; volunteers that were under physiotherapeutic or pharmacological treatment (analgesic, anti-inflammatory, and muscle relaxant), presented tooth loss, using a full or partial dental prosthesis, history of trauma in the face and/or TMJ, and history of dislocation and/or subluxation of the TMJ.

Assessment tools

Diagnostic Criteria of Temporomandibular Disorder (DC/TMD)

The DC/TMD is a validated biaxial questionnaire for myogenic TMD diagnosis[23]. Axis I of the DC/TMD includes a physical evaluation and considers recurrent factors in the patient's daily life, while Axis II considers the previous history, including the beginning and perpetuating factors of the dysfunction[22-24]. The evaluator was trained and calibrated to use this tool.

Fonseca Anamnestic Index (FAI)

The FAI is a scale developed in Portuguese that assesses the severity of the myogenic temporomandibular disorder. The Short-Form Fonseca Anamnestic Index (SFAI) demonstrates a high level of diagnostic accuracy and may be used as a new version of the index for the diagnosis of myogenous TMD[25]. The FAI also presents multidimensionality, with dimension one (primary) consisting of five reliable and well fitting items for the composition of its structure[26]. The high degree of diagnostic accuracy demonstrates that the FAI can be employed for the identification of myogenous TMD in women[27].

This instrument consists of ten self-answered questions, which include information on difficulty opening the mouth and moving the jaw sideways; tiredness and/or muscle pain when chewing; frequent headaches; neck pain and/or a stiff neck; ear or joint pain in the face; noises in the joint when opening the mouth or chewing; if the teeth are well articulated; and whether a person is tense/nervous and has the habit of teeth clenching or grinding. The scale presents three possible answers: "yes" with a score of 10, "sometimes" with a score of 5, and "no" with a score of 0.

Neck Disability Index (NDI)

The NDI measures the extent to which neck pain affects activities of daily living such as personal care, lifting, reading, headaches, concentration, work, driving, and sleeping. The NDI is a relatively short validated, reliable, and responsive questionnaire that is easy to administer[8,28]. The 10 items produce a score from zero to 50. The level of neck disability for the NDI was determined as follows: 0–4 points: 'no disability', 5–14 points: 'mild disability', 15–24 points: 'moderate disability', 25–34 points: 'severe disability', and >35 points: 'complete disability'. The total score on the questionnaire was used for statistical purposes.

Maximal Voluntary Isometric Contraction (MVC)

To evaluate the muscle strength of the right and left scapular elevations, a model MM-100 (Kratos ®, São Paulo, SP, Brazil) load cell was used. The volunteers remained standing, on an eight-centimeter-high platform, to better accommodate the load cell. One end of the load cell was fixed to the ground by a metal hook and chain, and the other end was held by the volunteer to pull; the load cell did not allow movement, only isometric contraction. All subjects were asked to perform a unilateral shoulder elevation (shoulder blade) to keep the shoulder blade muscles in voluntary isometric contraction. The volunteers were instructed not to perform elbow flexion and/or trunk inclination, and to avoid possible postural compensations. A therapist observed the data collection to prevent any compensations (Figure 1). Two interspersed measurements of ten seconds were performed for each side, that is, two attempts for the right and two for the left. A two-minute interval was given between each attempt to avoid interference of muscle fatigue in the results. The choice of the right or left side was randomized.

