Ultrasonography and electromyography of masticatory muscles in a group of adolescents with signs and symptoms of TMD

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The thickness and electrical activity of masseter and anterior temporalis muscles were compared in adolescents with and without signs and symptoms of TMD. Forty individuals were selected using the Cranio Mandibular Index and a questionnaire. There was no significant correlation between thickness and activity (p>0.05). However, there were correlations between thickness and weight and height (p<0.05). The effect of signs and symptoms on muscle thickness and activity was weak, considering the low CMI scores found.
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INTRODUCTION

The term “temporomandibular dysfunction” (TMD) refers to signs and symptoms associated with pain, functional and structural disturbances of the masticatory system, specially the temporomandibular joints and the masticatory muscles.[1] According to the literature, muscle hyperactivity is the most common etiological factor in myogenic TMD and this can contribute to internal derangement in the temporomandibular joint (TMJ).[2-6]

The field of medical imaging, stimulated by advances in digital and communication technologies, has expanded greatly. New imaging techniques that reveal greater anatomical detail are available in most diagnostic departments and among these, ultrasonographic imaging (US) analysis of the orofacial musculature is included.[7, 8] In several studies, ultrasonography has been advocated for measuring muscle cross-sections and to correlate the findings with those of temporomandibular dysfunction, muscle palpation pain, facial morphology, bite force and occlusal factors.[9-11]

Analyses of surface recorded EMG amplitudes versus force have been used to study muscular performance in terms of recruitment and motor unit firing frequencies.[12,13] Nevertheless, there are few studies concerning the correlation between muscle function and thickness, particularly in the masticatory muscles. In addition, the correlation between ‘height’ and 'weight' on the one hand and ‘muscle thickness’ on the other, in subjects with signs and symptoms of TMD is still not well studied, though these variables seem to influence muscle thickness.[14] Previous studies found a significant correlation between thickness and the masseter muscle activity in adults[9] while Class I children muscle activity was found in the anterior temporalis.[14] Conversely, studies dealing with adolescents with signs and symptoms of TMD are rare.

Therefore, the purpose of the present study was to compare the thickness and electrical activity of the masseter and anterior temporalis among adolescents, with and without signs and symptoms of TMD, and also to evaluate the relationship between muscle thickness, body weight and height.

MATERIAL AND METHODS

Two hundred and seventeen adolescents (120 girls/97 boys), aged 12 to 18 years were examined in public schools in the city of Piracicaba/Brazil, and 40 were selected, taking into account the presence and absence of signs and symptoms of TMD. The Ethics Committee of Piracicaba Dental School approved the research and parental and adolescents consent was obtained. Those who received any type of orthodontic treatment prior to or during the research examination period were excluded from the study.

TMD signs were assessed by calculating the CranioMandibular Index (CMI), as described by Fricton and Schiffman.[15] This was carried out by two calibrated examiners (Kappa=0.936). The CMI has a 0 to 1 scale that measures tenderness and dysfunction in the stomatognathic system and includes all currently recognized signs of TMJ disorders.[15,16] There are 2 subscales: the Dysfunction Index (DI) and the Palpation Index (PI). The DI is designed to evaluate limitation in mandibular movement, pain and deviation in movement, TMJ noise, and TMJ tenderness. The PI evaluates the presence of muscle tenderness in the stomatognathic system. Thus, the CMI distinguishes joint problems from muscle problems.

A self-report questionnaire was used to assess the presence of subjective symptoms according to Riolo et al.,[17] regarding pain in the jaws when functioning (e.g. chewing), unusually frequent headaches (more than once a week), stiffness/tiredness in the jaws,

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difficulty in opening the mouth wide, grinding teeth, and sounds in the TMJs. Each question could be answered with "yes" or "no".

