International Journal of Orofacial Myology and Myofunctional Therapy
Official Journal of the International Association of Orofacial Myology
50th ANNIVERSARY

Volume 40 | Number 1 | pp. 31-41 2014

Research Article

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Suggested Citation
de Figueiredo, A. B., et al. (2014). The masticatory system of the obese: Clinical and electromyographic evaluation. *International Journal of Orofacial Myology, 40(1)*, 31-41.
DOI: https://doi.org/10.52010/ijom.2014.40.1.3

THE MASTICATORY SYSTEM OF THE OBESE: CLINICAL AND ELECTROMYOGRAPHIC EVALUATION

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ABSTRACT

Masticatory performance is determined not only through the speed of mastication, or by the quantity of food ingested; it also depends on the structures and functional integration of the stomatognathic system (SS). Objectives: this study investigated differences in the SS and orofacial motricity between obese and normal - weight women. Method: a total of 18 obese women, with an average age of 28 ± 7.3 years and an average body mass index (BMI) of 37.4 ± 5.1 Kg/m2, and 18 normal - weight women, with an average age of 26 ± 7.6 years and an average BMI of 20.7 ± 1.8 kg/m2, took part in the study. During the speech therapy evaluation, chewing, the number of chewing strokes, and swallowing were observed. The posture, mobility and tonus of lips and tongue, morphology, mobility and tonus of cheeks were designated as normal or altered. The electrical activity of the anterior temporalis, the masticatory muscle was evaluated for both groups using surface electromyography (EMG), which was expressed in microvolts (μV) and registered as Root Mean Squares. Results: significant differences were found between the two groups in clinical evaluation. In surface EMG, the obese group showed asymmetry of electrical activity of the anterior temporalis. Conclusion: this study suggests that speech therapist investigation of the SS should be combined with interdisciplinary obesity management.

KEYWORDS: Obesity; mastication; stomatognathic system; electromyography

INTRODUCTION

Obesity is a multifactorial syndrome (Hainer, Toplak & Mitrakou, 2008) and reflects an interaction between genetic predisposition with dietary and environmental factors (Bray, 2008). Interactions between hypothalamic nuclei and neuronal, endocrine, adipose, and intestinal actions regulate the control of food intake and energy storage (Näslund & Hellström, 2007; Borberger, 2005). The oral cavity has an important role in the digestive process (Fukuoka, 1998). However, the role of the oral cavity in transmitting satiety signals as determined by chemical and mechanical receptors is not well established, and needs further study (Sakata, Yoshimatsu, Masaki & Tsuda 2003; Oka, Sakuarae, Fujise, Yoshimatsu, Sakata & Nakata, 2003; Diamond, Brondel, & LeBanc 1985; Le Blanc & Brondel, 1985; Le Blanc & Diamond, 1986; Druce & Bloom, 2006).

The idea that the obese show alterations in chewing, such as chewing too fast, was introduced in 1960 (Ferster, Numberger & Levitt, 1962). Some studies have investigated the differences in the chewing function between obese and lean subjects, comparing the number of masticatory strokes (Wagner & Hewitt, 1975), the size of the bite (Spiegel, Kaplan, Tomassini & Stellar,1993) and the speed of mastication (Spiegel, 2000); but significant differences were not identified. However, none of these studies considered possible anatomical, morphological, or functional differences in the SS.

Chewing initiates the digestive process (Hiiemae & Palmer, 2003). Despite being under a central control chewing is influenced by peripheral structures, such as dental anatomy, the morphology of the temporomandibular joint, and the precise coordination of the tongue, facial muscles and jaw (Yamashita, S. & Hatch & Rugh, 1999). Thus, chewing performance is directly related to the integration of the structures of the SS. The tongue, the cheeks, and the lips are responsible for the choice, transport, and distribution of larger particles of food on the corresponding occlusal surfaces (Van der Bilt, Engelen, Van der Glas, & Abbink, 2006; Pereira, Gaviao & Van der Bilt, 2006). Together with the quality and consistency of the food, the number of chewing strokes and the quality of the bolus will determine the masticatory performance required (Mioche, Hiiemae & Palmer, 2002; Koolstra, 2002). Disorders of the SS, such as projection of the tongue, deviations in swallowing and chewing, changes in orofacial muscle tone, deviation of the jaw during movement, and disorders in the articulation of speech sounds, can have a negative impact on oral and general health (Bigenzahn, Fischman, & Mayrhofer – Kramme, 1992).

