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Analysis of different tasks to normalize the electrical signal of the orbicularis oris muscle by maximum voluntary contraction: pilot study

Análise de diferentes tarefas para normalização do sinal elétrico do músculo orbicular da boca pela contração voluntária máxima: estudo piloto

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ABSTRACT

Purpose: To verify the electrical activity of the orbicularis oris in four different isometric tasks and to indicate the most appropriate task for use as a reference in the normalization of the electrical signal of the orbicularis oris muscle by maximum voluntary contraction. **Methods:** Twenty-two individuals participated in the study, of which 10 were male and 12 were female, with ages ranging from 20 to 33 years. The electrical activity of the upper and lower parts of orbicularis oris muscle was recorded during the following isometric tasks: lip protrusion with bilabial closure; lip protrusion without bilabial closure; the counter resistance using the plate of labial resistance and lips prehension. The order of the tasks was randomized among participants. Data were compared between tasks for each lip part. **Results:** in the upper marginal segment, the task with the highest mean and median amplitude was lip prehension, although there was no significant difference between tasks. The lowest coefficient of variation was obtained in the counter resistance task with the plate of labial resistance. In the lower marginal segment, the task with the highest mean and median amplitude was labial protrusion with lips closure, which also had the lowest coefficient of variation. In this segment, there was a significant difference between labial protrusion with lips closure and prehension, with the highest values obtained in the first task. **Conclusion:** lip protrusion with bilabial closure is suggested as reference for the normalization of the electrical signal of the orbicularis oris muscle, by maximum voluntary contraction.

Keywords: Masticatory muscles; Orbicularis muscle of the mouth; Facial muscles; Isometric contraction; Electromyography; Rehabilitation

RESUMO

Objetivo: pesquisar a atividade elétrica do músculo orbicular da boca em quatro diferentes tarefas isométricas e indicar a mais apropriada para utilização como referência na normalização do sinal elétrico do músculo orbicular da boca pela contração voluntária máxima. **Métodos:** participaram do estudo 22 indivíduos, sendo dez do sexo masculino e 12 do feminino, com idades entre 20 e 33 anos. A atividade elétrica das porções superior e inferior do músculo orbicular da boca foi registrada durante a realização das seguintes tarefas isométricas: protrusão labial com fechamento, protrusão labial sem fechamento, contrarresistência com a placa de resistência labial e preensão de lábios. A ordem de realização das tarefas foi randomizada entre os participantes. Os dados foram comparados entre as tarefas, para cada seguimento labial. **Resultados:** no segmento marginal superior, a tarefa com maior média e mediana de amplitude foi preensão labial, embora sem diferença significativa entre tarefas. O menor coeficiente de variação foi obtido na tarefa de contrarresistência com a placa de resistência labial. No segmento marginal inferior, a tarefa com maior média e mediana de amplitude foi protrusão labial com fechamento, que também teve o menor coeficiente de variação e diferença significativa entre as tarefas protrusão labial com fechamento e preensão, sendo os maiores valores obtidos na primeira. **Conclusão:** indica-se como referência para a normalização do sinal elétrico do músculo orbicular da boca, pela contração voluntária máxima, a tarefa de protrusão labial com fechamento.

Palavras-chave: Músculos da mastigação; Músculo orbicular da boca; Músculos faciais; Contração isométrica; Eletromiografia; Reabilitação

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INTRODUCTION

The orbicularis oris muscle, which constitutes the human lips, actively participates in important functions, such as speech, chewing, swallowing and facial mimicry[1]. Among the facial mimic muscles, the orbicularis oris is the only lip constrictor and its fibers are distributed from the nose to the labiomental sulcus[1]. This muscle has almost no bone origin, since only a few bundles are attached to the anterior nasal spine and incisive foveas of the maxilla and mandible[1]. The orbicularis oris muscle fibers have two different types of segments: peripheral and marginal, both divided into upper and lower. Peripheral segments refer to fibers distant from the mouth opening, while marginal segments correspond to the fibers surrounding the mouth opening[2].