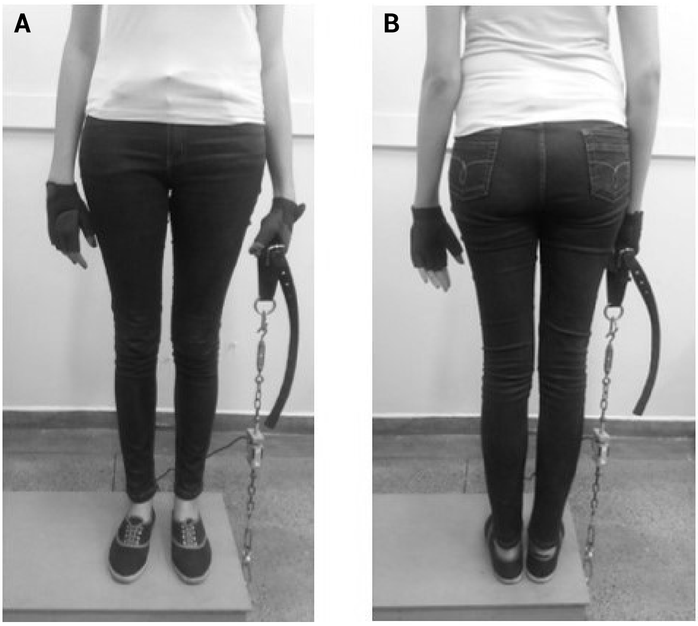

Figure 1. Muscle strength evaluation model of scapular elevation. a): anterior view; b): posterior view.

Procedures

At the beginning of the evaluation, all volunteers signed the consent form agreeing to participate of the study. The volunteers were instructed to answer an online questionnaire regarding personal and anthropometric data (body mass, height, age, sex), dominant hand, side preference for chewing, the FAI, and NDI. Next, the volunteers underwent the DC/TMD evaluation, and were divided into the control and TMD groups. Finally, the volunteers performed the MVC of the scapular elevation. Data from the MVC were obtained through EMG 830C signal acquisition module (EMG System do Brasil, São José dos Campos, Brazil) software. Data on the mean and maximum values of each attempt made using the load cell were extracted from this software and tabulated for later analysis.

Statistical analysis

Data were initially analyzed descriptively (means and standard deviations). Data normality was assessed by the Shapiro-Wilk test, which indicated normal data distribution.

To verify if there was a difference in the maximum muscle strength of right and left scapular elevations, and to compare the values of the NDI and FAI between the TMDG and CG, the t-test for independent samples was performed.

To compare the MVC of right and left scapular elevations between groups, and sides of masticatory preference, a two-way ANCOVA was used. The analysis was adjusted for age. Data analysis was performed using SPSS software, version 13.0.

It was considered statistically significant when the p-value was less than 5%.

Results

Figure 2 presents a flow chart of the recruitment and assignment to the groups.

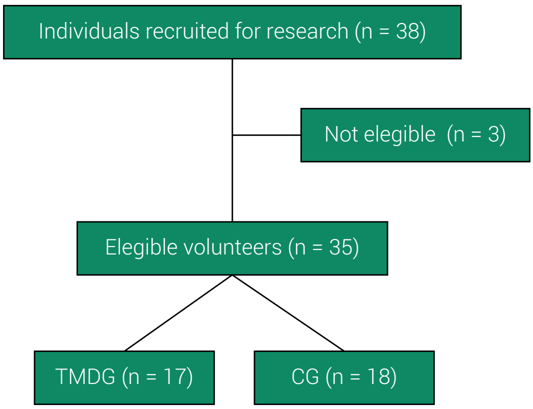

Figure 2. Volunteer recruitment flowchart.

Table 1 presents the characterization of the sample, highlighting the mean age of the volunteers of 22.89 ± 2.04 years, and chewing and manual preference on the right side.

Table 1. Sample characterization presented as mean and standard deviation for age, weight, height, and presented as the frequency of occurrence for chewing and manual preference (right/left) for the total sample, TMDG, and CG (n=35).

	N = 35	TMDG = 17	CG = 18
Age (years)	22.8±2.0	22.5±3.6	23.0±1.9
Weight (Kg)	61.6±7.2	61.8±11.5	62.5±6.5
Height (cm)	160.9±10.3	163.7±6.3	166.7±4.9
Chewing Preference (Right/Left)	30/5	13/4	17/1
Manual preference (Right/Left)	31/4	13/4	18/0

N: total sample; TMDG: Temporomandibular disorder group; GC: control group.

Table 2 presents the classification according to the DC/TMD for all volunteers.

Table 2. Diagnosis of volunteers according to the DC/TMD, presented as frequency of occurrence (n=35).

