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Electromyographic Analysis of the Masseter and Suprahyoid Muscles in the Oral Phase of Swallowing in Healthy Adult Individuals

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• Conflicts of interest: none declared.

Abstract

Objective: to evaluate by means of electromyographic analysis of the masseter and suprahyoid muscles the oral phase of the swallowing of different volumes of saliva and liquid in healthy adult individuals. **Material and Methods:** the method consisted in analyzing samples of three swallowing trials: voluntary and single swallow of saliva (dry), voluntary and single swallow of 10 ml of water, and voluntary and single swallow of 20ml of water. Statistical analysis: Through Friedman's ANOVA test we observed a significant variation in the medium potential of the right suprahyoid muscle (p=0.010) when compared to the left suprahyoid muscle (p=0.05). Other correlations were verified by using the Nemenyi test, the Wilcoxon test and the Spearman coefficient to support the different analyses of the results. **Results:** the analysis found a direct relation between the electrical activity of the masseter and suprahyoid muscles when swallowing 20 ml water as regards the highest potential values, irrespective of face side – left or right; i.e., when swallowing 20ml water, the higher the potential of one muscle group, the higher the expected value of its antagonist. **Conclusion:** the electromyographic behavior of the masseter and suprahyoid muscles during voluntary swallowing of saliva and two standardized liquid volumes showed that the electrical activity of the masseter muscles did not vary according to the type of swallowing.

Keywords: Electromyography; Masseter; Suprahyoid; Saliva; Swallow.

Introduction

Speech therapy could refer to the functional adaptation related to the form.[1,2] The interposition of the tongue, in resting position or in function, and its relation to malocclusions have been analysed by many authors.[3-5] Although some researchers consider that the interposition of the tongue is a consequence of an abnormal morphophysiological relationship, or an adaptive characteristic, others consider that a primary etiological factor determines the occlusion. Currently, the reciprocity of this relation is accepted with emphasis not only in the tongue, but also in all the structures in function.[6]

The speech therapist needs to be familiar with the anatomy and physiology of the masseter muscle, considering that the greater the evidence, the size and the rectangularity of the muscle, the greater the strength of the deglutition.[3, 7] The masseter muscle is divided in two segments – superficial and profound – and is responsible for the mandibular elevation. In addition, its superficial part protrudes the mandible, while its profound segment is responsible for retraction of the mandible. It consists of a skeletal muscle that has four properties – electrical excitability, contractility, extensibility, elasticity –, and its functions contribute to the system's homeostasis.[8,9] It receives its motor innervation from the mandibular division of the trigeminal nerve.

The deglutition is a dynamic phenomenon divided into three phases: oral (voluntary), and pharyngeal and esophagogastric (involuntary).[10,11] A study[12] shows the existence of an initial stage characterized by a complex and coordinated activation of the mandibular elevator muscles (masseters and anterior temporalis) and neck muscles (sternocleidomastoids). The bone-muscle-joints structures, which are responsible for the morpho-functionality of the mouth, create a propulsive pressure that drives the food to the pharynx.[10] The volume, density and viscosity of the material to be deglutted determines the pressure to be generated in the oral cavity during the ejection, thus influencing the pharyngeal phase.[13]

The electromyography (EMG) aims to help the diagnosis and therapy of orofacial motor disorders, breathing alterations, mastication, deglutition, speech and temporomandibular dysfunctions.[14, 15] The surface electromyography (sEMG) is an electrophysiological evaluation that measures the musculoskeletal activity at the skin level. It is a non-invasive procedure that utilizes sensors to detect the best variations of electrical potential amplitude that can occur at the activation of the muscle tissue,[16-20] given the relation between the electromyography signal magnitude and the muscle contraction produced.[21, 22] The objective of this article is to evaluate the deglutition by means of the analysis of the electromyographic activity of the masseter and suprahyoid muscles by charactering dry and liquid voluntary deglutition with volume standardization.

Material and Methods

Type of study

This is a cohort study carried out at Laboratório de Eletromiografia da Universidade Veiga de Almeida, Tijuca campus, Rio de Janeiro. The research was evaluated and approved under the number 72962 by the Research Ethics Committee of Universidade Veiga de Almeida (CEP-UVA).