Some clinical conditions lead to hypofunction or changes in the orbicularis oris muscle, such as mouth breathing[3], facial paralysis[4], and deleterious oral habits[5], among others. In such cases, one of the objectives of orofacial myofunctional therapy is to increase the strength and resistance of the orbicularis oris muscle, through myofunctional exercises, in addition to rehabilitating functions such as speech, chewing, swallowing, sucking and facial expressiveness[4,6]. However, information regarding the prescription of myofunctional exercises and the effectiveness of such muscle activities is still scarce and, therefore, there is no defined standard for such exercises[7].

It is known that surface electromyography is an important tool to provide information related to the state of muscle activation(8). Through this procedure, it is possible to investigate the electrical activity of the lips during effort tasks[8], making it a useful instrument in quantitative research on orofacial motricity[9,10]. Studies have shown that individuals with difficulty in lip sealing have higher electrical activity in the orbicularis oris muscle during the occluded lip posture than individuals who have a habitual posture of sealed lips[10,11] and that myofunctional labial exercises promote the reduced activity of this musculature at rest, that is, after the exercises, individuals with labial sealing difficulties require less effort to keep their lips sealed[11].

Given the large inter- and intra-subject variability in the electromyographic signal, in order for a comparison of muscle electrical activity between individuals, or even between different tasks, a reference pattern of muscle contraction needs to be used: this is a procedure called normalization of the signal[8].

In normalization, different parameters can be used in order to attenuate inter-individual differences. They are: the maximum voluntary contraction (MVC), in which the highest value found during a maximum isometric contraction of a certain muscle is used as a reference; the maximum signal peak[12], indicated to normalize dynamic contractions, using the signal peak found in a movement or cycle as a reference (dynamic peak method); the mean value of the signal, where the reference for normalization is the mean of the electrical signal of the muscle contraction (dynamic mean method)[13] and the fixed value of the signal, where the reference is the value of a submaximal or a submaximal isometric contraction of the studied muscle[12]. The submaximal contraction is performed with an absolute load lower than the maximum, or arising from a relative percentage of the maximum, such as 30%, 40% or 50%[14]. It is recommended that submaximal contractions be performed at a level lower than 80% of the MVC, as this provides more stable reference values for signal normalization[8].

MVC is the parameter recommended by the ISEK (International Society of Electrophysiology and Kinesiology)[15] and by SENIAM (Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles)[16]. Despite the criticisms that refer to the reliability of the value obtained as a true representation of the maximum contraction capacity of the assessed muscle and the great inter-individual variability, the MVC is the most commonly used parameter for normalizing the muscle electrical signal[8]. Sustained protrusion of the lips[17] and reciprocal lip compression (lip closure)[18] tasks have been proposed for normalization using the MVC parameter. However, there is a lack of research in the literature comparing the electrical activity of the orbicularis oris muscle during the performance of different tasks.

Therefore, this study aimed to investigate the electrical activity of the orbicularis oris muscle in four different isometric tasks (labial protrusion with closure, labial protrusion without closure, counter-resistance with the lip resistance plate and lip closure) so as to identify the most appropriate task for use as a parameter of maximum voluntary contraction in the normalization of the electrical signal of the orbicularis oris muscle. The literature points out that muscle contractions with resistance against movement promote more intense work in activating the motor units[19]. Thus, the study hypothesis is that counter-resistance tasks with the lip resistance plate and lip closure will present the highest values of electrical activity.

METHODS

This is a cross-sectional, observational and analytical study, carried out with a non-probabilistic, convenience sample, consisting of 22 individuals. The study was approved by the Research Ethics Committee of "Universidade Federal de Minas Gerais", under number 83652117.6.0000.5149.

