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Maximum bilateral bite strength and RMS EMG for the diagnosis of myogenic TMD

Paulo Fernandes Pires[1], Elisa Bizetti Pelai*[2], Marcio de Moraes[2], Ester Moreira de Castro Carletti[3], Fabiana Foltran Mescollotto[3], Fausto Berzin[4], Delaine Rodrigues Bigaton[2]

[1] Graduate Program in Physical therapy, State University of Northern Paraná – UENP – Jacarezinho, PR, Brazil.

[2] Post Graduate Program in Oral and Maxillofacial Surgery, Piracicaba Dental School, University of Campinas – UNICAMP – Piracicaba, SP, Brazil.

[3] Post Graduate Program in Human Movement Sciences, Methodist University of Piracicaba - UNIMEP – Piracicaba, SP, Brazil.

[4] Post Graduate Program in Oral and Dental Biology, Piracicaba Dental School, University of Campinas – UNICAMP – Piracicaba, SP, Brazil.

Corresponding author:
Elisa Bizetti Pelai
Post Graduate Program in Oral and Maxillofacial Surgery, Piracicaba Dental School, State University of Campinas – UNICAMP – Av. Limeira, 901 - Areião, Piracicaba - SP, 13414-903.
Phone number +55 19 998052628.
E-mail: elisabpelai@gmail.com

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Aim: The study aimed to evaluate the accuracy of the maximum bilateral molar bite force and the Root Mean Square (RMS) Electromyography (EMG) index of the masticatory muscles in the maximum bilateral molar bite (MMBMax) of women with myogenic Temporomandibular Disorder (TMD) and asymptomatic. **Methods:** This is a cross-sectional study, composed of 86 women allocated to the TMD Group (n=43) and Control Group (n=43) diagnosis through the Diagnostic Criteria for Temporomandibular Disorders. The maximum bilateral molar bite force was evaluated using a bite dynamometer and the RMS EMG index of the masticatory muscles (anterior temporalis, masseter) during 5 seconds of the MMBMax task. Student t-test was used for data comparison between accuracy of the bite force and RMS EMG of masticatory muscles during the MMBMax. **Results:** The maximum bilateral molar bite force showed high accuracy (AUC=0.99) for the diagnosis of women with myogenic TMD and asymptomatic women, and the RMS EMG index evaluated during the MMBMax showed a moderate level of accuracy for all masticatory muscles (AUC=0.70 to 0.75). **Conclusion:** The bilateral bite dynamometer with a surface EMG during bilateral bite can be used to diagnose TMD in young women.

Keywords: Diagnosis. Electromyography. Temporomandibular joint disorders.

Introduction

Temporomandibular disorder (TMD), considered the main cause of pain in the orofacial region[1], is characterized by joint and/or muscular pain, limited or irregular mandibular function, and noises in the temporomandibular joints (TMJ)[2,3]. TMD presents a multifactorial etiology[4] making the diagnosis complex[5].The Diagnostic Criteria for Temporomandibular Disorders (DC/TMD)[1] is the gold standard tool for TMD diagnosis.

Individuals with TMD exhibit many changes in the electrical activity of masticatory muscles due to their dysfunction or through a compensatory mechanism associated with symptoms[6]. Therefore, surface electromyography (EMG) emerges as a bioelectric and non-invasive instrument that allows the assessment of muscle electrical activity[7], which can be used in the clinical environment to assist in the diagnosis of myogenic TMD[8,9].

The electrical activity of the masticatory muscles during the sustained submaximal molar bite task has been evaluated using a bite dynamometer or small thickness tension measurement sensors[10,11]. Xu, et al.[11] evaluated the submaximal unilateral molar bite sustained at 30% of the maximum bite force (MBF), using a small thickness unilateral bite dynamometer, for the maximum time tolerated by the volunteers, and found significantly higher values of normalized Root Mean Square (RMS) EMG in the TMD group compared to the control group in masticatory muscles.

MBF is one of the indicators of the functional status of the masticatory system[12] and can be affected by some factors: craniofacial morphology, sex, age, and occlusal status[13-15]. Todic et. al.[12] indicated that the TMD significantly affects the potential of masticatory muscle action which is confirmed by the analysis of MBF with significantly lower values in patients with TMD[16] and with the fact that MBF values decrease with the increase in the severity of TMD. One possibility is that the presence of masticatory muscle pain and/or TMJ inflammation can play a role in the MBF[17]. However, it is currently unclear how TMD affects MBF.