Participants

The individuals participating in this study are healthy adults without deglutition alterations, selected in the Universidade Veiga de Almeida campus, including students, professors and administrative officers, who agreed to participate in the research.

Inclusion criteria: age between 18 and 50 years old; without complaints of deglutition or dysphagia history; no craniofacial deformity; no orthodontic treatment.

Before being explained about the procedures of the research, the volunteers signed the term of informed consent.

Exclusion criteria: gastric reflux history, or dysphagia history, or odynophagia; neurological disease history; use of medicine that affects the deglutition; symptom of temporomandibular dysfunctions; orofacial or pharyngeal anatomic alterations; absence of more than one tooth per quadrant or in the anterior region of the mouth.

Initially, 80 healthy adults were recruited. Later, 22 individuals were excluded due to the criteria adopted. Then, 58 individuals were submitted to the procedures of the research. After the examinations, 31 participants were excluded due to failures or unexpected alterations in the electromyography results. At the end, 29 participants, aged between 18 and 50 years old, were chosen according to the criteria used.

Electromyography of the swallowing

Electromyographic model Miotool 400USB of Miotec®(USA) was used with software compatible with the specifications eligible by the electromyographer, property of 'Programa de Pós-graduação Mestrado Profissional em Fonoaudiologia da Universidade Veiga de Almeida'.

The exam was performed in an appropriate room. All mobile phones, electric light, air conditioner, and other electronic equipment in the room were turned off in order to avoid possible interference with the exam. Two evaluators were present during the procedure. All explanations about the procedure were given to the volunteer, who was oriented to be relaxed, seated at a comfortable chair, with their feet on the floor and their hands on their legs, to avoid tension that could interfere with the exam. The muscles were located according to this description: for the masseters the volunteer was asked to clench the teeth, and for the suprahyoid the volunteer was asked to swallow saliva while one of the evaluators palpated the region to confirm the location. After the location of the muscles, the skin under the region of the muscles to be evaluated was cleaned by sweet abrasion with an appropriate sandpaper, and removal of oiliness with gauze soaked in alcohol 70%.

The bipolar surface electrodes were arranged on the skin covering the ventral portion of the right and left masseter muscles, parallelly to the fibres, as with the suprahyoid (Figure 1). The reference monopolar electrode was put in the distal extremity of the left humerus. The electrodes and the sensors connected to the equipment were checked by another professional for verification of correct colocation.

Figure 1. Placement of electrodes for electromyography.

The evaluation of the electric potentials of the muscle activity was performed in 5 tests: 2 rest tests to register the habitual posture, and 3 volunteer deglutition tests, with the following procedures oriented to the volunteer:

- rest with closed lips: sEMG for 15 seconds, with occluded lips, without associated movement;
- rest with half-closed lips: sEMG for 15 seconds, with half-closed lips, without associated movement.

Single volunteer swallowing of saliva: gather saliva in the mouth, wait for 30 seconds for accumulation. The volunteer was orientated to keep the saliva in their mouth, then swallow it at a single time at the researcher's command, while the sEMG was performed for 15 seconds.

Single volunteer swallowing of 10 ml of water: the volunteer was offered 10 ml of water in a plastic cup and was oriented to keep the volume in their mouth, then swallow it at a single deglutition at the researcher's command, while the sEMG was performed for 15 seconds.

Single volunteer swallowing of 20 ml of water: the volunteer was offered 20 ml of water in a plastic cup and was oriented to keep the volume in their mouth, then swallow it at a single deglutition at the researcher's command, while the sEMG was performed for 15 seconds.

In the swallowing tests, the initial 15 seconds following the command to swallow and sustain the saliva were recorded. The recordings were obtained in raw signal and analysed in root mean square signal. The parameters for evaluation in the research were the electric activity of the masseters and suprahyoid muscles, whose electromyographic deglutition amplitude was obtained from sEMG system functions.