Twenty-two participants between 18 and 33 years of age were evaluated, with a mean of 24.3 years (standard deviation = 4.1), with 12 (54.5%) females and ten (45.5%) males, who met the following inclusion criteria: age between 18 and 35 years old; agreed to participate in the study and signed the Informed Consent Form.

Exclusion criteria were: regular use of muscle relaxant and/or anti-inflammatory medication, or sporadic use within a week before collection; prior realization of Speech-Language Therapy; the presence of occlusal alterations or craniofacial anomalies that would make lip sealing impossible; the presence of disease leading to neuromuscular impairment; absence of lip sealing or lip sealing performed with mentalis muscle hypertension; not completing all stages of the study; not performing the proposed tasks and/or not presenting good signal quality in surface electromyography.

Before the electromyographic evaluation, the exclusion criteria were addressed through self-reporting in an interview with the participants. The presence of occlusal alterations or craniofacial anomalies that created impediments for the lip closure, as well as the position of the lips was evaluated through visual inspection, performed conjointly by two trained and experienced speech-language pathologists. Both evaluators needed to agree on the position of the lips in closure without mentalis hypertension for the participant to be included.

In the data collection process, surface electromyography was performed to obtain the electrical signal from the orbicularis

oris muscle. Initially, each individual sat on a chair without a headrest, with their backs supported, hands relaxed on their legs and feet flat on the floor, on a rubber mat. After correctly positioning each individual, the skin was cleaned using alcohol and gauze at the site where the electrodes were to be attached with shaving performed for males, where necessary.

The electromyographic evaluation was carried out using Miotec® brand equipment, model New Miotool Face, with two input channels, 16-bit resolution, 3,000 V safety isolation, with the acquisition of 3,000 samples per second, per channel, and high-pass filters of 20 Hz and low-pass of 500 Hz. The software used for analysis and data collection was the Miotec Suite with the laptop being used without connection to the energy supply, so as to avoid interference with the electrical signal. To capture the signal, surface sensors were used, also from the Miotec® brand, connected to Double type Ag/AgCl electrodes (Hal Indústria e Comércio Ltda.), in a circular shape, with a fixed distance of 20 mm between each one, 10 mm in diameter, 2 mm of the contact surface and a fixed amount of conductive gel, placed according to manufacturer's instructions. The gain was automatic, with an input impedance of 10 GΩ and a common mode rejection rate >100 dB.

The electrodes were placed on the belly of the orbicularis oris muscle, one on the upper and the other on the lower segment (Figure 1), following international standardization[8,14]. A reference electrode (ground) was also placed on the patient's wrist. The electrical signal was captured in the amplitude domain.

Each participant then received instructions regarding how to properly perform the four tasks under consideration (Chart 1).

The tasks were carried out by the participants in a randomized order, with an interval of one minute[20] between them. Each task was performed three times, with an average duration of five seconds[21] and an interval of thirty seconds between repetitions[22].

During the counter-resistance task with the lip resistance plate, the plate was positioned in the central region of the labial vestibule (between the teeth and lips) of the participant while the same researcher held the plate, performing a continuous traction movement towards the outside of the mouth, in a standardized way. The participant was asked to contract the lips in order to keep the plate in the labial vestibule.

To analyze the electrical activity, a cut was made in each electromyogram, lasting three seconds, eliminating the initial second and analyzing the three seconds after the initial one, in order to homogenize the analyzed sample, thus ensuring the same duration for all analyzed sections[17]. The onset of muscle contraction was defined as the moment when the signal amplitude exceeded twice the standard deviation value obtained at rest[8]. This procedure was performed manually by two researchers. The signal was analyzed, in the amplitude domain, through the RMS (root mean square).

To increase the reliability of the data, two researchers defined the collection sections to be analyzed. To verify the agreement between them, Spearman's correlation coefficient (Rho) was applied (Table 1). The interpretation of the correlation and agreement analyses was performed considering the following classification: r between 0 and 0.4, weak correlation; r between 0.41 and 0.7, moderate correlation and r between 0.71 and 1, strong correlation[23]. Spearman's correlation coefficient equality hypothesis test was applied in order to assess the significance level of the correlation.

