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ARTICLE

MASTICATORY FUNCTION ACCORDING TO BODY MASS INDEX. PART II: ELECTROMYOGRAPHIC ANALYSIS.

Función masticatoria según índice de masa corporal. Parte II: Análisis electromiográfico.

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ABSTRACT:

Introduction: The objective of this study was to explore the electrical activity of the superficial muscles of mastication required to exert unilateral maximum bite force in subjects with different body mass index.

Material and Methods: A cross-sectional observational study was conducted with a sample of 21 participants with an average age of 22.9 ± 3.5 years who were classified according to their body mass index, forming three study groups: normal weight (18.5-24.9), overweight (25-29.9) and obesity (≥30), with seven participants each. Through surface electromyography, the superficial muscles of mastication during right and left maximum bite force were evaluated.

Results: No statistically significant differences in the maximum bite force were observed between the study groups. The data obtained from the electromyographic analysis of the superficial muscles of mastication demonstrate a trend indicating that subjects with a normal body mass index similarly activate the muscles on each side when performing a maximum bite force on a particular side, while overweight or obese subjects demonstrated significantly greater activation of the temporalis muscle associated with the side where the maximal bite force is performed.

Conclusion: Our findings suggest that the maximum bite force is not influenced by body mass index and that during the performance of a maximum bite force subjects with increased body mass index present a greater activation of the temporalis muscle associated with the side where the maximum bite force was performed.

KEYWORDS:

Bite force; Mastication; Electromyography; Masticatory muscles; Temporal muscle; Body mass index.

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RESUMEN:

Introducción: El objetivo de este estudio fue explorar la actividad eléctrica de los músculos superficiales de la masticación, necesarios para ejercer la máxima fuerza de mordida unilateral, en sujetos con diferente índice de masa corporal.

Material y Métodos: Se realizó un estudio observacional de corte transversal con una muestra de 21 participantes con una edad promedio de 22.9 ± 3.5 años, quienes fueron clasificados de acuerdo a su índice de masa corporal, formando tres grupos de estudio: peso normal (18,5-24,9), sobrepeso (25,0-29,9) y obesidad (≥30.0), con siete participantes cada uno. La electromiografía de superficie evaluó los músculos superficiales de la masticación durante la fuerza de mordida máxima derecha e izquierda.

Resultados: No se observaron diferencias estadísticamente significativas en la fuerza de mordida máxima entre los grupos de estudio. Los datos obtenidos del análisis electromiográfico de los músculos superficiales de la masticación demuestran una tendencia que indica que los sujetos con un índice de masa corporal normal activan de manera similar los músculos de cada lado cuando ejercen la fuerza de mordida máxima en un lado en particular. mientras que los sujetos con sobrepeso u obesos demostraron una activación significativamente mayor del músculo temporal asociado con el lado donde se realiza la fuerza máxima de mordida.

Conclusión: Nuestros hallazgos sugieren que la fuerza de mordida máxima no está influenciada por el índice de masa corporal y que durante la realización de una fuerza de mordida máxima los sujetos con índice de masa corporal aumentado presentan una mayor activación del músculo temporal asociado al lado donde se realizó la fuerza de mordida máxima.

PALABRAS CLAVE:

Fuerza de la mordida; Masticación; Electromiografía; Músculos masticadores; Músculo temporal; Índice de masa corporal .

INTRODUCTION.

Obesity is a nutritional alteration associated with considerable health risks.[1,2] This disease has become more prevalent, passing an epoch from having underweight prevalence outpaced obesity, to one in which obesity outweigh underweight.[2] This implies an ever-increasing socio-economic load on the healthcare system3.

