Influence of Breathing Modes and Facial Growth Patterns on Electromyographic Fatigue of Masticatory Muscles in Children

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Abstract

Introduction Changes in breathing patterns affect the harmonious development of the structures of the craniofacial system, leading to changes in posture, occlusion, and facial growth patterns. However, little is known about how these changes influence the muscle contraction patterns, either at rest or while functioning, and either in a normal or unbalanced condition.

Objective To study the masseter and anterior temporal muscles fatigue during mastication in nasal- and mouth-breathing children, also considering their facial growth patterns. Methods: A total of 70 children aged 6 to 12 years old who met the study criteria were assessed. Speech-language-hearing, otorhinolaryngologic, and cephalometric assessments were performed to divide them into groups. In the electromyographic assessment, the children were asked to chew gum following a metronome until they felt fatigued. The median frequency of the muscles was analyzed at 15, 30, 45, and 60 seconds of mastication. The reported time of fatigue perception was recorded. The data were analyzed with analysis of variance (ANOVA) and the Kruskal-Wallis and the Mann-Whitney U tests.

Results There were no median frequency decrease patterns nor differences in the myoelectric manifestations and reported time of fatigue between the groups.

Keywords
- masticatory muscles
- muscle fatigue
- electromyography
- mouth breathing
- stomatognathic system

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Conclusion The masticatory muscles did not reveal fatigue in the electromyographic analysis; however, the fatigue time was reported, despite the absence of physiological fatigue. The breathing mode, the facial growth pattern, and the association between them did not interfere with the behavior of the median frequency of the electromyographic signal and the fatigue time perception.

Introduction

Little is known so far about the contraction patterns of the facial and masticatory muscles, either in normal or unbalanced conditions.[1] In the case of mouth-breathers (MBs), the discussions mainly approach the clinical characteristics of the craniofacial, stomatognathic, and body adaptations, which even affect the quality of life of individuals.[2–4]

Changes in the breathing mode are known to lead to various changes in the harmony and growth of the craniofacial structures, which result from compensations to make airflow easier. These changes include mandible posture and occlusal changes and influences on the facial growth pattern.[5–9]

Some studies have shown that MBs typically have an elongated face,[5] while others have found mesofacial[10,11] and brachyfacial growth patterns[12] as a characteristic of this population. All these imbalances may potentialize speech,[13] swallowing,[2,9] and mastication changes.[9,14,15]

Regarding mastication, specifically, mouth breathing may impair its efficiency. Because of the need to breathe through the mouth, mastication is interrupted, and the person takes longer to finish the masticatory movements. Changes in lip posture and masticatory muscle action (which is often underused) also appear when eating.[9,14,15] However, the literature disagrees whether the masseter and temporal muscles are hypofunctional in MBs,[14,16] and little is known about the extent to which this musculature can be required while maintaining an efficient motor performance.[17] Hence, researching this muscle fatigue can help understand this issue.

Muscle fatigue, which is a natural muscle mechanism, occurs when it is incapable of maintaining high force levels over time.[17–21] The fatigue depends on the type, duration, and intensity of the exercise; the muscle fiber type; the training level of the individual; and the environmental conditions where the exercise is performed.[5] This variable can be analyzed through electrical activity patterns, mainly obtained with surface electromyography (EMG) by means of isometric contractions, which causes this phenomenon more easily[1,22,23]–although usual isotonic situations are also investigated.[1,22,23] Isotonicity nears the usual training of the masticatory muscles,[24,25] which is why the present study seeks to investigate this situation more in depth.