Considering severity of clinical signs according to CMI, i.e., the lowest and the highest scores, the forty selected adolescents were distributed, respectively, in two groups: Control Group (10 boys/10 girls, mean age 14.3±2.2 and 13.7±1.8 years) and the group with signs and symptoms of TMD (SSTMD Group, 10 boys/10 girls, mean age 14.0±1.8 and 13.5±2.4 years). To be included in SSTMD Group, the subjects had to have at least one symptom of the condition based on the questionnaire.[17] There were significant statistical difference between group scores for DI, PI and CMI ($p<0.05$). US and EMG were performed in both groups.

Ultrasonography

The masseter and anterior temporalis evaluation was conducted using the Just-Vision 200 digital ultrasonography system (Toshiba Corporation, Japan) and the images were obtained with a high-resolution real-time 56mm/10-MHz linear-array transducer. All subjects were examined by one trained examiner, who had no information regarding symptoms or CMI scores. The transducer was positioned against the surface of the skin over the central portion of the masseter muscle (the area of greatest lateral distention) and for anterior temporalis it was placed just in front of the anterior border of the hair line (the area of greatest lateral distention).[14,18] The transducer was gradually shifted to obtain optimal visualization. The distance was measured directly on the screen. The measurements were recorded immediately both in the relaxed and clenched states of the jaws. The scanning was performed twice for each site and the means were used for statistical analysis.

Measurement error for ultrasound

The errors of measurement (Se) for the thickness of masticatory muscles were assessed from repeated measurements on two separate occasions (m1, m2) of 20 randomly selected subjects (n), using the Dahlberg's formula: Se =√_ (m1 – m2)2 / 2n. The error was 0.47 mm for the contracted and 0.26 mm for the relaxed masseter and 0.32 mm for the contracted and 0.29 mm for the relaxed anterior temporalis.

Electromyography

Muscle activities were measured with the EMG system (São Paulo/Brazil) MCS-V2 Electromyograph and passive silver-chloride surface electrodes (Tyco Healthcare – Kendall LTP/Canada). The electrodes were placed at the same sites as for the masseter and anterior temporalis ultrasonography recordings. The reference electrode was placed on the right fist. In order to minimize contact impedance, the recording sites were cleaned with a piece of cotton soaked with 70% alcohol.[19] The electrodes were held in position using Elastoplast. The muscle activity was recorded twice when the subjects clenched their teeth (maximum voluntary clench) while using the material Parafilm on their occlusal surfaces. The means of RMS in both trials were used. The methodology for signal treatment was in accordance with Merletti.[20]

Body measurements

Body measurements consisted of height (m) and weight (kg). Height was measured with participants standing with their backs and heels against a wall, to which a stadiometer was fixed. The individuals were asked to look straight ahead and to stretch as much as possible, but to keep their heels on the floor. A survey table was let down onto the head and the height was recorded to the nearest 1 mm. Body weight was measured using an anthropometric scale, with all the subjects bare-footed, and recorded to the nearest 0.5 kg.

Statistical Methods

The normality of the distributions was assessed by the Shapiro-Wilks W-test, showing that the DI, PI and CMI scores and the electromyography data were not normally distributed in the two groups. The electromyography data for both groups and CMI and subscales for SSTMD group were log[10] transformed to more closely approximate normality. It was not possible to transform CMI and subscales for the Control Group, thus the Mann-Whitney and "t" test were used to compare the scores between groups. Muscle thickness among groups, genders and data from the relaxed to contracted states, as well as the comparisons of the Electromyography data were evaluated by ANOVA. Spearman rank correlation analysis was used to evaluate the relationship between muscle thickness, activity and DI, PI, and CMI in the Control Group, and Pearson correlation analysis in the SSTMD Group, due to the normality of the samples, considering the contracted state data. The correlations between muscle thickness and body variables were assessed by Pearson's correlation test. The non-paired "t" test was performed to compare body weight and height in both groups.

RESULTS

The descriptive statistics for weight, height, muscle thickness and activity (RMS) are expressed in Table 1, which also includes the values for the CMI, DI and PI for both groups. Table 2 shows the frequency of subjective symptoms in the SSTMD group individuals, since the Control group was free of subjective symptoms. There was significant difference for CMI values between groups ($p<0.05$) and in the SSTMD group, girls presented higher values than boys ($p<0.05$). Values of body variables were not statistically different between groups and genders ($p>0.05$).