Statistical Analysis

The statistical analysis was processed by SAS 6.11 software (SAS Institute, Inc., Cary, North Carolina). The descriptive analysis presented the observed data expressed by median and interquartile interval (Q1-Q2) with tables and graphs. The inferential analysis consisted of the ANOVA method, the Nemenyi test, and the Friedman test. The difference between the electrical potential of the muscles was analysed by the Wilcoxon test, and the Spearman coefficient was used to measure the association between the electrical potential of the muscles. The value of significance was 5%.

Results

Table 1 shows the descriptive statistical analysis of the electrical potential of the masseters and suprahyoid muscles for each type of deglutition, expressed by medium, standard deviation, median, and interquartile interval, and the up and down values of swallow. This is the characteristic profile of the individuals participating in the experiments.

Table 1. Descriptive analysis of the electrical potential (μV) of masseter and suprahyoid muscles for each type of swallowing (n=29).

		Variable	Mean	SD	m	M	Me	Q1	Q3
Saliva	Masseter	Medium values – right	12.4	9.3	4.2	43.2	10	5.7	16.7
		Medium values – left	11.9	6.5	2.1	24.7	10.2	6.45	17.3
		Medium values – highest potential	15.5	9.1	4.2	43.2	13.4	8.1	20.6
		Maximum values – right	39.0	20.0	9.5	89.4	36.4	23.7	50.6
		Maximum values – left	47.0	37.9	10.3	182	38.1	24.5	54.0
		Maximum values – highest potential	53.0	36.9	13.8	182	49.9	30.1	57.8
	Suprahyoid	Medium values – right	12.9	5.5	6.1	24.7	11.5	8.5	16.1
		Medium values – left	17.2	17.1	5.7	91.4	13.1	8.7	17.2
		Medium values – highest potential	18.6	16.9	6.2	91.4	13.8	9.55	21.3
		Maximum values – right	97.3	52.4	34.2	255.2	82.5	57.7	130.6
		Maximum values – left	87.9	40.0	36	191.8	80.5	55.8	113.3
		Maximum values – highest potential	105.2	50.8	37.1	255.2	98.3	67.2	138.0
10ml	Masseter	Medium values – right	12.1	7.9	3.6	38.2	10.5	6.3	15.0
		Medium values – left	12.4	8.1	2.2	36.8	9.7	5.8	17.8
		Medium values – highest potential	15.2	9.2	3.6	38.2	13.3	8.5	18.8
		Maximum values – right	34.4	24.5	11.2	129.2	29	23.1	36.3
		Maximum values – left	50.5	53.9	12.1	275.8	37.2	25.1	43.6
		Maximum values – highest potential	54.8	54.6	14.4	275.8	40.2	27.8	46.0
	Suprahyoid	Medium values – right	11.6	5.2	5.1	23.2	9.3	7.1	15.5
		Medium values – left	15.8	11.7	6.2	59.3	12.1	9.5	18.7
		Medium values – highest potential	16.4	11.6	6.2	59.3	13	9.6	19.8
		Maximum values – right	80.6	50.7	29,6	240	67,6	44,3	106.0
		Maximum values – left	79,3	39.7	27.5	184.2	73.2	48.0	105.2
		Maximum values – highest potential	91,4	51,8	36,9	240	82.3	49,8	114.8
20ml	Masseter	Medium values – right	12.2	7.9	3.7	40.6	10.6	6.3	14.6
		Medium values – left	12.1	6.8	2.8	27.9	10.2	6.25	18.0
		Medium values – highest potential	15.1	8.4	3.7	40.6	15.6	7.9	20.3
		Maximum values – right	42.1	30.7	10.4	151.8	30.3	22.7	53.5
		Maximum values – left	46.8	32.8	9.1	162.4	37.9	27.0	54.8
		Maximum values – highest potential	55.4	37.2	15.8	162.4	42	31.4	66.6
	Suprahyoid	Medium values – right	13.1	6.0	5.8	29.5	11.7	9	16.0
		Medium values – left	16.7	11.7	6.7	60	13	10.7	19.9
		Medium values – highest potential	18.2	11.9	6.8	60	14	11.5	21.3
		Maximum values – right	92.8	49.3	38.4	269.1	76.8	57.2	112.5
		Maximum values – left	90.9	40.1	37.4	187.7	79.8	59.4	117.7
		Maximum values – highest potential	100.8	50.8,0	44.8	269.1	84.5	62.15	121.9

SD: standard deviation ; m: minimum; M: maximum; Me: medium; Q1: 1st quartile; Q3: 3rd quartile.