To determine if the obese show more alterations in the SS several factors were included in the evaluation. Motricity was evaluated. Motricity is the quality of the driving force using the set of nerve functions and muscles that allow the voluntary or automatic movements of the body which are evaluated by test of mobility – the ability to move. The evaluation also included an assessment of tonicity of the lips, tongue, cheeks, swallowing and chewing functions, and the number of chewing strokes compared to those of normal-weight individuals. Surface electromyography (EMG) of the anterior temporalis was performed for both groups.

MATERIALS & METHODS

This study was approved by the institutional review boards of the Hospital das Clinicas, University of São Paulo, Brazil, Protocol Nº: 0293/07, and was conducted at the Obesity and Metabolic Syndrome Ambulatory Group. The subjects of both groups were randomly chosen and received a registration number. Written informed consent was obtained from all participants before entry into the study.

For each subject, an orofacial myofunctional evaluation was conducted by a speech therapist using a pre - existing protocol based on the literature (Felicio & Ferreira, 2008; Valera, Trawitzki & Anselmo – Lima, 2006). Surface EMG of the anterior temporalis was then performed (Castroflorio, Icardi, Becchino, Merlo, Debernardi, Bracco, & Farina, 2006; Ferrario, 2000). All subjects were evaluated individually in a single session. The total time spent to evaluate the SS and perform the surface EMG for each subject was, on average, 45 min.

Criteria for inclusion in this study were: female; between 18 and 60 years of age; BMI ≥ 30 Kgm2 for individuals in the obese group and BMI of 25 Kgm2 for individuals in normal-weight management group. In addition, the individual should be clinically normal dental occlusion or Angle Class I (Angle, 1907). The established exclusion criteria were as follows: presence of facial deformity; dental absence (with the exception of third molars) and/or alteration of the dental anatomy by restoration of cavities, teeth with traumas (broken), alteration of occlusion (Angle Class II or Class III); alterations of the morphology of the lips, tongue or palate; nasal obstruction of respiration during the mirror test by Glatzel (Roloff, Winker & Musgille, 1989); complaints of pain or crepitation in the temporomandibular joint (TMJ) during chewing; pathology of the temporomandibular joint; presence of teeth grinding; central and peripheral neurological pathology; history of bariatric surgery; and/or orofacial myofunctional treatment.

Participants and procedure

According to the inclusion and exclusion criteria, 36 subjects, divided into two groups, were included in the study. The obese group was made up of 18 women with an average age of 28 ± 7.3 years and an average BMI of 37.4 ± 5.1 Kg/m2; the normal - weight group was made up of 18 women with an average age of 26 ±7.6 years and an average BMI of 20.7 ± 1.8 Kg/m2.

Speech therapy evaluation of orofacial motricity

During data collection, the examiner was positioned in front of the subject, who was seated in a normal chair with their feet on the floor and their hands on their thighs (Felício, Melchior, Silva & Celeghini, 2007). To register the data, scores were counted using a binomial system scale: 0= normal and 1=mid, moderate or severe alteration presents (Felicio & Ferreira, 2008).

The lips

The lips were observed during all evaluation sessions. The posture of the lips was considered (0) normal - if the lips were totally occluded at rest, or (1) altered - if the lips were constantly or sporadically open or half open. The sealing of the lips during chewing was registered as (0) normal - if 100% of the chewing cycle was performed with the lips closed or (1) altered - if there were occurrences of open lips during chewing. The tone of the upper and lower lips was determined by observation and pressure; it was registered as (0) normal, (1) reduced or (1b) increased. Evaluation of lip mobility was conducted by having the subject perform: altering protrusion and retraction of the lips; vibration (the ability to produce the 'brrr' sound with the lips; and, right left lateralization. Mobility was considered (0) normal - if the movements were performed correctly by the subject, or (1) altered - if the subject performed the movements with difficulty, or with shaking, or if they were not able to perform them at all (Valera et al, 2006).