Based on the capacity of EMG to evaluate the electrical activity of the masticatory muscles and the dynamometer to measure force between individuals with TMD and asymptomatic individuals, it becomes important to analyze the instruments in question, by measuring their accuracy, since they present good applicability, easy access, and non-invasive assessments, which could assist health professionals in the diagnosis and treatment of TMD[18,19].

Accuracy analysis is defined as the amount of agreement between the measurement results of an instrument studied with the measurement results of another instrument already established and used as the gold standard, which can be calculated using the receiver-operating characteristic curve (ROC curve)[20,21].

Berni et al.[9] demonstrated that the RMS EMG index of the masticatory muscles has a moderate level of accuracy for discrimination between individuals with myogenic TMD and asymptomatic individuals during the TMJ rest task and inadequate levels of accuracy during the maximum isometric bilateral molar bite task. In contrast, Manfredini et al.[8] demonstrated that the RMS EMG index of the masticatory muscles shows moderate to high accuracy for the diagnosis of myogenic TMD during the maximal isometric bilateral molar bite task, but low accuracy levels in the TMJ resting task.

Based on the cited literature, data on the accuracy of the RMS EMG index of masticatory muscles during specific tasks are still conflicting. Furthermore, no information was found on the electrical activity of the anterior masseter and temporal muscles considering the use of a bilateral molar bite dynamometer. We hypothesized that there is a significant difference between women with TMD and asymptomatic women for values of maximum force of bilateral molar bite using the bite dynamometer, in the RMS EMG index of the masticatory muscles during the maximum bilateral molar bite and that these are accurate for the diagnosis of women with muscular TMD and asymptomatic women.

The present study aimed to evaluate the accuracy of the maximum bilateral molar bite force and the RMS EMG index of the masticatory muscles during the maximum bilateral molar bite in women with myogenic and asymptomatic TMD.

Methods

Study design

This is a cross-sectional study, approved by the Research Ethics Committee of the University, protocol nº. 25/2015. The volunteers who agreed to participate in this research signed a Consent Form.

Subjects

A sample size calculation was performed based on a pilot study. The outcome used was the surface EMG (masticatory pattern). The mean and standard deviation normalized RMS values of the anterior temporal muscle during the biting phase of the Control (n=10) and the TMD group (n=10) were, respectively, 89.06±8.21% and 83.44±6.64%, and, an effect size of 0.34 was found. For a power of 95% and a 5% alpha, *n* was determined as 43 volunteers per group. The calculation was performed using GPower® software, version 3.1.9.2. (Uiversität Kiel Kiel, Schleswig-Holstein, Germany).

The volunteers were recruited, from May 2016 to April 2017, from the Surgery Sector of a School of Dentistry (Sao Paulo State, Brazil).

Inclusion and Exclusion Criteria

Women aged between 18 and 45 years and Body Mass Index (BMI)<25 kg/m²[7,22] were selected. For the TMD group, the volunteers were required to be diagnosed with myogenic TMD (DC/TMD)[1] with the presence of present pain and/or fatigue in the masticatory muscles for at least 6 months.

Women who received physical or pharmacological treatment (eg. analgesic), with dental losses, who used total or partial dentures, with a history of facial and TMJ trauma, a history of subluxation or dislocation of the TMJ, and who were diagnosed with degenerative joint diseases through the DC/TMD were excluded from the study. For the control group, the volunteers were required not to present pain and any diagnosis of TMD (DC/TMD).

It is important to highlight that both groups contain only women for convenience, according to epidemiological studies, TMD is more prevalent in women than in men[23].

Materials

Diagnostic Criteria of Temporomandibular Disorder (DC/TMD)

The DC/TMD is a validated questionnaire to diagnose TMD. Axis I of the DC/TMD contains a physical evaluation and considers recurrent factors of the patient's daily life; Axis II considers the previous history, beginning, and perpetuating factors of the dysfunction[1].

Visual Analogue Scale (VAS)

The VAS was used to measure orofacial pain. It is a linear scale, 10 cm in length, labeled at the two extremes with the boundaries of pain sensation: "no pain" at one end, and "worst pain imaginable" at the other end[24,25].

Maximum bilateral molar bite force (MMBMax)

The MMBMax force was assessed using a bite dynamometer DFM021115/200 (EMG System do Brasil, São José dos Campos, Brazil) with iron rods designed for the oral bite, protected by silicone material 15 mm thick. The device has a Kgf scale with a reading capacity from 0 to 200 Kgf and was connected directly to one of the channels of the electromyographic acquisition module. The bite dynamometer was used to assess strength during MMBMax, maintaining a sampling frequency of 2000 Hz.