One of the ways to measure muscle fatigue is the analysis of the EMG frequency spectrum, more specifically the median frequency (MF), which is an objective measure of the muscle fatigue process.[26] Much research approaching different pathologies has studied the muscle fatigue threshold. Using MF enables the verification of muscle susceptibility to induced physiological fatigue – that is, the desired force production momentum can no longer be maintained, and contractile fatigue is observed.[21,26]

Surface EMG is an important tool in the objective analysis of facial and masticatory muscle activity. Various methodologies are used to understand the signs and symptoms of muscle fatigue, making the analysis between results more difficult and, consequently, hindering the definition of parameters to choose orofacial muscle training exercises.[27]

Thus, the objective of the present research is to study the fatigue, during mastication, of the masseter and anterior temporal muscles of nasal-breathing (NB) and MB children, also considering their facial growth patterns.

Methods

Sample

The present cross-sectional study encompassed 70 children. Of these, 36 were NBs (21 girls and 15 boys) and 34 were MBs (13 girls and 21 boys), aged 6 years and 0 months to 12 years and 11 months old (mean NB = 9.6 years ± 22 months old; mean MB = 8.9 years ± 21 months old). The inclusion criteria were as follows: presenting agreement between the speech-language-hearing and otorhinolaryngological diagnoses for MB and NB; having the permanent upper first molars already erupted; and having body mass index (BMI) within the normal range for the age.[28] The exclusion criteria were as follows: having a history of speech-language-hearing and/or orthodontic treatment; missing more than three teeth; presenting with signs suggestive of pathological bruxism; having craniofacial syndromes or malformations; and having a neuromuscular impairment. Sex and age homogeneity between the groups was tested with the chi-squared test; no statistical differences between them were found (respectively, $p = 0.05$ and $p = 0.17$). They were divided into three age ranges to group children with structural similarities.

After obtaining this sample, the sample calculation was made, based on Callegari-Jacques,[29] considering the highest standard deviation found (36.18), 5% significance level, and 15-Hz sample error. The resulting minimum sample size was 23 subjects in each group, which had already been obtained.

The age range of the study participants was defined considering that it is potentially difficult to submit children < 6 years old to EMG assessment and that the first molars erupt at 6 or 7 years old. The BMI of the children was also delimited between 5 and 85 percent, considering that larger fat layers under the skin may interfere with the EMG signal pickup.[18,28,30]

Mouth breathing was diagnosed with the agreement between the speech-language-hearing and otorhinolaryngologic assessments; if they did not agree, the subject was excluded. The speech-language-hearing assessment was based on the MBGR Protocol,[31] with information on breathing, occlusion, other treatments, and signs suggestive of craniofacial syndromes or neuromuscular impairment. The otorhinolaryngologic assessment investigated breathing changes and, as performed by Berwig et al.[32] and Ritzel et al.,[33] encompassed oroscopy, anterior rhinoscopy, and otoscopy, followed by fiberoptic nasopharyngoscopy, when necessary. When cephalometry was enough to determine the degree of pharyngeal tonsil hypertrophy, the fiberoptic nasopharyngoscopy was not performed. After this assessment, the children were divided into NB (nasal breathing mode, without signs and symptoms of daytime and/or nighttime mouth breathing) and MB (oronasal or mouth breathing mode, with at least three signs and symptoms of daytime and/or nighttime mouth breathing, such as open mouth/open lips, dry lips, infraorbital dark circles, sagging/drooping face, among others). Of the 34 MB children, 15 were diagnosed from symptoms related to mouth breathing and 17 underwent cephalometry or fiberoptic nasopharyngoscopy, being classified as grades I, II or III of obstruction.

The children were also grouped according to their facial growth patterns. This diagnosis was based on Ricketts cephalometry analysis, performed with lateral teleradiography, using 18×24 cm Kodak film and a cephalostat to standardize the head position in ray emission, at a distance of 1.5 meters. The VERT index[34] was calculated, determining the following facial types: brachyfacial (index value $> +0.5$), mesofacial (index value between - 0.5 and $+0.5$), and dolichofacial (index value $<$ - 0.5).

Hence, the groups were initially formed with NB and MB children; they were afterward subdivided into brachyfacial (Br), mesofacial (Me), and dolichofacial (Do), totaling six groups.