The body mass index (BMI) is an indicator of body composition, it is calculated with the value of the weight in kilograms divided by the square of the height in meters[4,5] and has good specificity, but low sensitivity, as it does not differentiate lean body mass from fat, so it may not classify as obese people who are actually obese.[6] However, it is currently the most widely used index recommended by the WHO for the classification of overweight and obesity, simple and quick to apply.[4]

The stomatognathic system is responsible for complex vital functions, such as chewing, swallowing, breathing and phonation.[7]

Masticatory function involves the participation of a series of highly coordinated physiological mechanisms, including neuromuscular mechanisms that integrate and involve all the structures of the stomatognathic system.[8]

The muscles of mastication play an important role in the masticatory process, as they allow the generation of complex, well-organized and coordinated jaw movements.[8] The functionality of these muscles can be evaluated through different parameters, among the objective techniques for the evaluation of muscle function we find surface electromyography (sEMG), which allows the recording of the electrical activity generated by the muscle by detecting the changes in electrical

potential produced by the depolarization of the cell membranes during muscle contraction.[9] Another parameter to evaluate the function of the masticatory muscles is the maximum bite force (MBF), which is defined as the maximum force generated between the maxillary and mandibular teeth,[10] and is an attempt to quantify the total force of the muscles involved in mandibular closure.[11]

The literature has pointed out the importance of analyzing the electrical activity of the masticatory muscles during the performance of MBF, due to the association that exists between these two variables, since, as has been shown, the masticatory muscles are responsible for generating the force necessary to grind food.[12]

On the other hand, researchers have studied the influence of these two factors on BMI, where they have been able to demonstrate that subjects with a higher BMI tend to chew with greater force than those with a lower BMI.[13]

This led us to propose that the objective of this study, which is to explore the electrical activity of the superficial muscles of mastication required to exert unilateral maximum bite force in subjects with different body mass index.

MATERIALS AND METHODS.

The following exploratory study was conducted at the Universidad de La Frontera in the city of Temuco and analyzes the electrical activity of the superficial muscles of mastication required to exercise unilateral maximum bite force (right and left) in participants with different body mass index.

Ethics statement

The present study was approved by the Scientific Ethics Committee of the Universidad de La Frontera (File No. 039_19). In conformity with the World Medical Association's Declaration of Helsinki (2008), voluntary informed consent was obtained in writing from the volunteers prior to participation, who were informed of the nature of the study.

Sample and eligibility criteria

Sampling by convenience was used on 21 participants (14 men and 7 women, aged 22.9±3.5 years), who were classified according to BMI and divided into three groups: normal (BMI: 18.5 – 24.9), overweight (BMI: 25 – 29.9) and obese (BMI: ≥30), and each group had seven participants. Males and females over 18 years of age were included, with no current pharmacological treatments, with continuous and complete maxillary and mandibular dental arch (up to the second molar), with normal occlusion and no orthodontic devices. Subjects with oral injuries that made correct mandibular movement difficult, such as angular cheilitis, cankers or traumas, and those with signs or symptoms of temporomandibular joint (TMJ) disorders, were excluded.

For the identification of these signs and symptoms, the clinical screening and examination recommended by the American Academy of Orofacial Pain was applied (1993).[14] A temporomandibular joint diagnosis by a specialist in temporomandibular disorders was not included.

Anthropometric measurements

BMI was assessed using a clinical scale, which has a balance to measure weight in kilograms and a measuring rod to measure the height in meters.

Simultaneous measurement of MBF and sEMG

In this study, MBF was evaluated in simultaneity with sEMG of the superficial muscles of mastication.

To record the MBF, an occlusal force sensor (GM10, Nagano Keiki, Tokyo, Japón) was used: a hydraulic pressure device with an interchangeable polyvinyl cover that records force in Newtons, the measuring range of this instrument is from 0 to 1000 N, with an accuracy of ± 1 N. For the evaluation of the sEMG of the superficial muscles of mastication, a surface electromyograph (sEMG VIII, ArtOficio, Chile) was used, which has eight channels or electrodes, of which four were used for this study.

To conduct the recordings, each participant was seated on a chair without head support, with the Frankfurt plane parallel to the floor.[15] The electrodes of the sEMG were positioned, the area of the skin was cleaned previously with alcohol to eliminate fat and dead cells from the skin, reducing the impedance of the electrode-skin interface and

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improving the transmission of the electrical activity of the muscle. A small amount of conductive gel (Signa gel, Parker Laboratories, Inc, New Jersey, USA) was also used to enhance acquisition of the signal. Four bipolar sEMG electrodes were placed on the skin, distributed on the masseter muscle and anterior portion of the temporal muscle, on both sides. The poles of the electrode were located one after the other in the direction of the muscle fibers, over the most prominent region at the moment of muscle contraction, (Figure 1A).

