ELECTROMYOGRAPHIC STANDARDIZED INDICES OF MASTICATION IN HEALTHY BRAZILIAN CHILDREN AND ADULTS

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Abstract: Masticatory muscle EMG was assessed in a group of 13 healthy children (7-12 years old) and a group of healthy adults (21-30 years old) performing 15s unilateral gum chewing. By means of a wireless electromyographic analyzer, masseter and temporalis muscles' standardized activities were investigated, and the two groups' resulting characterization compared. As well as chewing frequency, a bivariate analysis was performed on the simultaneous differential right-left masseter (ΔM) and temporalis (ΔT) activity (Lissajous's plot) to analyze the coordination pattern. Symmetry indices, effort-related parameters and intra-group variability were also assessed. The outcomes showed that healthy children had a good muscular coordination, comparable with adults' condition. Though, in children, the working-side muscular prevalent activity (a physiologic condition) was significantly smaller than in adults, probably due to the neuromuscular immaturity that appears in less selected muscular side recruitment. Children also showed an accentuated divergence in muscular activation variability pattern between the two chewing sides, suggesting the existence of a temporary preferred side of mastication, likely induced by an asymmetric acute state of occlusal development. Different stages of stomatognathic apparatus development could explain the larger variability of children's chewing frequency. Overall, these control data provide reference database for the assessment of patients, either children or adults, with functionally altered stomatognathic conditions.

Keywords: Surface electromyography, masticatory muscles, chewing, health.

Introduction

Current clinical assessments and medical treatments are increasingly evidence-based, relying on a widespread diffusion of diagnostic tools and treatment protocols that should make scientific-based options available to the largest number of health professionals. Indeed, the quantitative and accurate evaluation of masticatory muscle activity is mandatory for a better understanding of the normal function and dysfunction of the stomatognathic apparatus, and should assist conventional clinical assessment.

Mastication is a complex task performed by combining contractile activity of several orofacial muscles. Among them, the masseter and temporalis muscles are those most often assessed in clinical evaluations because they are the strongest and the most superficial, being the only accessible to surface electromyography examination (EMG).

The measurement of the muscular electric signal has been used since the early 1950s for studying the action of the superficial masseter and temporalis muscles during mastication and is currently a part of patient assessment in dentistry. Indeed, in the assessment of stomatognathic dysfunction and several head disorders, the analysis of masseter and temporalis muscles' activity can provide quantitative functional data with minimal discomfort to the patient and without invasive or dangerous procedures [1,2,3]. The chewing EMG pattern is generally thought to be one of the most useful and reliable parameters for objectively evaluating neuromuscular coordination, and unilateral gum chewing is the task most commonly used for obtaining standardized data [4,5].

Both healthy and pathologic adults' chewing EMG characteristics have been widely studied with standardized protocols, but there is still a lack of information about children's masticatory muscular pattern. So, the aim of the current investigation was to quantitatively compare the masticatory muscles' activity of healthy children and adult subjects performing unilateral gum chewing. To the scope, a previously validated protocol [6], enhanced with new diagnostic parameters, was applied. The comparison of children and adults' data may offer a further contribution to the assessment of functional and anatomical development in the human stomatognathic apparatus.

Materials and methods

Subjects – Thirteen healthy children (8 male and 5 female, 7-12 years old, mean age 9.4 years) and 13 healthy adults (7 male and 6 female, 21-30 years old, mean age 26.1 years) were recruited for this study. All subjects had normal natural dentition for age and normal dental occlusion. They had no dental pain or periodontal problems, neurological or cognitive deficit, previous or current tumors or traumas in the head and neck region, current or prior orthodontic, orofacial myofunctional or

TMD treatment, current use of analgesic, anti-inflammatory and psychiatric drugs.

sEMG instrumentation – The masseter and anterior temporalis muscles of both sides (left and right) were examined. Surface EMG recordings were made by placing paired disposable Ag/AgCl pre-gelled electrodes (sensor area, 3.14 cm^2; inter-electrode distance, 2 cm; Kendall, Covidien, Mansfield, Canada) along the main direction of the muscular fibers, detected by palpation during maximum voluntary muscle activation. Before electrode placement, to reduce skin impedance, the skin was scrubbed with an alcohol soaked gauze pad. Men were kindly requested to attend clean shaven, to facilitate electrode placement. For each subject, the electrodes were positioned at the beginning of the experimental session, and all trials were performed without any modification of the electrodes and/or of their position (Figure 1).

Figure 1: Probes disposition.

