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Review articles

Surface electromyography in orofacial and cervical musculature in mouth breathing children: an integrative literature review

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ABSTRACT

Purpose: to review, in an integrative manner, studies using surface electromyography in the orofacial and cervical musculature in mouth breathing children aged from three to 11 years and 11 months old.

Methods: the survey was conducted in national and international databases, from 1998 to 2018, in Portuguese, English and Spanish. Review articles, dissertations, book chapters, case studies and editorials were excluded.

Results: 86 articles were found, 14 of which met the inclusion criteria. Most of these studies used surface electromyography to assess and describe the muscle condition of the mouth breathing population. Only one study addressed the influence of myofunctional speech therapy and two studies included physical therapy treatment, using electromyographic evaluation before and after the intervention. Given the main categories of analysis, the discussion was based on the year, state of publication and journal, sample size, scientific methodology, muscles assessed, assessment protocols used and the results of the publications.

Conclusions: surface electromyography has been used mainly in the initial assessment of orofacial and postural myofunctional changes caused by mouth breathing and not as a therapeutic biofeedback, thus, it is important to conduct longitudinal studies using this instrument in mouth breathers.

Keywords: Surface Electromyography; Mouth Breathing; Children; Preschool

INTRODUCTION

Nasal breathing plays an important role in the quality of life of humans, as it promotes the filtration, heating and humidification of inspired air in order to reach the lungs in an optimum temperature[1]. This type of breathing also favors the craniofacial growth as well as the development of the individual and the proper functioning of stomatognathic functions[2].

The literature indicates that any factor that leads to an upper airway (UA) obstruction, such as septum deviation, pharyngeal or palatine tonsil hypertrophy (adenoids and/or tonsils)[3], or even due to sagging on speech organs and simple parafunctional habits, causes nasal breathing to be replaced by mouth breathing[4].

Mouth breathing has been studied since the 20th century with publications focused on Dentistry due to the occlusal consequences[5]. However, as a public health problem, it has generated greater scientific interest in recent years in other health areas due to the multidisciplinary aspects involved[6]. Areas such as otorhinolaryngology, dentistry and speech-language pathology associate mouth breathing with nasal, dental and orofacial motricity aspects[7]. Most studies address mouth breathing in childhood[6], since the child's craniofacial growth and development occur at this stage and inadequate breathing, depending on its duration, may cause structural, functional, postural and behavioral changes that impact negatively on the individual's quality of life[8].

As for the aspects of orofacial motricity, the main characteristics of the mouth breather are the lack of lip sealing, arched or high palate, Angle's Class II occlusion, unilateral or bilateral crossbite, open bite, sleep apnea, everted lower lip, retracted upper lip, generalized facial hypotonia, changes in stomatognathic functions, postural changes[9,10] , among others. These postural changes include shoulders rotated forward, head projected forward from the body, forward displacement of the hip, and body weight resting on the belly[11].

The literature also describes the main signs and symptoms in mouth breathers, such as sleeping with an open mouth, snoring, scratching the nose, difficulty breathing at night or restless sleep, irritability, as well as daytime sleepiness, frequent tiredness, learning issues, learning deficit and behavioral problems[12]. Due to the wide changes found in mouth breathing children, it is important to emphasize the relevance of a multidisciplinary team, composed by otorhinolaryngologist, orthodontist, speech-language pathologist and physiotherapist[13].

In order to assist in the early assessment and diagnosis of children with respiratory disorders, advances and scientific studies have enabled additional clinical evaluation through instrumental tests, such as the surface electromyography (sEMG)[14].

The sEMG has been studied for some years in speech-language pathology research as an opportunity to analyze the muscle electrical activity in a quantitative manner, and may help in understanding the patterns of electrical activity of facial and masticatory muscles, leading professionals to an early diagnosis and a more effective intervention in Oral Motricity[15].

Thus, this article aimed to review, in an integrative manner, studies using surface electromyography in mouth breathing children aged from three to 11 years and 11 months old, in order to understand the purpose of using this instrument and its contribution to the therapeutic intervention and evaluation.

METHODS

An integrative review study was conducted in order to analyze the available scientific evidence, both in the speech-language pathology literature as in other health areas, on the use of sEMG in mouth breathing children upon the following questions: "*What is the purpose of using surface electromyography in orofacial and cervical muscles in mouth breathing children?*". *"What surface electromyography can provide to the assessment and intervention of these children?".* The researchers conducted a survey of studies in Portuguese, English and Spanish published in the US National Library of Medicine National Institutes Health (PubMed), Scientific Electronic Library Online (SciELO), Medical Literature Analysis and Retrieval System Online (MEDLINE) and *Literatura Latino-Americana e do Caribe em Ciências da Saúde* (LILACS) databases from 1998 to 2018. The descriptors found in the DeCS and MeSH that were used to find the studies in the three languages were: Electromyography *OR Electromiografia OR Eletromiografia*; Mouth Breathing *OR Respiración por la Boca OR Respiração Bucal AND* Child, Preschool *OR Preescolar* OR *Pré-Escolar OR* Child OR *Niño OR Criança*. The search was conducted by the association of at least two of the descriptors.