The tongue

For the observation of the position of the tongue at rest, the subject was asked to open their mouth. The position of the tongue was registered as (0) normal - if the anterior third of the tongue descended from the region of the papilla at the moment of opening of the mouth, or if it was already on the oral floor. The position of the tongue was registered as (1) altered - if the tongue was positioned between the cusps of the central incisors or between the upper or lateral dental arches. The tone of the tongue was observed with the mouth open, with the tongue positioned with its front third in contact with the region of the papilla palate, and with it positioned on the oral floor. Tone was registered as either (0) normal tone -with the tongue in contact with the palatine papilla, if the body and base of the tongue remained contracted with presence of contraction of muscle fibers or (1) reduced tone - remained extended and flaccid with decreased tonus. The mobility of the tongue was evaluated by its performance when: lateral, lifting, depressed and during vibratory movements and was registered as (0) normal - if the movements were performed precisely and without tremors or (1) altered - if the movements were performed with a lack of precision, with tremors, or if they were not performed (Felicio & Ferreira, 2008).

The cheeks

Cheek tone was evaluated by lateral traction of the cheeks with an oral spatula and was registered as: (0) normal - if the subject was able to offer resistance to the traction and at the same time to protrude both of the lips; or (1) reduced - if the subject was neither able to offer resistance to the traction nor protrude the lips (Felicio & Ferreira, 2008).

Chewing

Half of a white bread roll was used for the chewing test. The subject was instructed to chew the roll as they would normally. The following were observed: the incision of the food; the side on which the chewing occurred; the standard jaw movement during the chewing cycle; the presence of open lips and the presence of oral respiration. The following scores were registered: (0) normal chewing was characterized as alternating the bolus bilaterally and with vertical and rotational movements of the jaw; and (1) altered chewing was characterized as being exclusively unilaterally right or left, with predominantly or exclusively vertical jaw movements.

The number of chewing strokes

A standard quantity of $1.5cm^2$ of white bread roll was used for this chewing test, which was performed twice. The subject was instructed to place the food directly into the oral cavity and chew it as they would normally, but without speaking or smiling. A count of the chewing strokes was made from the first stroke until the first swallow (Felicio & Ferreira, 2008). An arithmetic mean of chewing strokes was constructed using the two counts.

Swallowing

The oral phase of swallowing was observed for both consistencies until the initiation of the swallow at the end of chewing of the half bread roll, and when 50 ml of water was consumed. Three swallows were observed. Visualization was achieved using a maneuver that involved opening the lips at the moment the hyoid bone was lifted, then asking the subject to open their mouth at the end of the swallow and, without interference from the examiner. Swallowing was registered as (0) normal - if it was performed without the projection of the tongue between the dental arches or (1) altered - if it was performed with the projection of the tongue between the anterior or lateral dental arches (Felicio & Ferreira, 2008).

Surface EMG

Consideration needed to be given to the effect of subcutaneous fat when collecting surface EMG information on the masseter muscle In obese individuals subcutaneous fat may significantly interfere with the amplitude of the EMG signal. Therefore, the rate of electrical activity of the masseter muscle was not able to be compared between the groups. Therefore EMG of the masseter muscle was not performed

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Surface EMG of the anterior temporalis muscle was able to be conducted because there is no concentration of fat in this region that may impede or interfere in EMG measurement, even in patients experiencing obesity degree 4 performed in accordance with the literature (Castroflorio et al, 2006; Biasotto, Gonzalez & Panhoca, 2005). To examine the anterior temporalis muscle, the subject was instructed to occlude the dentition and then press the mandibular teeth into occlusion with the maxillary teeth with maximum strength performing a contraction, without making any type of facial expression. At the same time, the examiner performed a digital palpation of the left and right anterior temporalis muscles (Castroflorio et al, 2006; Biasotto et al, 2005). Data collection of electrical activity of the contraction of the anterior temporalis muscle was achieved using disposable silver (silver chloride, Ag/AgCl) self-adhesive circular electrodes with gel, with a diameter of 10 mm (Medical Trace®) and an inter-electrode distance, center to center, of 20 mm. Alcohol (70%) was used to remove skin oil. The electrodes were fixed bilaterally on the left and right anterior temporalis muscles. The subject was then instructed to perform a maximum voluntary dental clench for five seconds, without relaxing, until verbally instructed by the examiner (Moreno, Sánchez, Ardizone, Aneiros & Celemin, 2008). Data from the EMG signal was captured using a two - channel monitoring system (EMG System do Brasil Ltda. ®), with a band - pass filter cut-off frequency of 20-500 Hz, an amplifier gain of 1000X and a common-mode rejection rate of 120 dB. Windaq software (Dataq Instruments®) was used to capture the data. This data was scanned by an A/D (analogue - digital) conversion card with 16-bit resolution and a signal frequency of 2 KHz. This system consisted of bipolar electrodes with a 20X active amplification gain. The electrical activity values of the anterior temporalis muscles were expressed in microvolts (µV) and registered as Root Mean Squares (Castroflorio et al, 2006).