The ultrasonographic evaluation determined that thickness increased significantly from the relaxed to the maximally contracted state ($p<0.01$). On the scan, this change was directly visible, as the muscle bulged during contraction and the septa curled. The comparison of muscle thickness between groups was not significant ($p>0.05$), which means that subjects in the SSTMD group presented the same range of muscle thickness than the matched Controls. In relation to gender, only the anterior temporalis of boys from control group was significantly thicker than that of girls in the same group ($p<0.05$). The relaxed and contracted thickness and EMG values were not different between right and left sides for massseter and anterior temporalis in both groups ($p>0.05$), thus right and left sides were pooled for statistical analysis. Besides, there was no significant difference between thickness and EMG activity between groups ($p>0.05$). The correlations among CMI and subscales, muscle thickness and activity were not significant in Control group ($p>0.05$). However, in the SSTMD group, contracted masseter correlated negatively with CMI ($r= -0.534$, $p= 0.015$). The correlations were not significant between muscle thickness and activity, as presented in Table 3. On the other hand, muscle thickness and body variables were significantly correlated (Table 4).

DISCUSSION

The present study evaluated the relationship between masticatory muscle variables in adolescents with and without signs and symptoms of temporomandibular dysfunction. The decision to implement a dysfunction index, specifically the CMI, was based on the possibility of being able to measure the severity of problems objectively, using clearly defined criteria, simple clinical methods and easy scoring. In addition, this index had a good intra and inter-examiner correlation.[15,21] The CMI index has established validity and reliability.[15,16] Recently, the operational definitions for CMI were redesigned to conform precisely to those of the RDC/TMD, resulting in a clinical evaluation protocol – the Temporomandibular Index (TMI). Ideally, criteria validity would be measured relative to a "gold standard".[21] As no such standard exists for TMD, criteria validity of a new index requires its comparison to an accepted index that measures the same construct. Since the CMI has been used and validated repeatedly in clinical studies, the TMI was compared to it. Criterion validity of the TMI and CMI showed excellent agreement (0.97). Because the CMI/TMI instruments include almost the same examination items as the RDC/TMD, the diagnostic outcomes are expected to be similar to that of RDC/TMD.[21]

The symptom questionnaire showed itself to be a simple and suitable tool, easily understood by the volunteers, thus allowing less examiner influence on the individuals and their answers. The most prevalent symptom in the SSTMD group was joint noises (Table 2). The application of an anamnestic questionnaire for detecting TMD symptoms has the advantage of being easily used by general practitioners or epidemiologists. Although, it has been proved to be a useful tool, in a complete clinical examination it is always mandatory to confirm subjective findings.[22]

The CMI scores obtained were lower than those presented by others,[15,16] probably due to the fact that this sample was comprised of non-patient adolescents, as the study was carried out in a general/randomized population and not among people seeking treatment. Several studies have reported that severe dysfunction at a young age is rare, supporting the results presented.[23,24] The girls selected for the SSTMD group presented significantly higher scores for CMI than boys in the same group, suggesting that girls were more affected than boys. These results may provide some evidence of gender differences in pain perception, as women have reported more clinical pain, lower pain threshold and tolerance levels than men and are vulnerable to the development and maintenance of musculoskeletal pain conditions.[25]

The anatomy and function of the human masticatory muscles have already been examined by US and EMG,[8,26,27] which makes their application useful for evaluating the masseter and anterior temporalis in adolescents with signs and symptoms of TMD, as was done in this study. The US technique is considered to be uncomplicated, and represents a considerable improvement compared to conventional methods for assessing masticatory muscles thickness.[28] Moreover, understanding muscular activity (EMG) related to the dysfunction, is an important resource to help with differential diagnosis and supplies substantial data for the survey and management of the suggested therapy.27 Computed tomography (CT) and magnetic resonance imaging (MRI) are also used for evaluating cross-sectional areas. However, both techniques have disadvantages related to cumulative biological effects and clinical availability and cost.[29, 30]