Before the tasks, all volunteers were trained on the day of collection to use the instrument and were asked to bite the instrument stem with upper and lower molar teeth bilaterally. Verbal encouragement was given during the bite tasks.

Electromyography

The EMG 830C signal acquisition module (EMG System do Brasil, São José dos Campos, Brazil) was used for reading the sEMG signals, with an impedance of >10 MΩ, analog/digital converter, 16-bit resolution, a sampling frequency of 2000 Hz, and fourth-order Butterworth filter.

Four differential surface electrodes (self-adhesive, Ag/AgCl, conductive gel) were used, and the distance inter-electrode was 10 mm. A reference electrode (30×40 mm) was positioned on the manubrium of the sternum. The electrodes were positioned following the criteria proposed by Cram[26]. The gain was 20×, a common mode rejection >130 dB, an input impedance of 10 GΩ, and signal-to-noise ratio <3 µV RMS.

Procedures

On the same day, after recruiting volunteers according to screening via the DC/TMD, anthropometric data, pain, EMG assessment of masticatory muscles, and MMBMax were collected in each volunteer for 5 seconds.

For the EMG evaluation procedure and MBF, the volunteers stayed seated in a chair respecting the Frankfurt parallel plan. For the MMBMax task, the volunteers were asked to perform the bilateral molar bite on the dynamometer with the maximum strength possible, even if they felt pain in the TMJ, to obtain the maximum bite force value and evaluation of the electrical activity of the masticatory muscles.

EMG signal processing and maximum bite force

The Matlab® Software 8.5.0.1976.13 (R2015a, MathWorks Inc., Natick, Massachusetts, USA) was used to process the EMG, and bite force data. A 4th order digital Butterworth filter was applied to the EMG signal, with zero phase delay (high pass of 10 Hz, low pass of 400 Hz). The first and second EMG signals were always eliminated to avoid interferences that occurred at the beginning and end of each collection.

The EMG indices were processed in the amplitude domain to determine the RMS values, through the evaluation of the magnitude of the electrical activity of the masticatory muscles during the MMBMax task.

Statistical Analysis

Data were submitted to the normality test (Kolmogorov-Smirnov) and described as mean, standard deviation, and 95% confidence interval.

The student t-test was used for intergroup comparisons of the RMS EMG index in the MMBMax task, as well as for anthropometric data, TMJ ROM movement, and maximum bilateral bite force.

The ROC curve was analyzed to determine the diagnostic accuracy (area under the curve - AUC), cut-off point, sensitivity and specificity of the maximum bilateral molar bite force, and RMS EMG index of the masticatory muscles referring to the MMBMax task. The values used for the AUC classification followed the recommendations of Greiner et al.[27] and Akobeng et al.[20]: excellent discrimination (0.90 to 1.0); good discrimination (0.80 to 0.90); moderate discrimination (0.70 to 0.80); poor discrimination (0.60 to 0.70); and discrimination no better than chance (≤0.50). The Youden index (YI) was also calculated by the formula: YI = ([sensitivity + specificity]–1)[28].

Based on the study by Akobeng, et al.[20], to identify the best cut-off point, the point with the lowest resultant value for the expression was selected: (1-sensitivity)2 + (1-specificity)2.

To guarantee the methodological quality of this study, intra-rater reliability was also analyzed for each muscle on the RMS EMG index and the maximum bilateral bite force considering the two repetitions collected in the MMBMax. For this purpose, the intraclass correlation coefficients (ICC), model: two-way mixed; type: absolute agreement; calculated reliability: single measurement. The ICC values were classified according to Weir[29]: ICC<0.40 (low reliability), ICC≥0.40to≤0.75 (good reliability), and ICC>0.75 (excellent reliability). The following formula was used to calculate the SEM: SEM=Standard Deviationx√(1-ICC).

Data processing was performed using SPSS® software, version 17.0 (Chicago, IL, USA). Significance was set at 5% (*p*<0.05).

Results

The final sample was composed of 86 women, divided into two groups: TMD Group (n=43) and Control Group (n=43).