DATA ANALYSIS

The SPSS software (version 9.0) for Windows was used for statistical analysis. Fisher's Exact Test was used for the comparison of the clinical evaluation data of the SS. Analysis of the numbers of chewing strokes between the two groups was conducted by applying a Student's t-test. The differences of the EMG indices were calculated by Student's t-test for dependent samples and by the Mann-Whitney Test for independent samples. A significance level of $p<0.05$ was used (Bussab & Morettin, 2004).

RESULTS

In the clinical evaluation of orofacial motricity, the obese group had a higher number of subjects with reduced lip, tongue and cheek tone (Table 1). The presence of a significant form of oral respiration was not observed in either of the two groups, while at rest or during chewing. Alteration of chewing was significantly more frequent in the obese group, but there were no differences in swallowing (Table 1). Of the 94.4% of obese subjects with alterations in chewing, 50% had exclusively vertical jaw movements, and 44.4% had predominantly vertical jaw movements. Of the 61.1% of normal - weight subjects with alterations in chewing, 22.2% had exclusively vertical jaw movements, and 38.8% had predominantly vertical jaw movements. Analysis of the chewing patterns of the two groups showed that 27.7% of obese subjects with alterations in chewing demonstrated exclusively unilateral chewing patterns (16.62% on the right side and 11.08% on the left side). Only 11% of the subjects from the normal - weight group performed exclusively unilateral chewing only on the right side; there were no statistically significant differences in either this variable or in the comparison of the number of chewing strokes between groups (Table1).

In the comparison of EMG indices, there were no differences between groups in the electrical activities during maximum voluntary dental clench of the right and left anterior temporalis muscles in obese and normal-weight subjects (Table 2). When comparing electrical activities of the anterior temporalis muscles in subjects within the same group, obese individuals showed asymmetry of electrical activity between the right and left anterior temporalis muscles. This asymmetry did not occur in the normal - weight group (Table 3).

Table 1. Comparison of the structures and functions of the stomatognathic system and the number of chewing strokes in obese and normal - weight subjects.

Variable	Obese N=18	Normal N=18	p
Altered mobility of the lips	7 (38.8%)	3 (16.6%)	0.1321*
Reduced tone of the tongue	15 (83.3%)	4 (22.2%)	0.0003*
Reduced lip tone	13 (72.2%)	5 (27.7%)	0.0092*
Reduced cheek tone	10 (55.5%)	4 (22.2%)	0.0429*
Alteration of oral respiration (at rest)	1 (5.5%)	0	0.5000*
Alteration of oral respiration (during the act of chewing)	1 (5.5%)	0	0.5000*
Alteration of chewing present	17 (94.4%)	11 (61.1%)	0.0204*
Alteration of swallowing present	13 (72.2%)	10 (55.5%)	0.2443*
Number of chewing strokes	21.1	25.2	0.1431#

* Fisher's exact test # Student's t - test

Table 2. Comparison of the medians of electrical activity in Root Mean Square of the right and left anterior temporalis muscles and the right plus the left anterior temporalis muscle between obese and normal - weight subjects.