Diagnosis	
Control Group	18
Myalgia	16
Myofascial pain	16
Disc displacement with reduction, with intermittent locking (R/L)	9 (7/6)
Disc displacement without reduction, with limited opening (R/L)	1(1/1)
Disc displacement without reduction, without limited opening (R/L)	1 (1/1)
Arthralgia	14 (12/11)

DC/TMD (Diagnostic Criteria for Temporomandibular Disorders)R/L= Right/Left.

The maximum strength values and means found for right and left scapular elevations for each of the groups are presented in Table 3. No statistically significant differences were found between the TMDG and CG for the MVC of the right and left scapula elevations. There was a statistically significant difference (p=0.001*) in FAI scores between the TMDG (71.76±11.71) and CG (36.94±22.89). However, there was no difference between groups in relation to the NDI.

Table 3. Maximum and mean of strength measures for the variables (M.S.S.L.), total NDI and FAI scores for the TMDG and CG (n=35).

	TMDG (Mean±SD)	CG (Mean±SD)	p value
M.S.S.L. right (Kgf) maximum	33.1±10.9	27.3±7.2	0.059
M.S.S.L. right (Kgf) mean	28.7±9.7	23.0±6.7	0.053
M.S.S.L. left (Kgf) maximum	33.4±10.9	27.9±7,3	0.090
M.S.S.L. left (Kgf) mean	29.0±9.5	23.6±6.8	0.059
NDI	8.5±3.8	5.7±3.3	0.270
FAI	71.7±11.7	36.9±22.8	0.001*

SD: Standard Deviation; M.S.S.L.: Maximal strength of the scapular elevations; TMDG: Temporomandibular disorder group; CG: control group; NDI: Neck Disability Index; FAI: Fonseca Anamnestic Index. *Statistically significant difference between groups (p<0.05). A *t-test* was applied.

Table 4 shows the analysis of mean and standard deviation of maximal strength of scapular elevations, right and left sides, and masticatory preference between the TMDG and CG, using a two-way ANCOVA test. A t-test for independent groups was applied. All outcomes were grouped and none of the differences found were statistically significant.

Table 4. Maximum and mean of strength measures (Kilogram force) for the variables (M.S.S.L.) in the comparison between masticatory preference, and TMG and CG (n=35).

Muscle	group	Masticatory preference	Mean±SD	p value
M.S.S.L. Right Mean	TMDG	Right	30.8±8.1	0.46
		Left	21.8±12.3	
	Control	Right	23.4±7.0	
		Left	21.6±0.0	
M.S.S.L. Right Max	TMDG	Right	35.1±9.2	0.54
		Left	26.6±14.9	
	Control	Right	27.4±7.4	
		Left	25.3±0.0	
M.S.S.L. Left Mean	TMDG	Right	30.9±9.1	0.34
		Left	22.8±9.3	
	Control	Right	23.9±7.1	
		Left	24.7±0.0	
M.S.S.L. Left Max	TMDG	Right	35.0±9.8	0.52
		Left	28.2±14.2	
	Control	Right	28.3±7.6	
		Left	28.1±0.0	

M.S.S.L.: Maximal strength of the scapular elevations; Max: maximum; TMDG: Temporomandibular disorder group; CG: control group; SD: standard deviation. An ANCOVA test was applied. *Statistically significant difference between variables (p<0.05).

Discussion

The present results did not confirm the hypothesis that women with TMD present decreased isometric strength generation of scapular elevation in the orthostatic position when compared with asymptomatic women. No statistically significant differences were found between groups. Statistically significant differences were only found in FAI (p <0.001*) between the CG and the TMDG.

In the current study, the FAI presents significantly higher values in the TMD group, reaching a severe index, and the CG, unexpectedly showed a level that was between mild and moderate. No statistically significant differences were found between groups for the mean and maximum MVC test, respectively. Indeed, when the MVC values were adjusted by age and compared considering the masticatory preference, no statically significant differences were found between mean and maximum in the MVC test.