The results on the verification of electrical potential of the masseters and suprahyoid muscles between the 3 types of swallow (saliva, 10 ml, and 20 ml) are found in table 2, that shows the median, the interquartile interval of the electrical potential (μV), and the descriptive level (p value) of ANOVA and Friedman test.

Table 3 shows the median and the interquartile interval of the difference of potential (delta) of the suprahyoid in relation to the masseters (μV) of each result for the 3 types of swallowing, as well as the descriptive level (p value) of the Wilcoxon test. There is significant increase in the highest values of electrical potentials of the right, left and in the highest potential sides of the masseters in relation to the suprahyoid muscles in the 3 types of swallowing. There is no significant difference ($p<0.05$) at medium values of potentials between both muscles for any of the 3 types of swallowing.

Table 2. Presentation and analysis of the variation in the electrical potential of the masseter and suprahyoid muscles between the 3 types of swallowing (*μ*Volts).

Variable		Saliva			10ml			20ml			*p value*[a]
		med	Q1	Q3	med	Q1	Q3	med	Q1	Q3	
Masseter	Medium value – right	10.0	6	14.2	10.5	6.3	14.2	10.6	6.7	13.6	0.28
	Medium value – left	10.2	6.5	17.2	9.7	6.3	17.6	10.2	6.3	17.7	0.44
	Medium value – highest potential	13.4	8.7	20.4	13.3	8.7	18.4	15.6	8	20.1	0.34
	Maximum value – right	36.4	25.3	50.6	29.0	23.3	34.1	30.3	23.1	52.2	0.26
	Maximum value – left	38.1	24.9	53	37.2	25.6	43.5	37.9	27.8	54.4	0.57
	Maximum value – highest potential	49.9	30.3	56	40.2	28.7	44.5	42.0	31.7	63.3	0.49
Suprahyoid	Medium values – right	11.5	8.9	16	9.3	7.1	14.9	11.7	9.2	14.9	0.010
	Medium values – left	13.1	8.9	16.2	12.1	9.5	18.1	13.0	10.8	19.8	0.050
	Medium values – highest potential	13.8	10.2	19	13.0	9.8	19.2	14.0	12.1	21	0.016
	Maximum values – right	82.5	58.1	121.1	67.6	45.4	105.5	76.8	57.3	109.2	0.085
	Maximum values – left	80.5	55.9	108.3	73.2	48.8	103.3	79.8	60.2	113.9	0.16
	Maximum values – highest potential	98.3	69.9	135.8	82.3	50.8	112	84.5	62.8	121.5	0.32

med: median; Q1: 1st quartile; Q3: 3rd quartile.
[a] ANOVA of Friedman.

Table 3. Presentation and analysis of Delta of the potential (*μ*Volts) of the suprahyoid in relation to the masseters for each type of swallowing.

Swallow	Delta (supramasseter)	median	Q1	Q3	p value[a]
Saliva	Medium values – right	1.80	- 3.7	5.2	0.52
	Medium values – left	2.80	- 0.7	4.2	0.11
	Medium values – highest potential	0.50	- 5.1	5.8	0.59
	Maximum values – right	46.2	26.1	80.5	0.0001
	Maximum values – left	40.3	17.8	63.6	0.0001
	Maximum values – highest potential	43.7	12.1	84.8	0.0001
10ml	Medium values – right	0.30	- 4.4	2.6	0.96
	Medium values – left	3.30	- 2.8	5.7	0.25
	Medium values – highest potential	0.30	- 4.6	5.2	0.59
	Maximum values – right	34.5	10.9	58.1	0.0001
	Maximum values – left	36.4	3.3	68.5	0.002
	Maximum values – highest potential	40.0	- 0.6	64.4	0.003
20ml	Medium values – right	2.10	- 1.9	3.8	0.28
	Medium values – left	3.10	- 1.9	6.7	0.082
	Medium values – highest potential	2.80	- 1.9	5.8	0.15
	Maximum values – right	43.7	26	58.3	0.0001
	Maximum values – left	40.5	14.8	67.1	0.0001
	Maximum values – highest potential	46.2	21	67.1	0.0001

Q1: 1st quartile; Q3: 3rd quartile.
[a] Wilcoxon test.