Average electrical activity	Obese N=18	Normal N=18	p*
RAT	129 (#35.2)	122 (#21.8)	0.1375
LAT	84.3 (#19.7)	110.7 (#21.7)	0.0920
RAT + LAT	106.7 (#26.6)	116.8 (#21.4)	0.1557

* Mann - Whitney test; RAT – right anterior temporalis; LAT – left anterior temporalis; # Standard error; Values expressed in microvolts (µV)

Table 3. Comparison of the electrical activities in Root Mean Square between the right and left anterior temporalis muscles at maximum voluntary dental clench in subjects of the same group.

N=18	Electromyographic activity		Average p*
Obese	LAT	84.3 (#19.7)	0.0242
	RAT	129 (#35.2)	
Normal Weight	LAT	110.7 (#21.7)	0.0813
	RAT	122 (#21.8)	

RAT– right anterior temporalis; LAT – left anterior temporalis ; * Student's t-test
Standard error; Values expressed in microvolts (μV)

DISCUSSION

In this study, surface EMG data and the components and functions of the SS in obese and normal-weight subjects were evaluated. When both populations were compared on muscle tone, the obese group exhibited alterations including: reduced lip (72.2%), tongue (83.3%), and cheek (55.5%). The results of the clinical evaluation findings were consistent with another observational study conducted by Bortolotti & Silva (2005). They found alterations of the SS in 90% of obese subjects, with the presence of reduced tone for lips (52%), tongue (72%), and cheek (90%). These alterations were observed to directly interfere with the functions performed by the lips, tongue and cheeks, thus hindering and reducing the maintenance of food around the occlusal surface of the teeth and altering the chewing performance, the quality of the food bolus and even swallowing (Van der Bilt et al, 2006). This could also be a reason why the obese group presented greater alterations in the functional evaluation of chewing. According to some authors, adequate chewing is characterized by alternate bilateral chewing (Bates, Stafford & Harrison, 1976; Gómez & Mesa, 1998) and the presence of rotary movements of the jaw (Engelen, Van der Bilt, & Bosman, 2004). In the obese group, vertical jaw movements were more frequent than in the normal-weight group. The physiological changes of mastication cause a direct action on the occlusal contact, on the forces exerted by the masticatory muscles, and even on the pressure exerted on the periodontal region (Fontijn - Tekamp, Van der Bilt, Abbink, & Bosman, 2004) which is directly linked to the sensory nucleus of the trigeminal nerve. While some studies have affirmed that this sensory nucleus is involved in satiety (Fukuoka, 1998; Sakata et al, 2003), the contribution of masticatory performance to satiety requires further investigation.

In comparing the number of chewing strokes between the two groups, the averages of 21.1 for the obese group, and 25.5 for the normal-weight group, obtained in our study were similar to those measured in other studies of normal-weight subjects (19.8 chewing strokes for plain foods and 25 for toast). Compared to other studies that did not identify differences in the number of chewing strokes between these two populations (Wagner & Hewitt, 1975), the authors concluded that obese people do not chew more quickly than lean people (Spiegel, 2000). Another study linked the motricity of the tongue, not the number of chewing strokes, with chewing efficacy (Engelen et al, 2004). No correlation between the numbers of strokes and chewing performance was identified (Altmann, 2005). Therefore, the authors affirm that the main chewing difference between obese and lean individuals is not the number of times they chew or the speed of chewing, but the physiology and chewing patterns.

The data in the literature indicate an incidence of atypical swallowing of 21% to 41% in the population 18 years of age and older (Bates, Stafford & Harrison, 1976). A total of 72% of obese and 55% of normal-weight individuals exhibited alterations in swallowing in the present study, but there was no significance difference between the groups for this variable.

Other authors have compared the EMG of the muscles involved in chewing in obese and normal-weight individuals with the purpose of analyzing the differences in eating behaviors (Spiegel et al, 1993). The results obtained by EMG compliment and support the clinical evaluation. The obese group showed asymmetry of electrical activity between the right and left anterior temporalis muscles within their group. This did not occur in the normal - weight group. Asymmetry in the EMG activities in muscle pairs in normal-weight subjects is more frequent in patients with temporomandibular joint disorders (Felicio et al, 2007). However, the exclusion criteria eliminated subjects with anatomical, morphological and temporomandibular alterations. Thus, it is probable that the asymmetry present in the obese group is a consequence of the alterations found within the SS, which may cause a decrease or asymmetry in the temporal muscle contraction.