In the case of the temporal muscle, the electrode was located in the anterior portion of the muscle at the level of the coronal suture, 2 cm above the zygomatic arch, and in the masseter muscle the electrode was located in the center of the muscle at its most prominent point during contraction.

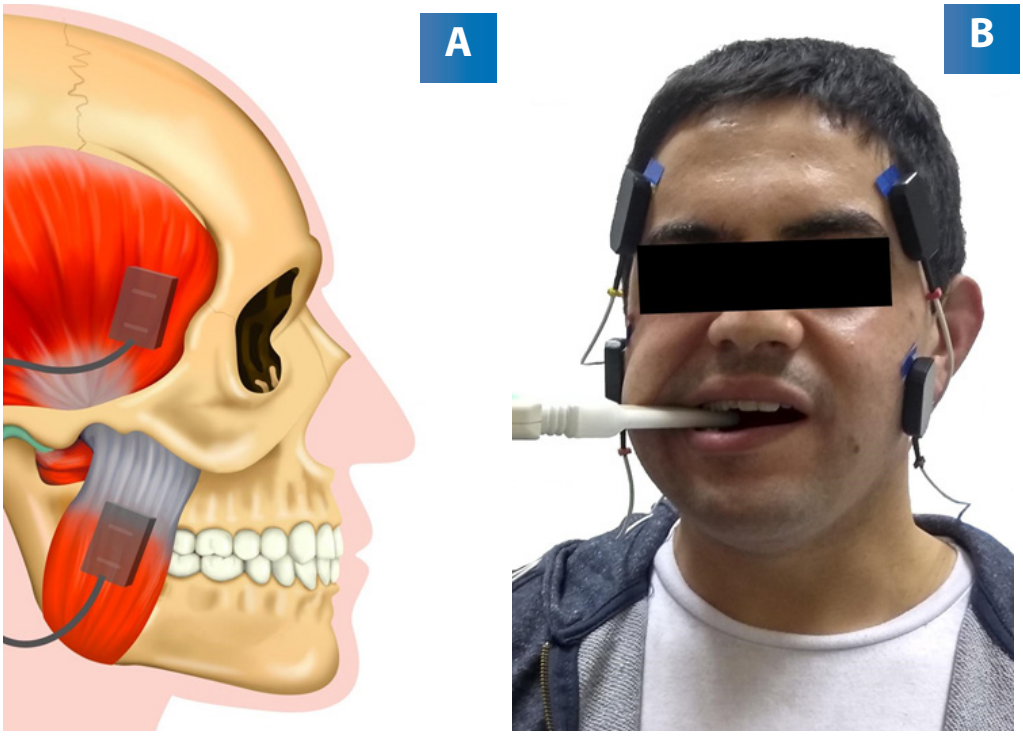
Finally, a reference sensor was placed on the elbow of the participant, as this is an electrically neutral area. With the sEMG electrodes located on the surface of the muscles to be analyzed, and the reference sensor placed on the elbow, the participant was prepared to begin with the simultaneous recording of electromyography and MBF. The participant had to press the occlusal force sensor as hard as possible without moving their head (Figure 1B).

The measurements were taken bilaterally in the molar area, with three repetitions per area and a 2-minute rest between recordings. The recording was taken for 5 seconds, and the highest value recorded in each position was used as the MBF.[15] The value of the electromyographic activity was the recording selected for the highest MBF.

Data processing

The sEMG data were stored in text files (.txt). The signals were processed using the MATLAB software (The MathWorks, Inc., Natick, MA, U SA), and through specific scripts specially developed for this study, it was possible to obtain the mean value of the EMG RMS signal, calculated for a window of 50ms.

Figure 1. Four bipolar sEMG electrodes were placed on the skin, distributed on the masseter muscle and anterior portion of the temporal muscle.