However, even without significance, the TMDG showed greater (28.7±9.71right; 29.07±9.56 left) development of isometric strength (mean) than the CG (23.03±6.79 right; 23.60±6.88 left). For the NDI, the groups were not statistically significantly difference and showed a mild disability index. The result presented by the TMDG in the measurement of strength may be related to the low values found in the NDI. The level of cervical disability was mild. Thus, we could suggest that the cervical musculature (upper trapezius and scapular elevation)[17,29], even with dysfunction, can still generate isometric strength normally. In addition, the FAI results showed severe levels in the TMDG and mild to moderate levels in the CG, yet despite this significant difference between the groups, the levels of isometric strength were similar. Some studies in the literature which also investigated the MVC of scapular elevation, evaluated women workers with self-reported neck/shoulder pain. The findings showed that the group with pain generated significantly lower force during maximal scapula elevation compared to healthy controls[30-32]. It is proposed that pain may impair the activation of the painful muscles. However, the same findings were not confirmed by the present study. This could occur due to the different population evaluated in this study, as well as the similar values in the NDI for both groups, showing that the control and TMD groups presented mild neck disability and, therefore, both groups presented pain, which could interfere in the strength measures.

Another study[33] that compared an asymptomatic group with a group presenting myofascial trigger points (MTP) and measuring the MVC of the scapular elevation, for both sides at the same time without trunk motion for 5 seconds, did not find a statistically significant difference between the groups. These findings agree with those in the present study since no difference was found between the groups. In addition, the authors reported that when scapular elevation was restricted, shoulder abductor strength was significantly lower in the MTP group than in the non-MTP group, suggesting that overuse of the upper trapezius can cause MTP by compensatory movements in shoulder abduction[33]. However, the present study did not evaluate the presence of myofascial trigger points or scapular restriction, therefore, this cannot be confirmed by our findings.

The current study also did not find significant differences when grouping and relating the masticatory preference with the mean and maximum forces of the control and TMD groups. The TMDG showed higher values of mean and maximum force, with the highest values predominating on the right side ($p=0.46$ and 0.54), but without statistical significance. These high values on the right side could be explained by the right hand and right chewing side dominance. In addition, Bech et al.[34] (2017) found that individuals with neck/shoulder pain compared with healthy subjects presented lower values in the MVC of scapula elevation, even after the data were adjusted for sex, which would confirm less capacity to generate MVC in muscles with pain or disability. However, when comparing the methodologies and resources used for the assessment with the current study, many differences stand out, such as self-assessment of pain and measurement of strength, in addition, of course, to the fact that the symptomatic group did not perform the TMD assessment[34].

It is well known that individuals with TMD present higher NDI scores than control groups[14]. According to the current literature, the prevalence of self-reported cervical pain ranges from 75 to 87.8% in individuals with TMD, and on average they present an NDI score 7.9 points greater than asymptomatic individuals[3]. This was partially found in the present study (TMDG: 8.59±3.82, CG: 5.78±3.37), however, although the TMD presented higher values than the control, no significant difference was found between the groups, and the scores of both groups can be classified as mild disability. Although this fact may influence cervical dysfunction, the focus of the study was the difference in strength between TMDG and CG individuals.

The FAI has been used as a complementary tool in the evaluation of TMD, due to its simplicity and the fact that it does not require specific pre-training for use in research, clinical practice, and in characterizing the severity of TMD. According to the study by Berni et al.[27] (2015) in the FAI accuracy assessment, a cut-off point was found, which determines the absence or presence of TMD, with a score between 0 and 45 and 50 to 100, respectively. This fact was demonstrated by the results of the FAI in the present study (TMDG: 71.76±11.71, CG: 36.94±22.89), with a statistically significant difference.

The contributions of this study are related to daily clinical practice and the belief that regions of dysfunction or muscles with local pain have less capacity to generate isometric strength. This fact reaffirms the importance of individualized assessment, independent of the diagnosis, to treat not only the pathology but also its causes and compensations.