An EMG study of subjects with temporomandibular joint disorders found average levels of electrical activity, ranging from 33 to 56.5 µV (Goiato, Garcia, & Santos, 2007). The averages observed in other studies for the mastication muscles (Ferrario, Sforza, Colombo & Ciusa, 2000; Felicio, Couto, Ferreira, & Junior, 2008; Mendonça, Oliveira, Pedroni, Bérzin, & Gastalde, 2005) ranged from 85 to 93.6 µV. In this study, the average electrical activity of the anterior temporalis muscles was 106.7 µV in the obese group and 116.8 µV in the normal-weight group. The similar ranges for the anterior temporalis muscles between the groups compliment the conclusion that obese individuals do not chew less than normal-weight individuals. However, the asymmetry in the range of electrical activity in the obese subjects provides additional support for the conclusion that there is a lack of integration in the chewing function and the components of the SS in the obese group.

In the early sixties, when the differences in chewing were established between obese and lean subjects (Ferster et al, 1962), it became a widespread consensus that obese individuals chew food less before ingesting it. However, studies that compared eating behaviors of obese and normal-weight subjects have criticized the recommendation given to obese individuals to chew their food more times with the intention of eating less or promoting satiety (Spiegel et al, 1993). In addition, it was concluded that chewing more slowly does not help individuals eat less (Spiegel, 2000). Indeed, the results show that the main chewing difference between the two groups is the physiological character of the action, which is determined by alterations in the muscular tone of the lips, tongue and cheeks (Van der Bilt et al, 2006; Pereira et al, 2006; Mioche et al, 2002).

Alterations of this system may have many causes. They may be consequences of a disturbance of the temporomandibular joint (Douglas & Avoglio, 2009), an oral respiratory pattern with nasal or pharyngeal obstruction (Balbani, Melle, Mion & Butagan, 2002; Ferla, Silva & Corrêa, 2008; Junqueira, Di Francesco, Trezza, Zeratti, Frizzarini, & Faria, 2002) or a congenital (Val, Limongi, Flabiano & Silva,, 2005) or acquired (Buchholz, 1994) neurological disorder.

Alterations in the occlusion may also cause functional oral disturbances proportional to their degree of severity (Suliano, Rodrigues, da Fonte & Porto - Carreiro, 2007). Individuals with malocclusion will eventually present an irregular chewing pattern (Koolstra, 2002). In other words, changes in the masticatory neuromuscular apparatus are partially compensated by changes in chewing behavior (Van der Bilt et al, 2006). Additionally, the properties of the swallowed bolus affected by oral conditions may modulate subsequent phases of digestion (N'gom & Woda, 2002).

Obesity is characterized by excess adipose tissue. From the exclusion of all these variables in our study, the probable etiology for the alterations of the SS found in the obese group was the greater accumulation of adipose tissue in structures in the system, such as in the oral region and the pharynx (De Carli, 2000).

The strength of the muscles involved in chewing is responsible for the maximization of the perception of the sensory characteristics of food in the oral cavity (Pierson & Magnen, 1969). Some studies have correlated this with the activation of histamine neurons and, consequently, with a reduction of food intake. However, the relationship between the findings in this study and satiety reduction must be further investigated.

Identifying all aspects of human appetite regulation could prevent the growth of obesity (Sorensen, Moller, Flint, Martens & Raben, 2003). The morphofunctional integration of the SS, resulting from correction of the alterations identified in this study, could help change the eating behaviors of obese subjects, such as eating too fast, drinking excess fluid during the meal to facilitate swallowing or swallowing without chewing. In addition, it is very important to remember that orienting the obese to chew more times without assuring the integration of the SS, may cause serious disturbances, including temporomandibular disorders. Thus, the obese subject that intends to change eating behavior as a component of treatment for obesity, should have the SS investigated by oral science professionals.

CONCLUSION

The results permit us to conclude that obese subjects exhibited more alterations of the SS and chewing function and had asymmetry in the electrical activities of the anterior temporalis muscles. There was no difference in the number of chewing strokes between obese and normal-weight groups.

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