All the children and their parents/guardians agreed to their participation in the study and signed the informed consent form – which had been previously approved by the Research Ethics Committee of the institution under approval protocol number 08105512.0.0000.5346.

Electromyography

The EMG signals were picked up with equipment available in the market – Miotool (Miotec – Brazil), with 8 input channels, 14-bit A/D converter – and saved in a portable computer not plugged into the electrical outlet. Active sensors with differential input (manufactured by Miotec) were connected to Ag/AgCl double electrodes (Hal Indústria e Comércio ltda.), placed on the belly of the right (RM) and left masseter muscles (LM) and of the right anterior (RT) and left anterior temporal muscles (LT). To better locate the muscle bellies, a function test was conducted with the isometric contraction of the mandibular elevator muscles. These disc-shaped electrodes have a fixed 20-mm distance from each other, 20x gain, 10 GΩ input impedance, and common-mode rejection rate > 100 dB.[35] To decrease skin impedance,[19] the sites where the electrodes would be positioned were cleaned with 70% ethyl alcohol and cotton; if necessary, the hair in the region was removed.

The collection room was also treated, having its floor covered with paviflex rubber flooring.[18] As a precaution, equipment that might interfere electromagnetically with the examination was put aside and turned off. The reference electrode (connected to the ground wire) was positioned on the glabela of the patient. The signal was picked up with 20- to 500-Hz filter and a maximum acquisition capacity of 2,000 samples/second/channel. This assessment was performed always by the same researcher to avoid deviations and differences in the collection procedure.

Fatigue Assessment Protocol

The children sat comfortably, hip, knees, and ankles flexed 90°, following the Frankfurt plane. They were instructed on the examination procedures, collection room setting, and equipment and were trained on the procedures before the collection.[12] Isotonicity (mastication) was used to test muscle fatigue, as this function is often trained in clinical practice to strengthen the masticatory muscles.[22,24,25,36,37]

The mastication test was performed three times in sequence, with 2-minute intervals in between them.[18] A digital 80-bpm metronome was used (Mendonça et al., 2005), as well as chewing gum (Plic Ploc - Brazil) because it best resembles food without deteriorating or producing residues that might interfere with the assessment. Two portions of chewing gum were placed on the molars, one on the right and one on the left side of the arch. Initially, the children were asked to chew the gum freely for 40 seconds, without removing it from the sides, to diminish and standardize its resistance. After some rest, they should chew rhythmically until they felt fatigued – that is, the first sign of discomfort in this musculature.[22,36]

Electromyography Signal Analysis

This analysis was performed with the Miograph 2.0 software, for 60 seconds of activity divided into four 15-second intervals (T1, T2, T3, and T4), encompassing $\sim$ 18 mastication cycles. In these intervals, the signal MF was analyzed, considering the moments of activation and inactivation of the cycle together. Of the three mastication collections, the one with the best signal quality was selected (analyzed with the fast Fourier transform [FFT]). Then, the initial 0.5 seconds were excluded to make the assessment period homogeneous. The time reported by the children when they began to feel muscle fatigue was analyzed by recording the moment when it occurred and then comparing them later. The researcher was unaware of the group identification for record analysis.

Statistical Analysis

After testing the normality of the variables with the Shapiro-Wilk test, the repeated measure analysis of variance (ANOVA) was conducted, with the Tukey post hoc test. For the reported fatigue time, without normal distribution, the Mann-Whitney U test and Kruskal-Wallis test were applied, according to the category of each group. The analyses were made in

Table 1 Distribution of means and standard deviations of the median frequency and statistical analysis found in the tests of the masticatory muscles, regardless of the groups, throughout the different collection moments (T1, T2, T3, and T4)