Given the strong correlation of the inter-rater analyses, the mean of the measurements between evaluators 1 and 2 was considered.

Descriptive data analysis was performed through frequency distribution and measures of central tendency and variability.

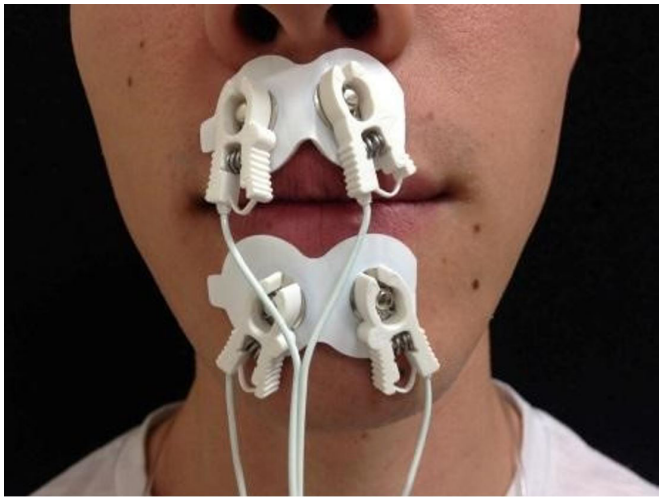

Figure 1. Positioning of electrodes in the belly of the orbicularis oris muscle

Table 1. Analysis of the degree of inter-rater reliability

Task	Lip segment evaluated	Rho	P-value
Lip protrusion with closure	Upper	1,000	<0.001
	Lower	0.994	<0.001
Lip protrusion without closure	Upper	1,000	<0.001
	Lower	0.997	<0.001
Counter-resistance with the lip resistance plate	Upper	0.999	<0.001
	Lower	0.989	<0.001
Lip closure	Upper	0.995	<0.001
	Lower	0.991	<0.001

P-value: hypothesis test of equality of Rho correlations (significance level: p<0.05)
Subtitle: Rho = Spearman's Coefficient of Variation

Chart 1. Instructions on how to perform the four researched tasks

Task	Instructions
1) Lip protrusion with closure	Protrude closed lips as much as possible and hold for five seconds.
2) Lip protrusion without closure	Protrude open lips as much as possible and hold for five seconds.
3) Counter-resistance with the lip resistance plate	Place the labial resistance plate (Pró-Fono®) in the region of the mouth vestibule and press the lips against the labial resistance plate as hard as possible, holding it for five seconds, while the researcher performs counterforce.
4) Lip closure	Press the upper lip against the lower lip as hard as possible, holding for five seconds.

The research of the distribution of continuous variables was carried out using the Shapiro-Wilk test and the comparison between the tasks, using the ANOVA or Kruskal-Wallis test with Bonferroni correction. For statistical significance, values of $p<0.05$ were considered.

RESULTS

In evaluating the upper marginal segment, the task with the highest mean and median EMG amplitude was lip closure. In the lower marginal segment, labial protrusion with closure had the highest mean and median. The values of electrical activity obtained with the electrodes placed on the orbicularis oris muscle, upper and lower segments, can be seen in Table 2.

In the upper marginal section, the counter-resistance task with the lip resistance plate had the lowest coefficient of variation, while in the lower marginal section, the labial protrusion with closure task had the lowest coefficient of variation.

It was found that the means for the lower marginal segment of the orbicularis oris were higher than those observed for the upper segment, considering the same task, except during lip closure, when there was no significant difference.

When comparing the electrical signals between different tasks of the same segment, there was no significant difference for the upper marginal segment, that is, the four tasks showed similar muscle activation. In the lower marginal segment, there was a significant difference only between the labial protrusion tasks with lip closure, with the highest values obtained in the former (Table 3).