This study proved to be innovative in the method of evaluation used and the methodological care taken, considering the muscle group evaluation, and the use of valid and reliable tools. In addition, a sample calculation was performed. The limitations include the small sample size, age range of the participants, absence of analysis of antagonist muscle strength, which could serve as a parameter for comparison. Other criteria for evaluating the cervical spine, such as range of motion, could provide further evidence of the relationship between the structures evaluated, especially regarding the functionality of both structures. Both groups presented a mild disability score on the NDI, which could interfere in the findings of the present study. Finally, it is known that young adult women can easily use adaptation and compensation mechanisms in presence of mild TMD, which can interfere with the results.

It is suggested that future studies using EMG evaluation be performed, as this tool could provide clarifications about the specific behavior of each muscle (scapula elevator, upper trapezius) and its antagonists (cervical flexors and sternocleidomastoid). It is also suggested that future studies evaluate a larger sample and men volunteers.

In conclusion, it was not possible to confirm the hypothesis that women diagnosed with TMD present lower isometric strength (mean and maximum) during scapular elevation (right /left). The results of the other comparisons and analyses between the groups also did not show statistically significant results, except for the results of the FAI.

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Data availability

Datasets related to this article will be available upon request to the corresponding author.

Lúcio Ferreira dos Santos: Data curation, Data analysis, Writing; **Fabiana Foltran Mescollotto:** Conceptualization, Methodology, Data curation, Data analysis, Writing; **Ester Moreira de Castro Carletti:** Methodology, Writing- Reviewing and Editing; **Elisa Bizetti Pelai:** Methodology, Writing- Reviewing and Editing; **Marcio de Moraes:** Writing- Reviewing and Editing; **Delaine Rodrigues Bigaton:** Conceptualization, Methodology, Writing- Reviewing and Editing; **Adriana Pertille:** Writing- Reviewing and Editing.

All authors actively participated in the discussion of the manuscript's findings and have revised and approved the final version of the manuscript.

References

1. Ferreira MP, Waisberg CB, Conti PCR, Bevilaqua-Grossi D. Mobility of the upper cervical spine and muscle performance of the deep flexors in women with temporomandibular disorders. J Oral Rehabil. 2019 Dec;46(12):1177-84. doi: 10.1111/joor.12858.
2. Fernández-de-las-Penas C, Svensson P. Myofascial Temporomandibular Disorder. Curr Rheumatol Rev. 2016;12(1):40-54. doi: 10.2174/1573397112666151231110947.
3. de Oliveira-Souza AIS, de O Ferro JK, Barros MMMB, Oliveira DA. Cervical musculoskeletal disorders in patients with temporomandibular dysfunction: A systematic review and meta-analysis. J Bodyw Mov Ther. 2020 Oct;24(4):84-101. doi: 10.1016/j.jbmt.2020.05.001.
4. Coskun Benlidayi I, Salimov F, Kurkcu M, Guzel R. Kinesio Taping for temporomandibular disorders: Single-blind, randomized, controlled trial of effectiveness. J Back Musculoskelet Rehabil. 2016 Apr 27;29(2):373-80. doi: 10.3233/BMR-160683.
5. Silveira A, Gadotti IC, Armijo-Olivo S, Biasotto-Gonzalez DA, Magee D. Jaw dysfunction is associated with neck disability and muscle tenderness in subjects with and without chronic temporomandibular disorders. Biomed Res Int. 2015;2015:512792. doi: 10.1155/2015/512792.
6. Hong SW, Lee JK, Kang JH. Relationship among Cervical Spine Degeneration, Head and Neck postures, and Myofascial Pain in Masticatory and Cervical Muscles in Elderly with Temporomandibular Disorder. Arch Gerontol Geriatr. 2019 Mar-Apr;81:119-28. doi: 10.1016/j.archger.2018.12.004.
7. Lai YC, Yap AU, Türp JC. Prevalence of temporomandibular disorders in patients seeking orthodontic treatment: A systematic review. J Oral Rehabil. 2020 Feb;47(2):270-80. doi: 10.1111/joor.12899.
8. Vernon H. The Neck Disability Index: state-of-the-art, 1991-2008. J Manipulative Physiol Ther. 2008 Sep;31(7):491-502. doi: 10.1016/j.jmpt.2008.08.006.
9. Armijo-Olivo S, Fuentes JP, da Costa BR, Major PW, Warren S, Thie NM, et al. Reduced endurance of the cervical flexor muscles in patients with concurrent temporomandibular disorders and neck disability. Man Ther. 2010 Dec;15(6):586-92. doi: 10.1016/j.math.2010.07.001.
10. Flores HF, Ottone NE, Fuentes R. Analysis of the morphometric characteristics of the cervical spine and its association with the development of temporomandibular disorders. Cranio. 2017 Mar;35(2):79-85. doi: 10.1080/08869634.2016.1162950.
11. Ferreira MC, Porto de Toledo I, Dutra KL, Stefani FM, Porporatti AL, Flores-Mir C, et al. Association between chewing dysfunctions and temporomandibular disorders: A systematic review. J Oral Rehabil. 2018 Oct;45(10):819-35. doi: 10.1111/joor.12681.
12. La Touche R, París-Alemany A, Mannheimer JS, Angulo-Díaz-Parreño S, Bishop MD, Lopéz-Valverde-Centeno A, et al. Does mobilization of the upper cervical spine affect pain sensitivity and autonomic nervous system function in patients with cervico-craniofacial pain?: A randomized-controlled trial. Clin J Pain. 2013 Mar;29(3):205-15. doi: 10.1097/AJP.0b013e318250f3cd.

