



Differences between the activity of the masticatory muscles of adults with cerebral palsy and healthy individuals while at rest and in function



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ABSTRACT

Objective: The aim of the present study was to compare the electromyographic activity of masticatory muscles of adult patients with different degrees of oral motor impairment (cerebral palsy) with the electromyographic activity of healthy individuals in a control group. Electromyographic activity was compared when the masticatory muscles were at rest and in motion.

Design: Thirty adult patients with cerebral palsy and 30 subjects without neuromotor disorders were enrolled in the present study. Oral motor function impairment was classified for each subject according to the Orofacial Motor Function Assessment Scale. Surface electromyography was bilaterally recorded in the masseter and anterior temporalis muscles at rest, during maximal voluntary clench and mouth opening. Comparisons between the groups were statistically assessed using Mann-Whitney test.

Results: At rest and mouth opening, electromyographic values were higher among patients with cerebral palsy than control group. During maximal voluntary clench, the opposite occurred. The degree of oral motor impairment affected mouth opening.

Conclusion: There are significant differences in masticatory muscle activity between adult patients with CP and healthy individuals, and the degree of oral motor impairment is important.

Significance: To improve the masticatory function of these patients, muscle therapy should approach rest, mouth opening and clenching differently.

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1. Introduction

Cerebral palsy (CP) is a clinical condition that is characterized by neuromotor disorders, caused by a brain injury during the prenatal, perinatal or postnatal period. Impairment of different areas of the brain results in different clinical types (Koman et al., 2004; Rosenbaum et al., 2007).

The prevalence of this condition is estimated at 2.4 per 1000 children, representing a significant number of people with this disorder (Hirtz et al., 2007).

The clinical manifestations associated with CP include loss of motor control, abnormal muscle tone, impaired coordination and an imbalance between the agonist and antagonist muscles (Castro et al., 2006; Deon and Gaebler-Spira, 2010; Koman et al., 2004). Consequently, difficulties in maintaining head posture and an unwanted bite reflex may occur (Vaughan, Neilson, & O'Dwyer, 1998; Furkim et al., 2003; Troughton and Hill, 2001; Santos, Manzano, Ferreira, & Masiero, 2005; Bigongiari et al., 2011)

In addition to motor disorders, cognitive limitations, sensory deficits, weakness and pain (with varying levels of severity) may also affect individuals with CP (Odding et al., 2006). Mastication, speech and swallowing can also be impaired. Associated disorders of the tongue, cheeks and lips often result in excessive drooling.

Concerning oral diagnoses, several scales have been developed to assess the oral motor function of patients with special needs (Ortega, Ciamponi, Mendes, & Santos, 2009). Among them, the

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Orofacial Motor Function Assessment Scale (OFMFAS) enables a quantitative assessment of the performance of oral movements (Santos et al., 2005), complementing the oral diagnosis and guiding odontological treatment and speech therapy.

Surface electromyography (sEMG) assesses muscle behavior by recording the electrical signals emitted by muscle cells, obtaining information such as the time of muscle activation, muscle activity, strength and fatigue (Hug, 2011). In cases of cerebral palsy, sEMG should be considered as a method of determining the efficiency of recommended treatment protocols and quantifying the improvement of neuromuscular functions.

Although there have been significant developments in research related to the behavior of individuals with CP in the last two decades (Blair, 2010), patients with CP still have difficulties in finding health professionals that meet and understand their needs. There is a lack of access to information about their condition and as a consequence, inadequate treatment is common (Odding et al., 2006). Furthermore, diagnosis and treatment generally emphasize the pediatric field. Health care services for adults patients with CP are limited, due to a lack of specialized professionals, insufficient financial resources and the fragmentation of health areas (Field et al., 2010).

Understanding the oral movements of individuals with CP is very important, since they directly or indirectly influence the coordinated functions of the stomatognathic system (Ries & Bérzin, 2008).

The aim of the present study was to compare the electromyographic activity of the masticatory muscles of adult patients with varying degrees of CP-related impairment with the electromyographic activity of healthy individuals in a control group.