		T1	T2	T3	T4	*p-value*
Mastication	RM	191.8 (19.5)	194.1 (19.6)	194.0 (18.1)	194.0 (18.9)	0.18
	RT	176.7 (25.0)	181.6 (23.8)	180.8 (20.8)	182.3 (20.3)	< 0.01*
		** T1 ≠ T2, T3, T4				
	LM	185.6 (22.4)	189.0 (20.6)	186.5 (22.9)	189.8 (20.4)	0.018*
		** T1 ≠T4				
	LT	184.3 (25.9)	187.4 (26.4)	187.9 (23.4)	188.9 (22.4)	0.02*
		** T1 ≠T4				

Abbreviations: LM, left masseter; LT, left temporal; RM, right masseter; RT, right temporal; T1, 15 seconds of activity; T2, 30 seconds of activity; T3, 45 seconds of activity; T4, 60 seconds of activity.
*Significance with the repeated measure ANOVA test.
**Significance with Tukey post hoc, ≠ difference.

Statistica 9.0 software, with the significance level set at 5% ($p < 0.05$).

Results

Electromyography Signal

The evolution of the MF of the masticatory muscles throughout the mastication, regardless of the groups, is shown in ►**Table 1**. A statistical significance was found for RT ($p < 0.01$), LM ($p = 0.018$), and LT ($p = 0.02$). The post hoc analysis showed that this occurred mainly between 15 and 60 seconds of activity. However, there was no defined MF decrease pattern.

The MF of the masticatory muscles in interaction with the breathing mode (►**Table 2**) revealed no MF continuous decrease. Only the LM and MB had statistical significance ($p < 0.05$), although it referred to an MF increase, instead of a decrease.

Considering the interaction with the facial growth pattern (►**Table 3**) and with its association with the breathing mode (►**Table 4**), there was likewise no decreasing MF pattern or statistical significance.

Perception of Fatigue

The analysis of the reported time of fatigue of the masticatory muscles, in the three group interactions, is shown in ►**Table 5**. There was no significant difference in either of the cases regarding the time when these groups perceived muscle fatigue. In the breathing mode, the MB perceived the fatigue sooner (mean of 95 seconds). In the facial growth pattern, dolichofacial and mesofacial children perceived it sooner (mean of 93 seconds). And in the association of the

Table 2 Distribution of means and standard deviations of the median frequency found for the masticatory muscles during mastication and statistical analysis of the interaction with the breathing mode, throughout the different collection moments (T1, T2, T3, and T4)

		Nasal breathers				Mouth breathers				*p-value*
		T1	T2	T3	T4	T1	T2	T3	T4	
Mastication	RM	194.1 (20.3)	195.8 (20.4)	195.3 (19.9)	195.3 (20.4)	189.0 (18.5)	191.9 (18.9)	192.4 (15.9)	192.3 (17.1)	0.78
	RT	178.5 (20.1)	182.4 (20.2)	181.0 (17.4)	182.5 (16.3)	174.4 (30.4)	180.7 (28.0)	180.5 (24.8)	182.1 (24.8)	0.57
	LM	189.1 (21.0)	189.9 (21.4)	189.5 (21.2)	190.1 (20.3)	181.3 (24.8)	188.0 (19.9)	182.8 (24.7)	189.5 (20.8)	0.04*
						** T1 ≠ T2, T4 and T3 ≠ T4				
	LT	186.4 (26.2)	189.0 (28.1)	189.2 (22.7)	191.3 (22.1)	181.8 (25.9)	185.4 (24.7)	186.2 (24.6)	186.0 (23.0)	0.89

Abbreviations: LM, left masseter muscle; LT, left temporal muscle; RM, right masseter muscle; RT, right temporal muscle; T1, 15 seconds of activity; T2, 30 seconds of activity; T3, 45 seconds of activity; T4, 60 seconds of activity.
*Statistical significance with the repeated measure ANOVA test.
**Analysis with Tukey post hoc, ≠ difference.