13. Ballenberger N, von Piekartz H, Danzeisen M, Hall T. Patterns of cervical and masticatory impairment in subgroups of people with temporomandibular disorders-an explorative approach based on factor analysis. Cranio. 2018 Mar;36(2):74-84. doi: 10.1080/08869634.2017.1297904.

14. Armijo-Olivo S, Magee D. Cervical musculoskeletal impairments and temporomandibular disorders. J Oral Maxillofac Res. 2013 Jan 1;3(4):e4. doi: 10.5037/jomr.2012.3404.

15. von Piekartz H, Pudelko A, Danzeisen M, Hall T, Ballenberger N. Do subjects with acute/subacute temporomandibular disorder have associated cervical impairments: a cross-sectional study. Man Ther. 2016 Dec;26:208-215. doi: 10.1016/j.math.2016.09.001.

16. Truong Quang Dang K, Le Minh H, Nguyen Thanh H, Vo Van T. Analyzing surface EMG signals to determine relationship between jaw imbalance and arm strength loss. Biomed Eng Online. 2012 Aug 22;11:55. doi: 10.1186/1475-925X-11-55.

17. Diener I. The effect of levator scapula tightness on the cervical spine: proposal of another length test. J Manual Manip Ther. 1998;6(2):78-86. doi: 10.1179/jmt.1998.6.2.78.

18. Cools AM, De Wilde L, Van Tongel A, Ceyssens C, Ryckewaert R, Cambier DC. Measuring shoulder external and internal rotation strength and range of motion: comprehensive intra-rater and inter-rater reliability study of several testing protocols. J Shoulder Elbow Surg. 2014 Oct;23(10):1454-61. doi: 10.1016/j.jse.2014.01.006.

19. Kibler WB, Ludewig PM, McClure PW, Michener LA, Bak K, Sciascia AD. Clinical implications of scapular dyskinesis in shoulder injury: the 2013 consensus statement from the 'Scapular Summit'. Br J Sports Med. 2013 Sep;47(14):877-85. doi: 10.1136/bjsports-2013-092425.

20. Behrsin JF, Maguire K. Levator Scapulae Action during Shoulder Movement: A Possible Mechanism for Shoulder Pain of Cervical Origin. Aust J Physiother. 1986;32(2):101-6. doi: 10.1016/S0004-9514(14)60646-2.

21. Henry JP, Munakomi S. Anatomy, Head and Neck, Levator Scapulae Muscles. In: StatPearls. Treasure Island (FL): StatPearls Publishing; 2022.