2. Materials and methods

2.1. Inclusion and exclusion criteria

Thirty adult subjects with CP, aged from 20 to 35 years, of both genders, were enrolled in the present study based on the following inclusion criteria: patients admitted via the Training Program in Dentistry for Persons with Disabilities (PFOPD), School of Dentistry of São José dos Campos/UNESP, before the beginning of any rehabilitation treatment that could alter masticatory muscles function; quadriparetic CP; Gross Motor Function ranging from level 1 to 4, according to the classification of Palisano, Rosenbaum, Bartlett, and Livingston (2008); voluntary participation; collaborative behavior and the ability to understand and respond to verbal commands such as “open your mouth”, “close your mouth” and “clench your teeth”.

The following exclusion criteria were applied: adult patients with CP and caries; tooth mobility; absence of posterior teeth; undergoing orthodontic and/or functional orthopedic treatment. A dental examination was performed in order to avoid such factors, since they would affect the individuals biting force. Patients with level 5 Gross Motor Function were also excluded, due to their difficulty in controlling and maintaining head posture (Palisano et al., 2008). After the research had been explained in simple language and any doubts were clarified, the patients caregivers signed the informed consent form (ICF), after the volunteer's approval.

The control group contained 30 subjects aged between 20 and 35 years, of both genders, without cerebral palsy or any other health problems.

The present study received approval from the Ethics Committee on Human Research of the Dentistry School of São José dos Campos – FOSJC-UNESP under protocol number 054/2011. The project was approved by the Brazilian Clinical Trials Registry under protocol

number RBR-2M9MGQ 994XFS 054/2011 (São José dos Campos, SP, Brazil).

2.2. Assessment of orofacial motor function

Orofacial motor function was assessed in accordance with the OFMFAS, developed by Santos et al. (2005), in order to classify the degree of impairment of patients with CP. Their protocol was followed, with the subjects positioned in a comfortable position, with the trunk and pelvis aligned and the cervical spine elongated. A dentist assessed voluntary facial movements such as jaw opening, protrusion, laterality and rapid coordinated movements. A speech therapist assessed lip, palatal and tongue movements. The scale included 30 items, for which the subject could score 0 (inability to perform the movement), 1 (partial ability) or 2 (total ability).

The final score was obtained by the sum of all the sub-item scores. Therefore, the minimum score was 0 and the maximum score was 60.

In accordance with Santos's et al. (2005), the subjects were classified as severely impaired (score ≤ 19), moderately impaired ($20 < \text{score} < 31$), slightly impaired ($32 < \text{score} < 41$) or very slightly impaired (score ≥ 42).

2.3. Surface electromyography

In order to make the acquisition of the EMG signal for adults with cerebral palsy reliable and reproducible, before the sEMG analysis, calibration of the rater and evaluation of within-day and between-day reliability of sEMG of the masticatory muscles for the same subject was previously tested (Giannasi et al., 2014).

The following procedures were followed in both groups: eight-channel electromyography (EMG-800C, EMG System of Brazil Ltda, Sao Jose dos Campos, SP, Brazil); calibrated with an amplification of 2000; band pass filter with a cut off frequency between 20 and 500 Hz; high common mode rejection ratio (>100 dB); analog-to-digital converter board (AD); and 16-bit resolution.

Surface electrodes were positioned on the following locations, based on the recommendations of Vitti and Basmajian (1977): 1) on the anterior portion of the right temporal muscle; 2) on the superficial portion of the right masseter; 3) on the anterior left temporal muscle and 4) on the superficial portion of the left masseter. Disposable Ag/AgCl bipolar and circular surface electrodes (Meditrace[®] Kendall-LTP, Chicopee, MA, USA) were used.

Two channels were used for the force transducer and mandibular goniometer.

A rectangular metallic electrode measuring 3×2 cm coated with Lectron II conductive gel (Pharmaceutical Innovations) to increase the conduction capacity and avoid interference from external noise was attached to the left wrist of the volunteer for reference.

The electromyography device was connected to a computer (HP pavilion dv4 laptop, Hewlett-Packard, CA, USA) to enable the data analysis.

The patients skin was cleaned with 70% alcohol to reduce impedance.