Table 3 Distribution of means and standard deviation of the median frequency found for the masticatory muscles during mastication and statistical analysis of the interaction with the facial growth pattern, throughout the different collection moments (T1, T2, T3, and T4)

		Dolichofacial				Mesofacial				Brachyfacial				*p-value*
		T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4	
Mastication	RM	190.8 (16.5)	196.2 (13.5)	194.5 (13.0)	194.1 (13.9)	194.3 (22.9)	190.5 (26.9)	193.7 (21.9)	194.0 (23.0)	191.1 (19.3)	195.0 (17.9)	194.1 (18.0)	193.9 (18.7)	0.24
	RT	178.8 (20.0)	188.1 (30.9)	185.8 (23.1)	186.6 (24.3)	169.9 (28.3)	172.4 (23.1)	173.4 (21.9)	177.0 (22.2)	178.8 (24.9)	183.7 (21.8)	182.4 (19.7)	183.4 (18.7)	0.77
	LM	189.6 (16.6)	194.1 (19.0)	192.3 (20.6)	197.8 (17.2)	180.0 (31.1)	183.8 (19.1)	176.1 (30.2)	183.5 (24.4)	186.9 (20.6)	189.9 (21.6)	189.2 (19.3)	190.3 (19.1)	0.49
	LT	173.2 (24.2)	178.1 (35.8)	183.1 (30.3)	184.5 (21.8)	183.9 (27.1)	185.4 (24.9)	184.2 (25.1)	185.2 (24.1)	187.2 (25.8)	190.5 (24.8)	190.4 (21.3)	191.5 (22.2)	0.49

Abbreviations: LM, left masseter muscle; LT, left temporal muscle; RM, right masseter muscle; RT, right temporal muscle; T1, 15 seconds of activity; T2, 30 seconds of activity; T3, 45 seconds of activity; T4, 60 seconds of activity.

Table 4 Distribution of means and standard deviations of the median frequency found for the masticatory muscles during mastication and statistical analysis of the interaction with the breathing mode in association with the facial growth pattern, throughout the different collection moments (T1, T2, T3, and T4)

		NBDo				NBMe				NBBr				
		T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4	
Mastication	RM	193.8 (16.8)	194.4 (14.5)	192.7 (13.8)	192.0 (16.9)	203.1 (18.4)	198.3 (25.3)	204.5 (21.3)	202.3 (18.9)	191.5 (21.5)	195.4 (20.7)	193.1 (20.5)	193.9 (21.8)	
	RT	171.0 (7.3)	173.6 (20.9)	172.9 (13.8)	178.3 (13.8)	173.1 (19.8)	177.6 (15.2)	176.8 (12.5)	181.7 (11.8)	181.6 (21.7)	185.6 (21.5)	183.9 (19.1)	183.6 (18.2)	
	LM	188.6 (22.2)	191.5 (28.2)	192.8 (29.1)	196.3 (22.3)	192.5 (24.1)	186.7 (13.0)	187.1 (23.2)	186.3 (21.6)	188.1 (20.9)	190.5 (22.9)	189.6 (20.2)	190.0 (20.4)	
	LT	155.6 (15.6)	161.1 (40.9)	169.6 (29.3)	176.2 (26.9)	184.2 (25.7)	185.8 (14.6)	182.9 (21.0)	184.1 (17.6)	193.1 (24.1)	195.6 (25.9)	195.0 (20.2)	196.5 (21.3)	
		MBDo				MBMe				MBBr				
		T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4	p
Mastication	RM	187.8 (18.1)	197.9 (14.3)	196.3 (13.9)	196.3 (12.3)	186.7 (24.9)	183.9 (28.4)	184.4 (19.0)	186.8 (25.1)	190.5 (16.1)	194.3 (13.1)	195.6 (14.1)	194.0 (13.4)	0.49
	RT	186.5 (26.9)	202.7 (35.0)	198.8 (24.6)	194.9 (31.8)	167.1 (35.4)	168.0 (28.8)	170.5 (28.3)	173.0 (28.7)	174.5 (29.6)	180.7 (23.0)	180.3 (21.3)	183.1 (20.3)	0.75
	LM	190.5 (12.0)	196.7 (5.6)	191.9 (11.9)	199.3 (13.7)	169.2 (34.1)	181.3 (23.9)	166.7 (33.9)	181.2 (28.2)	184.9 (20.8)	188.9 (20.4)	188.7 (18.6)	190.9 (17.8)	0.08
	LT	190.9 (17.1)	195.1 (23.3)	196.7 (28.1)	192.8 (14.0)	183.5 (30.3)	185.1 (32.6)	185.4 (29.8)	186.2 (30.1)	178.1 (26.6)	182.6 (21.4)	183.5 (21.8)	183.9 (22.2)	0.59