Concerning the level of overall intra-rater reliability of the data, between the 2 repetitions in the MMBMax, excellent reliability was observed for the maximum bite force assessed through the dynamometer (ICC=0.97; EPM=6.67 Kgf). For the RMS EMG index, excellent levels of reliability were found for the right anterior temporal muscle (ICC=0.94; EPM:51.38 μV), left anterior temporal muscle (ICC=0.95; EPM:42.27 μV), right masseter (ICC=0.85; EPM:100.7 μV), and left masseter (ICC=0.86; EPM:101.39 μV).

Table 1 shows the TMD classifications of all volunteers, diagnosed using the DC/TMD.

Table 1. Diagnosis of volunteers according to the DC/TMD (n=86).

Diagnosis	
Control Group	43
Myalgia	22
Myofascial pain	15
Myofascial pain with referral	6
Disc displacement with reduction (R/L)	14 (10/9)
Disc displacement without reduction, with limited opening (R/L)	4 (4/4)
Disc displacement without reduction, without limited opening (R/L)	6 (5/6)
Arthralgia	34 (25/28)

R/L= Right/Left

Table 2 shows that the groups were homogeneous in terms of age and BMI and presented a significant difference in ROM of mouth opening without pain. The groups also demonstrated homogeneity regarding the preference of the chewing side (X2=2.90; p=.14), since in the TMD group 15 volunteers had a preference for chewing on the left side and 28 on the right side and, in the Control Group, 8 volunteers had a preference for chewing on the left side and 35 on the right side.

Table 2. Intergroup comparison of anthropometric data and ROM of the TMJ.

	Mean±standard deviation	Significance
AGE (years)		
TMD Group	28.72±8.04	*t*=1.25; p=0.21
Control Group	22.69±6.94	

Continue

Continuation

BMI (Kg/m2)		
TMD Group	22.43±2.51	*t*=-0.61; p=0.54
Control Group	22.74±2.13	
Orofacial pain intensity in rest (cm)		
TMD Group	3.13±2.68	NA
Control Group	0.0±0.0	
ROM of active mouth opening without pain (mm)		
TMD Group	33.04±11.73	*t*=-6.91; p<0.001*
Control Group	46.85±5.51	
ROM of active mouth opening with pain (mm)		
TMD Group	41.16±11.33	NA
Control Group	NA	
Right lateralization ROM of the ATM (mm)		
TMD Group	9.27±5.95	*t*=-1.63; p=0.10
Control Group	10.85±1.93	
ROM of lateralization to the left of the ATM (mm)		
TMD Group	10.81±8.06	*t*=-0.73; p=0.46
Control Group	11.76±2.29	
TMJ protrusion ROM (mm)		
TMD Group	6.32±4.80	*t*=-1.15; p=0.25
Control Group	7.23±1.8	

*Significant intergroup difference (T-student test). NA: not applicable.

Table 3 expresses the values of bite force and RMS EMG in the MMBMax task, in which a significant intergroup difference was found in the MMBMax and the electrical activity of the temporal and masseter muscles, with greater strength and activity in the control group.

Table 3. Comparison of maximum bite force (Kgf), orofacial pain (cm), and RMS EMG index (μV) in the MMBMax task.

	Mean±standard deviation	Mean difference (95%CI)	Significance
Maximum bilateral molar bite force			
TMD Group	30.85±9.69	-39.67 (-44.04\-35.30)	*t*=-18.03; p<0.001*
Control Group	70.52±11.13		
Orofacial pain intensity after MMBMax			
TMD Group		5.76±2.68	NA
Control Group		0±0	

Continue

Continuation

RMS EMG Anterior Temporalis Left Muscle			
TMD Group	114.90±57.60	-63.46 (-100.71\-26.22)	*t*=-3.40; p<0.001*
Control Group	178.36±111.19		
RMS EMG Masseter Left Muscle			
TMD Group	192.91±148.79	-69.50 (-125.34\-13.66)	*t*=-2.48; p=0.02*
Control Group	262.40±115.56		
RMS EMG Anterior Temporalis Right Muscle			
TMD Group	125.28±62.46	-78.89 (-120.41\-37.37)	*t*=-3.80; p<0.001*
Control Group	204.17±124.66		
RMS EMG Masseter Right Muscle			
TMD Group	192.68±126.65	-89.15 (-140.18\-38.11)	*t*=-3.47; p=0.00*
Control Group	281.83±117.53		

*Significant intergroup difference (t-student test). 95% CI: 95% confidence interval. NA: not applicable.

Figure 1 shows the ROC curves, respectively, of the MMBMax and the RMS EMG values of the masticatory muscles in the MMBMax.