2.4. Electromyographic analysis

The sEMG recordings were initiated with both groups of patients at rest. Three 10-s recordings were taken in this position at 1 min intervals (Sforza, Rosati, de Menezes, Musto, & Toma, 2011).

It was determined that, in the presence of any physical complications or emergency, such as a convulsive seizure, procedures should be stopped immediately, thereby ensuring the patient's safety and the reliability of the examination.



Fig. 1. (A) Maximum mouth opening assessment; (B) Maximum bite force assessment.

The electromyographic examination continued with an assessment of the mouth opening movement towards maximum opening. This assessment was performed using a mandibular goniometer (EMG System of Brazil Ltda, Sao Jose dos Campos, SP, Brazil) (Fig. 1A).

Three records were taken, lasting 10 s each, at 1 min intervals.

Subsequently, the patients were asked to bite the force transducer (EMG System do Brazil Ltda, Sao Jose dos Campos, SP, Brazil) with maximum force in the maximum intercuspatation position. Three records of isometric contraction were taken, lasting 10 s each, at 1 min intervals.

During all records, two operators directly monitored the patient and the electromyogram.

Finally, the electromyographic signals were recorded on computer files.

For each patient, the mean amplitude (RMS) in microvolts (μV) was calculated for each muscle assessed in the three different situations. Subsequently, the final mean and standard deviation values were calculated from the mean values for all patients.

For method error analysis and the repeatability of measurements, the sEMG examination was repeated after 30 days, following the same methodology.

2.5. Statistical analysis

The sample size was obtained by means of statistical power analysis, considering reference values from the literature (Yoshida, Nakajima, Uchida, Yamaguchi, & Akasaka, 2003; Santos, Manzano, Chamlian, Masiero, & Jardim, 2010), confirming a 90% power to detect a clinically relevant difference at an alpha level of 0.05.

Normalization of the values was analyzed by means of the Anderson-Darling test. The non-parametric Mann-Whitney test was selected (comparison of two independent samples).

The Mann-Whitney test was used to determine if subjects with CP exhibited statistically significant sEMG values for the

masticatory muscles, when compared with individuals in the control group.

3. Results

The mean age of the patients with CP was 27.08 years ($\text{SD}=8.11$). In total, 50% ($n=15$) were male, 80% ($n=24$) were Caucasian and 20% ($n=6$) were Black. The mean age of the patients in the control group was 27.5 years old ($\text{SD}=2.09$). In this group, 40% ($n=12$) were female and 100% were Caucasian.

3.1. Assessment of the degree of oral motor function in adult patients with cerebral palsy

Concerning the assessment of oral motor function, the scores obtained by the OFMFAS ranged from 23 (worst performance) to 58 (best performance). The maximum score possible for this test is 60.

None of the patients were classified in the severely impaired group, while seven (23.33%) were classified in the moderately impaired group, two (6.66%) were placed in the slightly impaired group and four were classified in the very slightly impaired group. For the statistical analysis, patients from the slightly impaired group were grouped together with those from the very slightly impaired group.

Table 1 displays the differences in performance between slightly and moderately impaired groups for the movements required for the OFMFAS.

3.2. Assessment of the electromyographic activity of the masticatory muscles of patients with CP and control group at rest, during maximal voluntary clench and during maximal mouth opening

Table 2 displays the mean values of the sEMG amplitude (RMS) in microvolts and the standard deviations of the sEMG data at rest, during maximal voluntary clench and during mouth opening for patients with CP and control group. Maximal bite force (kgf) and maximal mouth opening (m) are also listed.

3.3. Comparison between the electromyographic results of the moderately impaired and slightly impaired groups at rest and in action

Mann-Whitney Test was used to determine differences between the electromyographic results of the moderately impaired and slightly impaired groups in all situations (at rest, during maximal voluntary clench and during mouth opening). During rest and maximal voluntary clench, for each of the masticatory muscles, patients classified in the moderately impaired group exhibited no statistically significant differences for sEMG values,

Table 1
Percentage of patients capable of performing the movements of OFMFAS from slightly and moderately impaired groups.