A: sEMG electrode positioning on the masseter muscle and anterior fibers of the temporal muscle.
B: Sensor positioning occlusal force molar area and sEMG electrodes on the masticatory muscles.

Statistical analysis

The data was organized in an OpenOffice Calc spreadsheet (Apache Software Foundation, Los Angeles, USA). A descriptive analysis of the data was performed, in which the mean and standard deviation were determined.

The Shapiro-Wilk test was applied to check normality. The non-parametric Kruskal-Wallis test was applied for the comparison of the MBF between the different BMI groups and the Wilcoxon sign rank test for the comparison of the electrical activity of the muscles between pairs of muscles.

The Mann-Whitney U test was applied post hoc. Pearson's correlation between BMI and MBF, and also between BMI and electromyographic activity of the studied muscles was performed. For the analysis of the data, the software SPSS Statistics (IBM, New York, USA) (version 27.0) was used. A value of α= 0.05 was chosen as the threshold of significance

Table 1. Maximum bite force according to BMI (n=21). Comparison of the average *p*-values of the maximum bite force in the three study groups

CLASSIFICATION Body mass index	AGE (YR) MEAN ± SD, (RANGE)	MEAN ± SD, FORCE (N) RIGHT	LEFT	*p*-value
Normal (n=7)	23 ± 2.7, (20-28)	454.86±248.22	421.86±273.33	0.86
Overweight (n=7)	22.1 ± 3.5, (18-28)	538.14±159.95	507.14±117.72	0.61
Obese (n=7)	23.6 ± 3.6, (19-29)	450.29±201.31	477.60±189.18	0.49
p-value =		0.49	0.53	

p<0.05: Kruskal-Wallis test. BMI: Body mass index.

Table 2. Surface electromyography of the muscles of mastication during MBF according to BMI (n=21).

BMI	Age (year) Mean ± SD (Range)	Molar Area MBF	Mean ± Standard Deviation / EMG (μV) Masseter (M)	Temporal (T)	Masseter (M)	Temporal (T)	p (R-L) M	T
Normal	23 ± 2.7	Right	73.0 ± 46.7	87.1 ± 39.2	71.2 ± 34.6	70.6 ± 65.4	1	0.23
(n=7)	(20-28)	Left	53.9 ± 28.3	47.1 ± 40.0	71.8 ± 38.9	83.5 ± 48.7	0.06	0.06
Overweight	22.1 ± 3.5	Right	45.7 ± 15.3	80.3 ± 58.6	58.9 ± 36.0	44.9 ± 23.3	0.31	0.02
(n=7)	(18-28)	Left	58.4 ± 23.0	44.4 ± 23.0	56.3 ± 37.4	61.9 ± 18.8	0.86	0.01
Obese	23.6 ± 3.6	Right	57.4 ± 24.7	48.6 ± 33.0	60.1 ± 41.8	66.5 ± 53.1	0.61	0.86
(n=7)	(19-29)	Left	46.0 ± 20.3	29.9 ± 20.2	66.5 ± 43.9	77.4 ± 49.8	0.12	0.01

Comparison of the average values of the surface electromyography of the muscles of mastication during MBF in the three study groups. *p*<0.05: Wilcoxon sign range test. SD: Standard deviation. MBF: maximum bite force. BMI: Body mass index.

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RESULTS.

Of the evaluations performed, it was possible to analyze the following.

Maximum Bite Force

The results of the MBF measurements in molars on both sides (Table 1). We did not observe any significant differences in the values among any of the study groups, nor on the right and left sides of each group. No significant correlation was found between MBF and BMI.

Surface electromyographic activity in isometric contraction

The analysis of the electromyographic activity of the superficial muscles of mastication was analyzed according to the side in which the MBF was measured in each group.The analysis revealed that in the normal BMI group there were no significant differences in the electromyographic activity in the right and left master and temporal muscles according to the side where the MBF was performed, however in the overweight group there was a significantly higher electrical activity in the temporal muscle associated to the side where the MBF was performed: right side (p=0.02) and left side (p=0.01), in the obese group the electrical activity of the temporal muscle was only greater when performing MBF on the left side (p=0.01) (Table 2). No significant correlation was found between the electromyographic activity of the muscles evaluated and the BMI.