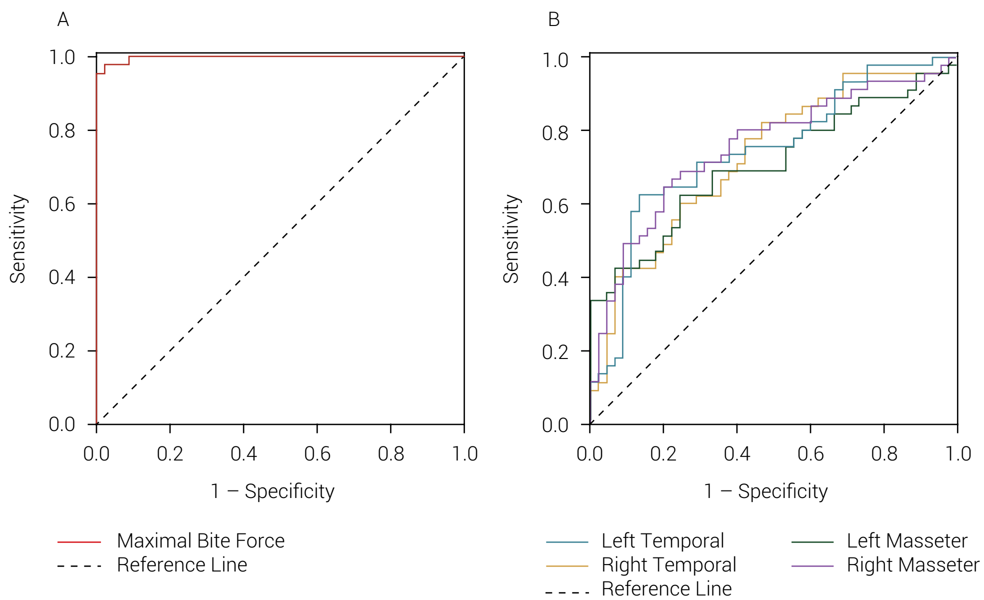

Figure 1. ROC curve A of the maximum bilateral molar bite force; B EMG RMS of masticatory muscles in the MMBMax.

Table 4 shows the levels of accuracy, sensitivity, specificity, and best cut-off point of the data illustrated in figure 2. It was observed that the maximum force of the bilateral molar bite showed a high level of accuracy and the values of RMS EMG during the MMBMax showed a moderate level of accuracy for the masseter and temporal muscles.

Table 4. Accuracy level of maximum bite force (Kgf) and RMS EMG values (µV) of masticatory muscles in MMBMax.

AUC (IC95%)	Best Cut Point	Sensitivity (%)	Specificity (%)	J ([sensitivity+specificity] – 1)
Maximum bilateral molar bite force				
0.99(0.00 - 1.00)	52.41	97.78	97.78	0.95
RMS EMG Anterior Temporalis Left Muscle				
0.74(0.64 - 0.85)	107.4	62.22	86.67	0.49
RMS EMG Masseter Left Muscle				
0.70(0.60 - 0.81)	173.03	62.22	75.56	0.38
RMS EMG Anterior Temporalis Right Muscle				
0.73(0.63 - 0.83)	136.9	60	75.56	0.35
RMS EMG Masseter Right Muscle				
0.75(0.65 - 0.86)	208.59	68.89	75.56	0.44

AUC: Area under the ROC curve; J: Youden Index

Discussion

Force

The results demonstrated a high level of accuracy in the maximum bilateral molar bite strength assessed using a bite dynamometer for the diagnosis of women with myogenic TMD. It is important to emphasize that this research is pioneering since it defines the best cut-off point in the use of the instrument in question for the diagnosis of myogenic dysfunction. These findings need to be interpreted with caution, since they should be used in line with the criteria employed in this study, that is, in young women, using a 15 mm thick bilateral molar bite dynamometer.

Considering the methodology used in this research, the value of 52.41 Kgf was established as the best cut-off point for the diagnosis of myogenic TMD; positive cases should be diagnosed when the MMBMax is less than the cut-off point, and negative cases when the maximum force is equal to or greater than the cut-off point.