Figures 2 and 3 illustrate the electrical potential between the studied muscles in each type of swallowing.

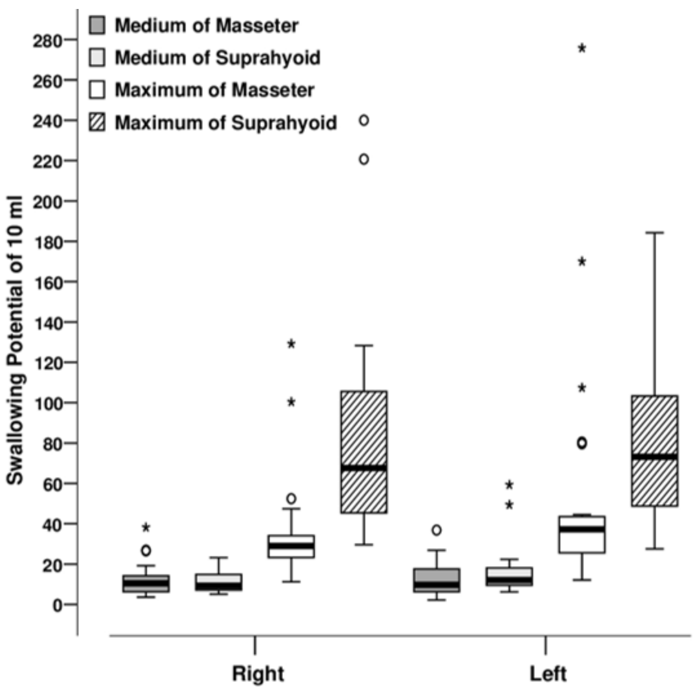

Figure 2. Variation in μVolts of the distribution of electrical potentials medium and maximum between the muscles on swallowing of 10ml.

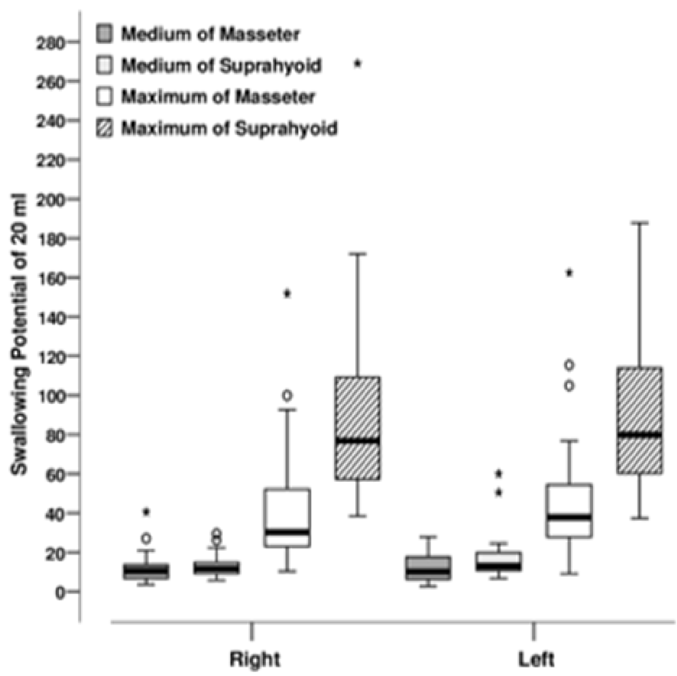

Figure 3. Variation in μVolts of the distribution of electrical potentials medium and maximum between the muscles on swallowing of 20ml.