OFMFAS	Slightly impaired group	Moderately impaired group
1. Jaw mobility	76.66% ($n=23$)	56.66% ($n=17$)
2. Voluntary jaw protrusion	30% ($n=9$)	23.33% ($n=7$)
3. Voluntary lateral jaw movements	13.33% ($n=4$)	10% ($n=3$)
4. Rapid coordinated jaw movements	46.66% ($n=8$)	26.66% ($n=8$)
5. Voluntary facial movements	50% ($n=15$)	46.66% ($n=14$)
6. Lip muscle strength: puff out cheeks/maintain pressure	80% ($n=24$)	46.66% ($n=14$)
7. Rapid coordinated lip movements	56.66% ($n=17$)	40% ($n=12$)
8. Glossopharyngeal and vagal motor activity	73.33% ($n=22$)	50% ($n=15$)
9. Rapid coordinated palatal movements	67% ($n=20$)	56.66% ($n=17$)
10. Hypoglossal motor: voluntary tongue movements	50% ($n=15$)	33% ($n=10$)
11. Voluntary elevation and lateralization of tongue	33% ($n=10$) and 26.66% ($n=8$)	20% ($n=6$) and 13.33% ($n=4$)

Table 2

sEMG amplitude (RMS, microvolts) and standard deviation (SD) of electromyographic evaluation of masticatory muscles at rest, maximum voluntary clench, and open mouth situation for CP group and Control group.

Muscle	Rest				Maximum voluntary clench				Open mouth			
	CP (n = 30)		Control (n = 30)		CP		Control		CP		Control	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
RM	13.48	5.75	10.55	3.74	344.04	184.72	615.61	489.93	54.47	27.97	68.34	51.98
LM	11.12	54.91	10.51	4.02	442.98	281.8	696.61	603.04	61.2	26.71	74.89	46.04
RT	16.80	8.54	13.66	4.40	437.37	235.13	525.41	288.38	54.91	34.4	40.09	24.89
LT	16.24	7.93	13.70	6.39	384.56	200.7	477.47	314.66	72.24	61.2	33.56	11.05
Opening (m)	\	\	\	\	\	\	\	\	0.0374	1.11	4.24	0.69
Bite force (kgf)	\	\	\	\	69.75	20.01	86.38	14.54	\	\	\	\

RM = right masseter; LM = left masseter; RT = right temporalis; LT = left temporalis; SD = standard deviation.

when compared to patients classified as slightly or very slightly impaired.

However, a statistically significant difference was recorded between the groups for the maximum mouth opening measurement, which was greater in the slightly impaired group than in the moderately impaired group.

3.4. Comparison of the electromyographic activity of the masticatory muscles of patients with CP and healthy individuals in the control group

Table 3 displays the results of the Mann-Whitney Test for the comparison between the sEMG values of patients with CP and those in the control group. P-values were lower than the level of significance (0.05). This means that for each of the muscles assessed at rest and in action (mouth opening and maximal voluntary clench), patients with CP exhibited statistically significant different sEMG values (RMS), when compared with those in the control group. The only exception was the goniometer measurement (m) for maximal mouth opening, for which the p-value was greater than the significance level.

At rest and during mouth opening, all sEMG values were substantially higher among patients with CP than among those in the control group. On the other hand, during maximal voluntary clench, the sEMG values were higher among the individuals in the control group than among patients with CP.

4. Discussion

Given the significant prevalence of CP (Hirtz et al., 2007; Deon & Gaebler-Spira, 2010) and the increased life expectancy of patients with this condition (Blair, 2010), improving the quality of life of patients with CP is a matter of great importance.

However, studies concerning adult patients with CP are scarce and there is a gap in knowledge of the behavior of the masticatory muscles of adult patients with CP. The lack of previous studies and the knowledge gap lead to limitations in the treatment of patients with CP.

The aim of the present study was to help health professionals understand the masticatory muscle activity of these patients through clinical examinations and sEMG assessments. The sEMG assessment is a simple and effective method of studying muscle function (Hug, 2011). However, this method is very sensitive and requires experienced researchers in order to detect noise errors.