The current research showed that muscle area increased significantly from the relaxed to the maximally contracted states, as also verified by others,[9,28,29] which is predictable, despite the muscle shortening during contraction. Both contracted and relaxed muscle thicknesses were measured, because in the literature the relaxed muscle thickness has been considered less accurate, owing to higher susceptibility to the pressure with which the transducer is placed on the cheek.[31,32]

There was no correlation between the US and EMG data in the two groups, which could be attributed to the evaluation in contracted state. It is possible that this position does not always coincide with maximum muscle activation, and therefore, in some cases, the muscle thickness measurements might not be indicative of the true contraction potential of the muscles. There are few studies regarding the correlation between these variables in the masticatory musculature, mainly in presence of signs and symptoms of TMD, consequently it is difficult to compare and to draw definitive conclusions about this finding. However, in adults without signs and symptoms, a connection was observed between masseter thickness measurements and muscle function.[9] In children with class I molar occlusion having normal anterior relationship, there was a significant correlation between thickness and activity in the anterior temporalis muscle, but it was also considered premature to give a final verdict based on this result, since it was a pioneering study.[14] Nevertheless, similar absence of correlation between muscle thickness and EMG was found for the obliquus externus muscle in subjects with and without low back pain.[33] Differences in sample composition and subjects variations in age and occlusion are possibly the cause of the differing outcomes.

The extent of occlusal contacts affects the electric activity and a reduction in the number of occlusal contacts might result in insufficient masticatory muscle strength development,[34] which could explain the variability in the EMG signal achievement, in spite of the number of occlusal contacts not being taken into account in the methodology used in this study. On the other hand, the thickness and composition of the cutaneous and subcutaneous tissues overlying the masticatory muscles are made of connective tissue and fat, which are low-pass filters.[19] Thus, changes in the composition of EMG frequency and amplitude of the EMG signal during maximal voluntary contraction are likely to be attenuated. Hence, a systematic difference between the various subject groups, with regard to the thickness of the soft tissues covering the muscle may, at least in part, be an explanation for the differences in mean levels of jaw-elevator muscle activity among groups or subjects.

The mean muscle thickness values found for both groups (Table 1) were in agreement with the literature.[9,31,32,37-39] There was no difference for muscle thickness between the two groups, probably due to the sample age and because the signs and symptoms of TMD, even when present, tended to be mild to moderate, and this might be not enough for an alteration in muscle size. Gender differences in muscles thickness were also not significant, except for the anterior temporalis in the Control group, but this difference could be explained by masticatory side preferences and/or the fact that in the absence of pain, boys tend to have thicker muscles than girls.[39] On the other hand, the pubertal stage can also influence the muscle size and these data were not evaluated in this study. The increase in muscle mass during puberty may be influenced by androgenic steroids creating the difference between male and female muscle strength.[40]

There were no significant correlations among CMI and subscales and muscle thickness and activity in the Control group. But in the SSTMD group there were significant negative correlations among masseter thickness and CMI, which could suggest that, as the signs and symptoms increase, the masseter thickness decreases, probably due to masticatory function impairment. However, it has already been stated that an ultrasonographic feature of the masseter muscle would be an increase in muscle thickness in patients with TMD.[8] The cause or mechanism of thickening is not well defined. The masseter muscle thickness measured by US decreased after stabilization-type splint therapy in patients with TMD, although no significant difference was found between values before and after treatment.[10] It was suggested that the cause of muscle thickening would be an edematous change in the muscle.[41,42] Based on these observations, long-term low-level contraction, which is suggested to be caused by psychological stress or prolonged work, may be related to edematous muscle thickening. The increased thickness in patients who have suffered from muscle pain for a relatively long time would be related to muscle edema.[8] In the present sample, only the presence of signs and symptoms of TMD were stated and consequently, the level of dysfunction was probably not enough to cause muscle edema.