Discussion

Swallowing involves the oral, preparatory, pharyngeal and oesophagi phases, each dynamic related with specific anatomical structures.[10, 11] The systematicity and frequency of swallowing 300 to 2400 times a day consist of precise coordination of stomatognathic system and of the structures that fulfill it.[23] Due to the importance of this stomatognathic function, some authors searched qualitative instrumental data that express the behaviour of the muscle involved in this process for decades.[24, 25]

The sEMG is one of the instruments of quantitative evaluation of swallowing; although it is not easy to obtain the application, reproducibility and utilization of this methodology, it is used in various works to quantify parameters and to fix standards of normal and dysphagia swallowing as sEMG.[26, 27] The saliva is cited as the best option in the electromyographic evaluation of the swallowing, because it is easy to implement, avoid food characteristics variability of deglutition and to be a good stimulus for swallowing reflex.[28, 29] Other authors cite the swallowing of water for sEMG evaluation because it is easy to control the volume, it does not interfere in the difference of solutions and it enables to obtain differential diagnosis in some cases of swallowing alterations.[30-32]

The electrical activity of masseters does not differ significantly for the 3 types of swallowing, it means that with bigger volumes there is no need for more activation of the masseters in the swallowing, according to later studies that pointed to results similar and masseters primordial function in relation to jaw stabilization.[33,34] For this muscle group, maximum media values in 49.9 microvolts for 10ml of water, and 42.0 microvolts for 20ml are found. These electrical potentials increased in relation to the resting stage (basal), confirming its activation, although without variation in relation to the ingest volume. The results of this study are confirmed by previous studies that considered the masseters not only mastication muscles but also important in the swallowing process,[3,7] because they have fundamental action with the suprahyoid muscle, enabling the stabilization of the jaw in the moment of hyolaryngeal anteriorization and elevation.[35] The increase of the electrical activity of the masseters in the moment of swallowing, following of a decreasing is due to the antagonistic action of this muscle against the jaw depressors action.[35]

More potentials registered for the suprahyoid were found, considering the maximum values of the potentials obtained in the different swallowing with significant differences for saliva, 10ml and 20ml of water, confirmed more activity of this muscle group during the swallowing, independently of the type of ingest volume. Those findings confirm the results of later studies that pointed this muscle group as the most active in the oral phase of swallowing, because it acts in oral motor reflex mechanisms.[36, 37]

The recording of these electrical potentials is about all the muscle group involved in swallowing, including the tongue, an organ that works intensely in the oral preparation and ejection and whose signal is described as the action of the muscles of the mouth floor and suprahyoid, initiating the movement of the hyoid – elevation and anteriorization – resulting in the opening of the pharyngeo-esophagic segment, related to the amplitude of the electromyographic signal.[38, 39]

For each type of swallowing the relation between the electrical potential of masseters and suprahyoid muscles were evaluated, and statistical results were obtained for swallowing of 20ml with significance ($p<0.05$). In this volume, significant relation between the electrical activities of the muscle groups were observed, related to the highest values of the masseter potentials, independently of the side (right or left), with the potentials of the suprahyoid. For the swallowing of 20ml of water, the higher the potential of one of the muscles, the higher the expected value of the potential of its antagonist. These results were confirmed with further studies that associated the masticatory muscles, the suprahyoid and the intrinsic and extrinsic muscles of the larynx in the dynamic process that is swallowing.[40, 41]

Conclusions

The electromyographic behaviour of the masseter and suprahyoid muscles during the voluntary swallowing of saliva and liquid swallowed in standardized volumes in healthy adults could present differences suggested by our results. Firstly, with increased volumes of water it was not necessary to activate the masseters during swallowing, no difference in electrical activity was found for the masseter muscle in the three types of swallowing. Secondly, regarding the suprahyoid group, there is a difference between the potentials in the three types of swallowing, and they increased in the swallowing of 20 ml of water. The electrical potential of the suprahyoid group was higher than that of the masseter group for swallowing of saliva, 10 ml and 20 ml of water, confirming the increased activity of this group during swallowing. There is a direct relation between the electrical activity of the studied muscles groups for swallowing of 20 ml of water, independently of the side (right or left). More experimental studies will be necessary to establish the relation with these muscles and others participating in the swallowing.

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