EMG activity was recorded using a wireless electromyographic system (FreeEMG, BTS S.p.A., Garbagnate Milanese, Italy). The analog EMG signal was amplified and digitized (gain 150, 16-bit resolution, sensitivity 1 μV, temporal resolution 1 ms) using a differential amplifier with a high common mode rejection ratio (CMRR>110 dB in the range 0-50 Hz, input impedance >10 GΩ). All the recorded EMG signals were digitally band pass filtered between 80 and 400 Hz with a 2nd order Butterworth filter, and rectified by calculating the root mean square (RMS) in temporal windows of 25 ms; the software adopted to the scope was the SMART Analyzer (BTS S.p.a.).

sEMG analysis – Surface EMG of the masseter and temporalis anterior muscles were measured in all subjects, who were allowed to familiarize with the experimental apparatus and procedures before actual data collection. The subject, who sat on a chair with his/her head in a natural erect position, was asked to perform 15s unilateral chewing (right and left) of a pre-softened gum (1.5 g; Trident, Kraft Foods Brasil, Sao Paulo, Brazil).

To standardize the EMG potentials of the four analyzed muscles, two 10mm thick cotton rolls were positioned on the mandibular second premolar/first molars of each subject (Figure 2) in a final experimental task wherein a 5s maximum voluntarily dental clench (MVC) was recorded [7]. During this further performance, the subjects were verbally encouraged to perform at their best. The 3s period with the most stable signals was automatically detected and the corresponding mean value of each muscle's RMS sequence was referred to as 100% of amplitude.

Figure 2: Detail of the MVC task.

From the 600 RMS potentials recorded for each muscle during each chewing test, the masticatory cycles were automatically detected and the chewing frequency computed (unit, sps, strokes per second).

A bivariate analysis was performed on the simultaneous differential right-left masseter (ΔM, x-coordinate) and temporalis (ΔT, y-coordinate) standardized activity (Lissajous's Cartesian plot) [4,5]. Within each subject and chewing trial, each cycle peak's coordinates were plotted. The pair of coordinates of the center of their distribution (unit, %) and the 90% standard ellipse area (unit, $\%^2$) were calculated. The 90% standard ellipse is a bivariate statistic that contains the 90% of the sample data, and can be used to assess the repeatability of the pattern of contraction of the jaw-elevator muscles: small ellipses correspond to highly repeatable muscular patterns, while large ellipses indicate a larger variability for the same task. In subjects with a normal neuromuscular coordination, the centers of the ellipses describing unilateral chewing plotted as a Lissajous figure should be located in the first (right side chewing, R) and third (left side chewing, L) quadrants of a Cartesian coordinate system [5], with about symmetric figures. Actually, to directly compare right- and left-side chewing figures, the latter was mirrored, making the ΔM and ΔT coordinates worth the differentials between the working side muscles and the balancing side ones (Figure 3).

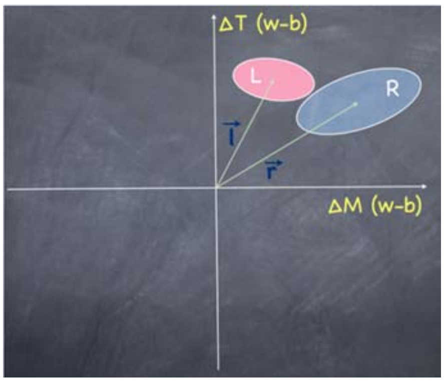

Figure 3: Example of a post-processed Lissajous figure.

To assess if the two unilateral side chewing tasks were performed with symmetrical muscular patterns, the symmetrical mastication index (SMI, %) was computed as follow:

$$SMI\% = 100 \cdot \left(1 - \frac{\|r-l\|}{r+l}\right) \quad (1)$$

SMI ranges between 0% (totally asymmetrical muscular pattern) and 100% (symmetrical muscular pattern).

The total (right and left masseter and temporalis muscles) standardized effort during 15s chewing was computed as the sum of the four integrated areas of the EMG potentials over time (unit, %·s). Also, the mean effort of a single chewing cycle (unit, %·s) and the percentage of the effort referred to the working-side muscles were calculated (unit, %).

Actually, for each subject's chewing index other than SMI, the mean between right and left chewing side values was calculated and further considered for the inter-group comparison. Then, for the chewing frequency, the 90% standard ellipse, the 15s effort and the cycle effort indices, the inter-side difference was quantified by an index of symmetry (SI), calculated as the ratio between the lowest side value and the highest of the two (range: 0-100%). For the working side effort, the SI was calculated as the remainder to 100% of the absolute difference between right and left chewing side values. The inter-side mismatch of ΔM- and ΔT-coordinate of the distribution center was calculated as the absolute difference between right and left chewing side values.

The research protocol did not involve dangerous or painful procedures and was previously approved by the local Ethical Committee (HCRP-14332/2011). Written informed consent was also obtained from the adult volunteers and the parents/legal guardians of the underage participants.