22. Schiffman E, Ohrbach R. Executive summary of the Diagnostic Criteria for Temporomandibular Disorders for clinical and research applications. J Am Dent Assoc. 2016 Jun;147(6):438-45. doi: 10.1016/j.adaj.2016.01.007.

23. Schiffman E, Ohrbach R, Truelove E, Look J, Anderson G, Goulet JP, et al. Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) for Clinical and Research Applications: recommendations of the International RDC/TMD Consortium Network* and Orofacial Pain Special Interest Group†. J Oral Facial Pain Headache. 2014 Winter;28(1):6-27. doi: 10.11607/jop.1151.

24. Ohrbach R, Fillingim RB, Mulkey F, Gonzalez Y, Gordon S, Gremillion H, et al. Clinical findings and pain symptoms as potential risk factors for chronic TMD: descriptive data and empirically identified domains from the OPPERA case-control study. J Pain. 2011 Nov;12(11 Suppl):T27-45. doi: 10.1016/j.jpain.2011.09.001.

25. Pires PF, de Castro EM, Pelai EB, de Arruda ABC, Rodrigues-Bigaton D. Analysis of the accuracy and reliability of the Short-Form Fonseca Anamnestic Index in the diagnosis of myogenous temporomandibular disorder in women. Braz J Phys Ther. 2018 Jul-Aug;22(4):276-82. doi: 10.1016/j.bjpt.2018.02.003.

26. Rodrigues-Bigaton D, de Castro EM, Pires PF. Factor and Rasch analysis of the Fonseca anamnestic index for the diagnosis of myogenous temporomandibular disorder. Braz J Phys Ther. 2017 Mar-Apr;21(2):120-6. doi: 10.1016/j.bjpt.2017.03.007.

27. Berni KC, Dibai-Filho AV, Rodrigues-Bigaton D. Accuracy of the Fonseca anamnestic index in the identification of myogenous temporomandibular disorder in female community cases. J Bodyw Mov Ther. 2015 Jul;19(3):404-9. doi: 10.1016/j.jbmt.2014.08.001.

28. Vernon H, Mior S. The Neck Disability Index: a study of reliability and validity. J Manipulative Physiol Ther. 1991 Sep;14(7):409-15. Erratum in: J Manipulative Physiol Ther 1992 Jan;15(1):followi.

29. Ourieff J, Scheckel B, Agarwal A. Anatomy, Back, Trapezius. In: StatPearls. Treasure Island (FL): StatPearls Publishing; 2022.

30. Schulte E, Kallenberg LA, Christensen H, Disselhorst-Klug C, Hermens HJ, Rau G, et al. Comparison of the electromyographic activity in the upper trapezius and biceps brachii muscle in subjects with muscular disorders: a pilot study. Eur J Appl Physiol. 2006 Jan;96(2):185-93. doi: 10.1007/s00421-004-1291-2.

31. Søgaard K, Gandevia SC, Todd G, Petersen NT, Taylor JL. The effect of sustained low-intensity contractions on supraspinal fatigue in human elbow flexor muscles. J Physiol. 2006 Jun 1;573(Pt 2):511-23. doi: 10.1113/jphysiol.2005.103598.

32. Andersen H, Ge HY, Arendt-Nielsen L, Danneskiold-Samsøe B, Graven-Nielsen T. Increased trapezius pain sensitivity is not associated with increased tissue hardness. J Pain. 2010 May;11(5):491-9. doi: 10.1016/j.jpain.2009.09.017.

33. Kim HA, Hwang UJ, Jung SH, Ahn SH, Kim JH, Kwon OY. Comparison of shoulder strength in males with and without myofascial trigger points in the upper trapezius. Clin Biomech (Bristol, Avon). 2017 Nov;49:134-8. doi: 10.1016/j.clinbiomech.2017.09.001.

34. Bech KT, Larsen CM, Sjøgaard G, Holtermann A, Taylor JL, Søgaard K. Voluntary activation of the trapezius muscle in cases with neck/shoulder pain compared to healthy controls. J Electromyogr Kinesiol. 2017 Oct;36:56-64. doi: 10.1016/j.jelekin.2017.07.006.