There were significant correlations among thickness and weight and height of the masseter and anterior temporalis in the two groups, in agreement to Kiliaridis and Kalebo31 and Raadsheer et al.,[39] who found significant correlation only between muscle thickness and weight. Lack of some of the correlations for weight and function and muscle thickness could be related to facial morphology, as has already been found in other studies.[9,43] The interaction between muscle thickness and facial morphology in individuals with signs and symptoms of TMD are also of interest and these data were obtained in the present sample and will form the basis of another report. Other factors, such as occlusion, preference of masticatory side, feeding behavior, and parafunctional habits are also of interest and further studies in this field are encouraged. Furthermore, epidemiologic evaluations and follow-up studies concerning young individuals are rare.

CONCLUSIONS

It was concluded that in the sample studied there was no correlation between masticatory muscle thickness and electrical activity. However, there were significant correlations between muscle thickness and body variables, mainly in the Control subjects, indicating that masticatory muscle thickness follows the general body develop-

Table 1. Craniomandibular Index (CMI), Palpation Index (PI), Dysfuntion Index (DI), muscle thickness (mm) and root mean square (RMS) (µVs) in Control and SSTMD groups.

	Weight(Kg)	Height (m)	DI*	PI*	CMI*	MR	MC	TR**	TC**	EMG M	EMG T
Control group											
Median	52.75	1.63	0.07	0	0.04	10.15	13.32	3.05	4.47	24.51	33.53
Mean	53.41	1.62	0.06	0.01	0.03	10.00	13.30	2.96	4.50	33.81	60.87
SD	9.91	0.09	0.03	0.02	0.01	0.86	1.27	0.53	0.79	30.25	72.50
SEM	2.22	0.02	0.01	0	0.00	0.19	0.28	0.12	0.17	6.76	16.21
SSTMD group											
Median	50.15	1.62	0.14	0.31	0.23	10.15	12.52	2.80	4.20	14.69	39.09
Mean	53.88	1.59	0.16	0.31	0.23	10.55	13.31	2.89	4.21	27.05	66.49
SD	14.25	0.12	0.10	0.17	0.09	1.50	2.05	0.42	0.66	26.98	72.81
SEM	3.19	0.03	0.02	0.04	0.02	0.33	0.45	0.01	0.14	6.03	16.28

MR: masseter relaxed; MC: masseter clenching; TR: anterior temporalis relaxed; TC: anterior temporalis clenching; EMG M: activity masseter; EMG T: activity anteriror temporalis

*p<0.05 between groups in the same column

**p<0.05 between relaxed to contracted state for muscle thickness inside the groups

Table 2. Subjective symptoms occurrence in TMD group

Symptoms	Nº of positive answers
Pain or tiredness in the jaws/face	9
Problem in open mouth wide	4
Joint sounds	13
Grinding teeth	7
Headache	8

Table 3. Correlation coefficients and p values for muscle thickness (contracted state) and activity in the Control and SSTMD groups

		Masseter	Anterior Temporalis
Control	R	0.05	0.06
	p	0.83	0.80
SSTMD	R	0.21	0.11
	p	0.37	0.65

p>0.05 all correlations were not significant

Table 4. Correlation coefficients and p values for muscle thickness and weight and height in Control and SSTMD groups

			Masseter		Anterior Temporalis	
			MR	MC	TR	TC
Control	weight	R	0.69*	0.38	-0.70*	-0.58*
		p	0.00	0.10	0.00	0.01
	height	R	0.70*	0.46*	-0.50*	-0.49*
		p	0.00	0.04	0.02	0.03
SSTMD	weight	R	0.58*	0.64*	0.42	0.30
		p	0.00	0.00	0.06	0.19
	height	R	0.65*	0.70*	0.29	0.28
		p	0.00	0.00	0.22	0.24

*p>0.05

ment in normal conditions. The effect of signs and symptoms of TMD on the muscle thickness and activity of adolescents was weak, considering the low CMI scores found.

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