Statistical calculations – For each group, descriptive statistics (mean and SD) were calculated for all the EMG indices of gum chewing. The normal distribution of data was checked with the Kolmogorov-Smirnov test. Subsequently, for each index, the Student t-test for independent samples and Fisher F-test were applied to assess the difference of means and the homogeneity of variances of the two groups. The significance level was set at 5% for all statistical analyses (p>0.05, NS, non-significant).

Results

All data within each group were normally distributed (Kolmogorov-Smirnov test, NS).

No significant difference was found between children and adults' mean chewing frequency (1.36 vs. 1.28 sps; t-test, NS), whereas its intra-group variability was larger in children (SD: 0.23 vs. 0.13 sps; F-test, p=0.050).

Adults showed a slightly larger prevalence activity of both masseter and temporalis of the working side with respect to children (Table 1); this difference was significant when considering the global (masseter plus temporalis) effort. No significant F-test were found.

Table 1: EMG indices (right and left chewing side values were averaged), mean±SD.

Measure [unit]	children	adults	p (t-test)
Center ΔM [%]	68±39	93±54	NS
Center ΔT [%]	52±33	64±44	NS
90% Std. Ellipse area [%^{2}]	24712±12907	18824±17042	NS
Effort-15s [%·s]	1070±487	823±401	NS
Effort/cycle [%·s]	51±19	43±20	NS
Effort-working side [%]	63±8	69±6	.045

Overall, the chewing inter-side indices of symmetry (SMI, SIs) and the inter-side mismatch of ΔM- and ΔT-coordinate of the distribution center were all similar between the two groups (Table 2). Also the rate of intra-group variability was comparable between the two groups (F-tests, NS).

Table 2: EMG symmetry indices (mean±SD).

Measure [unit]	children	adults	p (t-test)
SMI [%]	63±20	70±21	NS
Center ΔM_abs. diff. [%]	35±23	36±29	NS
Center ΔT_abs. diff. [%]	43±39	40±29	NS
90% Std. Ellipse area_SI [%]	55±18	70±20	NS
Effort-15s_SI [%]	84±19	83±13	NS
Effort/cycle_SI [%]	80±18	82±15	NS
Effort-working side_SI [%]	91±9	91±8	NS

The SI of Lissajous ellipse area was remarkably smaller in children, even if the difference was not significant (p=0.058).

Also, the SI of the chewing frequency (mean values: children, 89%; adults, 95%; t-test, NS), resulted more variable among children than inter-adults (SD: 10% vs. 3%; F-test, p=0.001).

Discussion

The purpose of the study was to investigate the major masticatory muscles' function during the performance of standardized chewing task, comparing the resulting characterization between healthy adults and children.

Surface EMG of the head muscles has been reported to be an effective method for the functional assessment of the stomatognathic apparatus [8], with a good repeatability [5,9]. In particular, a standardized protocol was devised, in order to solve problems like the wrong positioning of the electrodes, the different thickness of the skin fat layer, the crosstalk from different muscles). Also, a pre-softened gum was chosen to obtain a standardized and constant (volume and weight) bolus all over the chewing test; no significant modifications of its texture are to be expected in this short duration (15 s for each trial).

Overall, chewing frequency, relative muscular energy expense and pattern variability resulted a little higher in children, although the differences with respect to adults were not statistically significant. Moreover, during chewing, both young and adult healthy subjects had a good coordination between masseter and temporalis contractions, with a prevalent activity of the working-side muscles, as expected under normal conditions [10,11]. Though, in children, the working-side muscular prevalent activity was significantly smaller than in adults: the increased relative activity of the muscles of the balancing side is probably due to the neuromuscular immaturity that appears in less selected muscular side recruitment.

The degree of symmetry between the two chewing side characteristics was quite comparable between the two groups, except for the area of the standard ellipse. In children, the smaller index of the ellipses symmetry, meaning an accentuated divergence in muscular activation variability pattern between the two chewing sides, suggests the existence of a temporary preferred side of mastication, probably induced by an asymmetric acute state of occlusal development.

Overall, an important inter-subject variability was found in both groups. However, frequency and its inter-side asymmetry appeared significantly more variable among children; it is likely that the range of different stages of stomatognathic apparatus development present in the children's group could explain the larger variability of these two parameters, which are the ones representing dynamic temporal characteristics.

Conclusions

Apart from some peculiar differences depending on the dentition stage and the craniofacial development, overall, these findings in healthy subjects with normal occlusion may be interpreted as adequate muscular coordination.

The results of the present investigation are obviously strictly inherent to the extremely standardized protocol and cannot be directly extended to natural chewing (free movements of bolus in both sides of mouth) or to other foods with different mechanical characteristics. However, the proposed method could be a useful tool to evaluate the neuromuscular coordination and to detect functionally altered stomatognathic conditions; in particular, these control data provide a first reference for the assessment of patients, children or adults, with alterations in the cranio-mandibular system.

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