DISCUSSION.

The characteristics of muscle activity and bite force have a great influence on masticatory performance,[16,17] this has been evaluated in different studies that associate a greater muscle activity with greater masticatory performance and efficiency,[13,18] thereby demonstrating the fundamental role muscles fulfill in the masticatory process. Thus, their analysis both during MBF (static condition) and masticatory function (dynamic condition) is necessary.[12] In this study, we focused on evaluating the muscle activity generated in static conditions.

Different methodologies have been reported in the literature that have been used for the evaluation of masticatory force. Some are direct, using occlusal force sensors during the performance of MBF, while others have estimated it through the electromyographic signals generated by the superficial masticatory muscles during the masticatory process.[13] Among the possibilities for the assessment of muscle function, the simultaneous measurement of the electromyographic signal of the superficial muscles of mastication generated during MBF has been proposed, has been shown to be sufficiently reproducible for clinical application19 and was selected for this study.

Frecka *et al.*,[20] demonstrates that BMI has no effect on bite force or masticatory power through a study that determined masticatory force through electromyographic signals generated during mastication in normal weight and obese subjects.

These results are contrary to the study by White *et al.*,[13] in which normal, overweight and obese subjects were evaluated with a similar methodology, and it was observed that participants with a high BMI tend to chew more forcefully than participants with a BMI in the normal range.

The discordances in these results can be attributed mainly to the methodology used, as both assessed force through electromyography signals and not specific sensors as in the present study. A study conducted in Brazil by Isabel *et al.*,[21] in which they evaluated the MBF with a methodology similar to that presented in this study and compared it among participants classified according to their BMI into underweight, normal, overweight and obese, reported that the MBF values of the normal weight group were higher than those of the other groups, whose values did not differ from each other.

With respect to the electromyographic analysis of the masticatory muscles related to MBF, it was observed in the obese group that the electrical activity of the left temporalis muscle was significantly higher than that of the right during left MBF.

These results are in agreement with the study by Santos *et al*.,[22] where the electrical activity of the masseter and temporalis muscles was analyzed in a voluntary maximal intercuspal squeeze in a group of obese candidates for gastroplasty in Brazil, it was observed that the left temporalis muscle presented a higher percentage of electrical activity than the right one. Furthermore, they are related to the results reported by Figueiredo *et al*.,[23] who had already reported that in obese women, the electrical activity of the temporalis muscle presented certain asymmetries.

However, this last study, being performed in an exclusively female population, there may be other variables that influence muscle activity, such as differences in body composition that exist according to sex.[24] When evaluating the sEMG, it is important to take into account the degree of facial adiposity, since it can interfere with the passage of the electric current. For this it is necessary to evaluate the impedance, which is measured through the skin, thus avoiding abnormal results in the electromyographic analysis.[25]

Therefore, we could consider that the asymmetry observed in the results may be due to the degree and distribution of facial adiposity that obese people present and that was not analyzed in this study; therefore, it is necessary to perform studies that evaluate the value of the impedance corresponding to each sector to be analyzed by surface electromyography; no studies were found that analyze this variable.

Our results only demonstrate a trend indicating that subjects with a normal BMI similarly activate the muscles on each side when performing a MBF on a particular side, while overweight or obese subjects demonstrated significantly greater activation of the temporalis muscle associated with the side where the maximal bite force is performed.

In the limitations of the study we found that the small sample size of each group, negatively affects the statistical power of the study, also the lack of skin impedance assessment does not allow to detect whether the asymmetries in temporalis muscle electrical activity are due to facial adiposity or other related factors.

CONCLUSION.

Our findings suggest that the maximum bite force is not influenced by body mass index and that during the performance of a maximum bite force subjects with increased body mass index present a greater activation of the temporalis muscle associated with the side where the maximum bite force was performed.

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Conflict of interests:

No conflict of interest to declare.

Ethics approval:

The study was approved by the Scientific Ethics Committee of the Universidad de La Frontera, approval number: 039_19.

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Authors' contributions:

All authors contributed to the execution of the study and writing of the manuscript.

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