At rest, for each of the masticatory muscles, patients classified in the moderately impaired group exhibited no statistically significant differences in sEMG values when compared to patients classified as slightly or very slightly impaired. This difference could be explained by the exclusion criteria, which removed patients with the most severe impairment of gross motor function and cognitive problems, possibly reducing the variability of the sample.

Maximum mouth opening, however, was greater in the slightly impaired group than in the moderately impaired group. This confirmed the correlation between the clinical and electromyographic findings and corroborates the results of Santos et al. (2010),

Table 3

Comparison between the electromyographic results of patients with cerebral palsy and control group.

Position	Muscle	Mean sEMG amplitude (RMS)		p-value
		CP (n = 30)	Control (n = 30)	
Rest	RM	95.94	9.97	0.00
	LM	78.86	9.56	0.00
	RT	104.74	13.07	0.00
	LT	98.84	12.97	0.00
Mouth opening	RM	147.77	53.23	0.00
	LM	123.06	70.04	0.00
	RT	149.23	34.67	0.00
	LT	129.69	31.79	0.00
	Maximum mouth opening (cm)	4.16	4.26	0.58
Maximum voluntary clench	RM	215.79	528.37	0.01
	LM	183.11	520.20	0.00
	RT	231.44	542.13	0.01
	LT	206.21	473.95	0.02
	Maximum voluntary clench (kgf)	4.82	88.47	0.00

CP = cerebral palsy, RM = right masseter; LM = left masseter; RT = right temporalis; LT = left temporalis.

who reported that slightly and very slightly orally impaired patients with CP exhibited more EMG activity than individuals with CP who were severely or moderately impaired.

In the present study, the mean value of maximal mouth opening was 0.0374 m, which is lower than the findings of a previous study of young patients with CP (0.049 m) (Ortega, Guimarães, Ciamponi, & Marie, 2008). The fact that maximal mouth opening was more limited among adults than among children may indicate a worsening of this condition with age. One possible explanation for this may be the discontinuance of treatment among adult patients.

When compared to the control group, patients with CP exhibited statistically significant differences in the electromyographic values for all muscles (at rest and in action) assessed in the present study. This result is significant, since it shows that adult patients with CP exhibited abnormal values in all of the simulated situations (at rest, opening and closing the mouth).

At rest, all sEMG values were substantially higher in the CP group than in the control group, which means that treatment protocols should focus on muscle tension reduction while at rest. This result is similar to that reported in a study by Briesemeister, Schmidt, and Ries, (2013), in which the amplitude of masseter and temporal muscles in the inactive period of children with CP was higher than the same amplitude in a group of children with typical development.

Higher sEMG values for mouth opening were also found in the CP group. This suggests that the jaw muscles are tensioned when they should not be. This is in accordance with Yoshida et al. (2003)'s study. Although their control group was composed of a different sample, the EMG results were, at pre-treatment stage, also higher among CP patients than in the control group during mouth opening.

During maximal voluntary clench, the CP group exhibited lower bilateral EMG activity than the control group. This indicates that patients with CP experience a certain difficulty in the muscle recruitment required to reach maximum strength. This result is in agreement with Santos et al. (2010), who concluded that individuals with CP exhibit motor weakness in the jaw-closing muscles, a condition that may impair their masticatory function.

One of the limitations of the present study was the wide range of combinations of characteristics among individuals with CP. All patients with CP, regardless of their degree of oral motor function impairment, can exhibit individual responses in the masticatory muscles. All of the patients were exposed to etiological factors in different levels, leading to different levels of severity and different types of treatment (medical, physiotherapy, speech therapy, psychological and dental).

Thus, decisions related to treatment options should also consider the individuality of the patient, based on an assessment of their oral motor function, determining which functions (swallowing, chewing and speech) are more severely impaired and the severity of this impairment.

5. Conclusions

Based on the results of the present study, it is possible to conclude that there are differences in electromyographic activity of the masticatory muscles among adult patients with CP, when compared to healthy individuals (control group). Jaw muscles exhibited greater activity during mouth opening and less activity during maximal clench.

In addition, significant differences were recorded between the electromyographic activity of patients with different degrees of oral motor impairment during mouth opening, although this was not the case while at rest or during maximal voluntary clench.

Conflict of interest

None.

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