DISCUSSION

The present study sought to investigate the electrical activity of the orbicularis oris muscle during different tasks of maximum voluntary isometric contraction, in nasal breathing individuals, with lip sealing and without the aspect of mentalis hypertension, in order to identify a task appropriate for data normalization by the MVC parameter.

When comparing the performance of the orbicularis oris muscle between the upper and lower segments, it was found that, except for the lip closure exercise, there was a statistical difference between the electrical activity of the upper and lower marginal segments of the musculature in the different labial tasks. During the labial protrusion task with closure, the upper marginal segment of the orbicularis oris muscle presented a lower electrical potential than that verified in the lower marginal segment. The same behavior was observed when analyzing the data from the labial protrusion tasks without closure and counter-resistance using a lip resistance plate. Based on the literature, these results can be explained by the fact that the lower and upper marginal segments of the orbicularis oris function as separate and independent parts[24]. There are

Table 2. Descriptive analysis of electromyographic measurements, in microvolts, and comparative analysis of muscle electrical activity between the labial segments

Task	Lip segment evaluated	Minimum	Maximum	Median	Average	Standard deviation	VC	P-value
Lip protrusion with closure	Upper	18.33	201.34	97.20	105.92	48.36	45.65	<0.001*
	Lower	106.78	508.00	263.32	268.92	99.35	36.94	
Lip protrusion without closure	Upper	24.50	259.52	133.47	128.64	65.44	50.87	0.001*
	Lower	54.21	385.84	228.85	222.26	101.65	45.74	
Counter-resistance with the lip resistance plate	Upper	14.43	250.05	136.65	132.95	57.49	43.24	0.001*
	Lower	48.48	476.93	207.83	219.72	97.14	44.21	
Lip closure	Upper	25.83	310.83	150.23	143.35	72.31	50.44	0.078
	Lower	61.71	597.08	165.07	196.09	116.43	59.38	

Kruskal Wallis test (*significance level: $p<0.05$)
Subtitle: CV = Coefficient of variation

Table 3. Comparative analysis of muscle electrical activity between pairs of tasks

Lip segment	Tasks compared to each other		P-value
Upper	Lip protrusion without closure	Lip protrusion with closure	0.197
	Lip protrusion without closure	Counter-resistance with the lip resistance plate	0.818
	Lip protrusion without closure	Lip closure	0.483
	Lip protrusion with closure	Counter-resistance with the lip resistance plate	0.099
	Lip protrusion with closure	Lip closure	0.055
	Counter-resistance with the lip resistance plate	Lip closure	0.600
Lower	Lip protrusion without closure	Lip protrusion with closure	0.131
	Lip protrusion without closure	Counter-resistance with the lip resistance plate	0.933
	Lip protrusion without closure	Lip closure	0.432
	Lip protrusion with closure	Counter-resistance with the lip resistance plate	0.104
	Lip protrusion with closure	Lip closure	0.031*
	Counter-resistance with the lip resistance plate	Lip closure	0.469

Mann-Whitney test (*significance level: $p<0.05$)

anatomical and physiological differences between the upper and lower marginal portions of the orbicularis oris muscle. Regarding anatomy, the upper portion is generally thinner, while the lower portion is thicker and is approximately three times stronger[25]. Other authors who measured the electrical activity of this musculature reported higher electrical activity of the lower portion[26], which confirms the findings of the present research. With regard to function, studies have suggested that the lower lip plays an active role in lip sealing, while the upper lip plays a passive role[27].