This research also found a significantly greater difference in MBF for the control group compared to the TMD group. This fact is in agreement with previous research, such as the study by Kroon and Naeije[30], who evaluated maximum strength with a force transducer for an incisive bite; Castroflorio et al.[10] who portrayed the maximum force of the bilateral molar bite with an intraoral force transducer; and Xu et al.[11] who observed maximum strength with a unilateral molar bite dynamometer. On the other hand, Koyano, Kim and Clark[31], analyzed maximum strength with a bilateral molar bite dynamometer and found no significant difference between the group with dysfunction of the masticatory muscles and the control group.

These disagreements are due to the influence of anatomical and physiological factors of each individual evaluated, which directly influences the measurement of the bite force. It is also known that the MBF varies according to the location of the force transducer or bite dynamometer in the oral cavity; the more posterior, the greater the maximum bite force record[14]. For the most adequate record of maximum bite force, an interocclusal distance of 9 to 20 mm should be used, with a load applied on several teeth for larger support area[32].

In the present study, the greater magnitude of maximum bite force found in the control group may be justified by the 15 mm thickness of the bite dynamometer, which in turn may have favored the optimization of the length-tension relationship of masseter muscles during the evaluation in the masticatory muscles or TMJ in this group. The myogenic TMD group, due to the chronic installed dysfunction and pain during the bite task, may have presented inhibitory mechanisms of the maximum bite force[17,33].

Electromyography

This study showed a moderate level of accuracy in the RMS EMG values of the masticatory muscles during the MMBMax for the diagnosis of women with myogenic TMD.

Considering the masticatory muscles, the following values are established as the best cut-off points for the diagnosis of myogenic TMD, in which positive cases should be diagnosed when the RMS EMG value is less than the cut-off point, and negative cases when the maximum force is equal to or greater than the cut-off point: left anterior temporal muscle (107.4 μV), right anterior temporal muscle (136.9 μV), left masseter (173.3 μV), and right masseter (208.59 μV).

Manfredini et al.[8] and Berni et al.[9] assessed the accuracy levels of the RMS EMG parameter in a bite task and reported inconsistent findings. In general Berni, et al.[9] demonstrated that the RMS EMG parameter of the masticatory muscles showed a moderate level of accuracy for the discrimination between individuals with myogenic TMD and asymptomatic individuals during the TMJ rest task and inadequate levels of accuracy during the maximum isometric bilateral molar bite. Conversely, Manfredini, et al.[8] demonstrated that the RMS EMG parameter of the masticatory muscles demonstrated a high level of accuracy for the diagnosis of myogenic TMD during the maximal isometric bilateral molar bite task, but low levels of accuracy in the TMJ rest task.

Strengths and Limitations

This study presents as strengths a large sample size, robust statistical analysis, the cut-off of MMBMax and the RMS EMG index of the masticatory muscles during the maximum bilateral molar bite, and a new perspective of tools already used in research and clinical practice.

The limitations were: absence of an evaluation of the facial pattern of the volunteers; the need for caution when interpreting and using the accuracy cut-off point for MMBMax for discrimination of women with myogenic and asymptomatic TMD, as these values should be used only for young women and with the use of a 15 mm thick bilateral molar dynamometer; the presence of some cases with other joint symptoms, such as disk displacement and arthralgia, in the sample.

Future studies

The evaluation of the volunteers' menstrual cycle phase is suggested. The literature portrays a greater capacity for modulating pain in the ovulatory phase of the cycle, which may complement the findings of this research.

Considering the ability of surface EMG to assess myogenic TMD, non-invasively and painlessly, providing quantitative and reliable information both in the clinical and research environment[10], its use is suggested for monitoring and directing the treatment of myogenic TMD, as already used in research over the years.

In conclusion, the research hypothesis was confirmed, the maximum bilateral bite force demonstrated high precision for myogenic TMD diagnosis women, and the RMS EMG index of the masticatory muscles in the MMBMax was able to discriminate between groups. The bilateral bite dynamometer with a surface EMG during bilateral bite can be used to diagnose TMD in young women.

Data availability

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

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Paulo Fernandes Pires: Conceptualization, Methodology, Data curation, Data analysis, Writing; **Elisa Bizetti Pelai:** Conceptualization, Methodology, Data curation, Data analysis, Writing; **Ester Moreira de Castro Carletti:** Writing- Reviewing and Editing; **Marcio de Moraes:** Writing- Reviewing and Editing; **Fabiana Foltran Mescollotto:** Writing- Reviewing and Editing; **Fausto Berzin:** Writing- Reviewing and Editing; **Delaine Rodrigues Bigaton:** Conceptualization, Methodology, Writing- Reviewing and Editing

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