Abbreviations, LM, left masseter muscle; LT, left temporal muscle; MB, mouth breathing; MBBr, mouth breathing with a brachyfacial pattern; MBDo, mouth breathing with a dolichofacial pattern; MBMe, mouth breathing with a mesofacial pattern; NB, nasal breathing; NBBr, nasal breathing with a brachyfacial pattern; NBDo, nasal breathing with a dolichofacial pattern; NBMe, nasal breathing with a mesofacial pattern; RM, right masseter muscle; RT, right temporal muscle; T1, 15 seconds of activity; T2, 30 seconds of activity; T3, 45 seconds of activity; T4, 60 seconds of activity.

groups, the MB children with mesofacial patterns were the first ones to perceive it (78 seconds). In all cases, the standard deviations (SDs) were high.

Discussion

The analysis of the masticatory muscles, regardless of the interaction with the groups, showed that RT, LM, and LT had a significant change in MF, particularly between 15 and 60 seconds of mastication. However, it was not a decreasing change and therefore was not suggestive of muscle fatigue. These findings corroborate two aspects reported in the literature: the fiber arrangement of this musculature and the dynamic test condition. In the masticatory muscles, more specifically the masseter, there is a predominance of type I[38] and hybrid fibers,[39] which are both more resistant to muscle fatigue because they have an aerobic pattern of energy production.

Regarding the use of chewing gum in the mastication test, the literature reports that the EMG activity of the masseter and temporal muscles is associated with the mechanical properties of the selected foods. In this case, chewing gum enables stable mandible movements and EMG activity, which are considered adequate to analyze the masticatory

Table 5 Distribution of means and standard deviations of the reported fatigue time (in seconds) found for the masticatory muscles during mastication and statistical analysis of the interaction with the groups

Groups		Mastication fatigue time	
		Mean and SD	*p-value*
Breathing Mode	NB	102.7 (63.5)	0.56
	MB	95.5 (65.2)	
Facial Growth Pattern	Dolichofacial	93.6 (36.8)	0.68
	Mesofacial	93.2 (63.5)	
	Brachyfacial	103.2 (68.6)	
Breathing Mode and Facial Growth Pattern	NBDo	95.6 (32.9)	0.75
	NBMe	118.3 (77.8)	
	NBBr	99.5 (63.0)	
	MBDo	92.0 (43.5)	
	MBMe	78.5 (51.5)	
	MBBr	108.6 (77.9)	

MB, mouth breathing; MBBr, mouth breathing with a brachyfacial pattern; MBDo, mouth breathing with a dolichofacial pattern; MBMe, mouth breathing with a mesofacial pattern; NB, nasal breathing; NBBr, nasal breathing with a brachyfacial pattern; NBDo, nasal breathing with a dolichofacial pattern; NBMe, nasal breathing with a mesofacial pattern; SD, standard deviation.

pattern. Moreover, as the muscle blood flow is not interrupted, isotonicity would not easily cause fatigue.[22,23,37]

The interaction of the masticatory muscles with the breathing mode revealed that only the LM had a difference in MF throughout the mastication in the MB group. However, since it referred to its increase, rather than decrease, it was likewise not suggestive of muscle fatigue.[18] Studies with EMG have shown that MBs tends to have less masseter and temporal muscle activity than NBs.[15,40] In another study, children without changes had a diminished masseter and temporal muscle behavior, which may be associated with immature motor coordination, resulting in incapacity to maintain high force levels.[21]