In comparing the tasks, the values indicated greater muscle recruitment in the upper segment for the of lip closure task and in the lower segment for the lip protrusion with closure task. However, no statistically significant differences were found when comparing the electrical activity in the upper marginal segment between different tasks. In the lower marginal segment, the activity recorded during lip closure was lower than that recorded during the labial protrusion task with closure, thus indicating that the muscle activity performed in this task was more intense when compared to the lip closure task. No other studies were found in the literature that compared different activities performed with the lips to correlate the findings, however, a study that investigated the task of pressing a device between the upper and lower lips highlighted the participation of the mentalis muscle in facilitating lower lip movement[28]. It is believed that the greater participation of the mentalis may be related to the lower activity of the lower lip in the labial closure task, even in individuals with lip sealing, since the requested tasks required the performance of maximum strength.

In this study, individuals were instructed to keep their mouths slightly open or closed, according to the proposed task. In tasks such as lip protrusion without closure, for example, the individual needed to keep the mouth ajar, which may have interfered with the results obtained. It is suggested that the mouth opening amplitude be a controlled variable in future research. Another variable that needs to be better controlled in future research is the resistance in the task performed with the lip resistance plate. Although the same researcher was responsible for performing the counter-resistance, it is known that the variation in force used is a bias which needs to be better controlled in the studies. A sample containing participants with difficulty with lip sealing is also suggested for future research.

According to the data from the present study, initially, labial protrusion with or without closure was considered a possible task for the normalization of the electrical signal of the orbicularis oris muscle. The lip closure task presented, in the lower marginal segment, a statistically smaller amplitude than the labial protrusion task with closure, identified in this study as the one with the greatest amplitude. Therefore, it should not be considered a good standardization activity.

Data variability must also be taken into account when choosing the task for signal normalization[29]. When analyzing the coefficient of variation of the tasks, it was found that lip protrusion with closure had the lowest values for the lower lip segment and, lower values for the upper lip segment than the other tasks, except for counter-resistance with the plate lip. However, although the counter-resistance task with the lip resistance plate presented no significant difference between the values for the upper marginal segment when compared to the lip closure values, or between the values for the lower marginal segment when compared to the labial protrusion with closure, it is not a recommended option as it depends on the parameter and the strength applied by the evaluator. Therefore, the labial protrusion with closure task is indicated as a reference for normalizing the electrical signal of the orbicularis oris muscle.

The primary aim of this study was to identify a task for use in electromyographic normalization. A secondary aim was the identification of the task that presented the greatest activation for each marginal segment. The secondary result can be useful to professionals when choosing exercises to in therapeutic planning for patients with alterations in the upper or lower lip segment. The literature suggests that investigations be carried out regarding the electromyographic signal during the performance of therapeutic strategies (isometric, isotonic exercises and commercial instruments), due to the scarcity of research that adopts this approach[9,21].

The amplitude values of the electrical signal are directly related to the number of motor units recruited and, consequently, to muscle strength[8]. Thus, while the lip closure task recruited a greater number of motor units for the upper segment, the same was not observed for the lower lip. A possible explanation may be the tendency to activate the mentalis muscle in this task in order to aid contraction, which may have reduced the participation of the lower lip[28,30]. To gain lower lip strength, the other tasks seem to be more effective, as they have been found to recruit more motor units.

The limitations of this research were: the sample size; the participant selection method by convenience; the fact that the assessment of lip position was performed only by visual inspection, without a complete clinical examination, or even without palpation of the orbicularis oris muscle, and the absence of blinding of the evaluators who performed the analysis of the electrical signal. To minimize this limitation, all analyses were performed independently by two different examiners, and the agreement between them was presented. Furthermore, the electrodes used, due to their size and weight, may have limited lip movement during the tasks, which should be considered. However, this bias was minimized due to the same electrodes being used for all tasks with the same participant, with no exchange of electrodes between tasks.

CONCLUSION

The electrical activity of the orbicularis oris muscle was higher in the lip closure task for the upper marginal segment and the labial protrusion with closure task for the lower marginal segment. However, the labial protrusion activity with closure had a lower coefficient of variation.

Based on the results observed here and on the literature used to support and outline this work, the labial protrusion with closure task is indicated as a reference for the normalization of the electromyographic signal of the orbicularis oris muscle.

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