The diminished muscle behavior in MB may be caused by the hypofunctioning of the masticatory muscles of these subjects, especially the mandibular elevators, as the mouth remains open for breathing.[5,8] The masticatory preference pattern and changed head posture of MBs can also interfere with the asymmetry of the musculature, though with no defined pattern.[16,40] Thus, it was hypothesized that the possible asymmetry in the masticatory muscles of this population can also interfere with muscle fatigue – which, however, was not observed.

The perception time of masticatory muscle fatigue reported by the sample children was not statistically different between NBs and MBs, with an approximate mean of 102 and 95 seconds, respectively, and a SD of 63 and 65, respectively. Other authors[22] researched reports of the masseter and temporal fatigue feeling and likewise observed large SDs of the means, suggesting great subjectivity in this variable.

Each facial pattern determines specific characteristics regarding the soft and hard structures, which influence the development of the stomatognathic functions.[32,41] As for the clinical aspects, people with a brachyfacial pattern have thicker and more powerful mandibular elevator muscles. The opposite occurs with the dolichofacial pattern, in whom these muscles are feebler and less strong.[32]

Concerning the myoelectrical manifestations in the facial types, the literature only researched EMG approaching the amplitude and, even so, with disagreements. Some authors did not find differences in the masticatory muscles between the various facial patterns during mastication,[42] whereas others observed that the masseter muscles of the dolichofacial pattern were more active in this function.[43] Since there is a muscle imbalance, especially in the brachyfacial and dolichofacial patterns,[6,32,42] it was hypothesized that the masticatory muscles could also have fatigue differences – which, however, was not proved.

There was no difference in the reported time of masticatory muscle fatigue of the children between the facial growth patterns. Another study[44] investigated reports of pain and fatigue in the masseter muscle of people with different types of craniofacial morphology and observed that people with normal and elongated facial patterns have greater resistance and take longer to start feeling pain. The authors pointed out, as a plausible explanation for the observed differences, the theory of mechanical advantage, in which subjects with an elongated face have a smaller mechanical advantage in the mandibular elevator muscles. Hence, those with a short face have more occlusal force and consequently greater intramuscular pressure. This may limit the muscle blood flow, which is necessary to maintain force. This disagreement may be explained by the difference between samples, as the one in the present study encompassed children, whereas the one in the literature encompassed adults. Furthermore, the subjectivity of this variable may indicate greater perception difficulty in children.

The breathing mode was also considered along with the facial growth pattern because it was believed that changes in these two aspects may potentialize each other. Nevertheless, although the sample distribution into these new groups showed their stomatognathic characteristics in further detail, it did not occur in myoelectric terms for the masticatory muscles. The analysis of the MF and the fatigue perception time for this musculature throughout the collection time revealed no difference.

Thus, it seems clear to say that the masticatory muscles are rather resistant to fatigue, especially in dynamic situations, which elongate the muscle belly and consequently increase the blood flow. This increases the muscle temperature and metabolism, further removing the substrates that cause fatigue.[45] However, future studies should address other aspects neither investigated nor controlled in the present study – such as the amplitude of the EMG signal –, aiming at a more precise interpretation of these findings.

It is important to highlight that the present study has some limitations, such as the small sample size when the six groups were analyzed separately and the muscle fatigue analysis based exclusively on the EMG signal frequency, without its amplitude – which is already being addressed in other studies of this research group.

Conclusion

The EMG analysis of the masticatory muscles during mastication showed that they were not suggestive of fatigue. However, the fatigue time was reported despite the absence of physiological fatigue. The breathing mode, the facial growth pattern, and the association between them seemed not to influence the behavior of the MF of the EMG signal and the fatigue time perception.

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Conflict of Interests
The authors have no conflict of interests to declare.

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