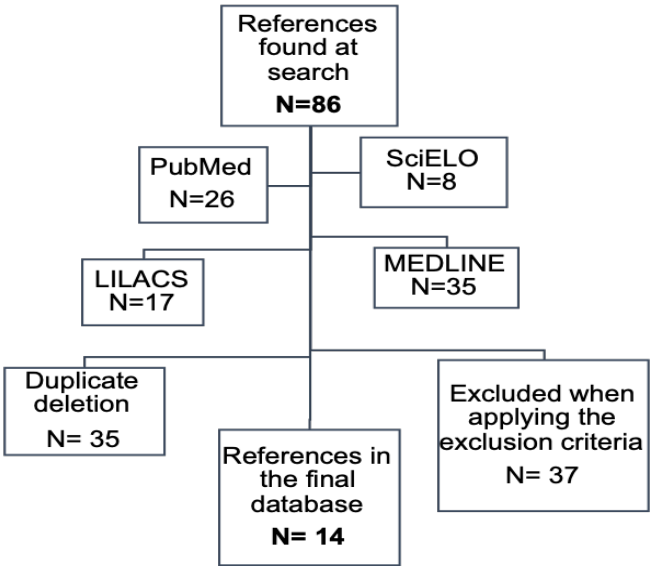
Exclusion criteria were: studies not published in journals indexed in PubMed, SciELO, MEDLINE and LILACS databases; studies not published from 1998 to 2018; studies that did not included surface

electromyography in mouth breathing children; studies with a sample population with an age range different of three to 11 years and 11 months of age; literature review, dissertations, book chapters, case studies and editorials, as well as those that did not have the subject addressed in this review in its title, abstract or text. The study included original research articles published in journals of speech-language pathology and other health areas, such as physical therapy and dentistry.

The selection stages of the articles were: first, a reading of the title of the studies found and the exclusion of those that did not fit the purpose of this study; then, a reading of its abstracts including the use of surface electromyography in the mouth breathing children population and the exclusion of those that did not fit the inclusion criteria.

The search and selection of articles were conducted as follows: 1) initial search for references in databases; 2) selection of references based on inclusion criteria by reading title and abstract; 3) duplicate deletion; 4) exclusion of studies according to the exclusion criteria, by reading the abstract and the methodology. All stages of the study were performed by the researcher student and the professor adviser.

Figure 1 shows the search and selection process of studies until the final design of the database for the analysis process.



N: number of studies

Figure 1. Organization chart of the literature search and selection process

LITERATURE REVIEW

Eighty-six references were found from the search descriptors. Out of these, 26 were found in PubMed, 8 in SciELO, 17 in LILACS and 35 in MEDLINE. 35 studies were excluded in the third stage due to duplicate databases and 37 studies were excluded when applying the exclusion criteria, resulting in the 14 articles remaining in this study. Although the descriptors were used in the three languages (Portuguese, English and Spanish) in the databases, the final result included only articles published in Brazil. As shown in Figure 2, the studies were initially described by their main characteristics and then characterized in three items, for descriptive statistics of the frequency of each characteristic: scientific production (year of publication, journal of publication and the state in which the study was conducted); population (number of sample subjects, gender and age group) and assessed muscles, according to Tables 1, 2 and 3, respectively.

The year of publication ranged from 1998 to 2015, that is, it can be noticed that the articles found were published in the last 17 years, and no study of the current year met the inclusion criteria. It can also be noted that most studies were published annually from 1998 to 2011. It may be related to the emergence of new devices that makes it easier to perform electromyography and to the training of professionals for the electromyographic technique after the creation of the standardized protocol suggested by the *Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles* (SENIAN) during the *International Society of Electrophysiology and Kinesioly* (ISEK), in 2002[16]. Subsequently, the next study is from 2015, which is also the last publication found in the survey.

There was a higher number of publications in the Rio Grande do Sul state with 8 (57.1%) studies published from 2002 to 2015, which is believed to be due to the study group led by the speech-language pathologist Ana Maria Toniolo da Silva with a team of students and colleagues at the Universidade Federal de Santa Maria, RS, Brazil, following a line of research associated with orofacial motricity, mouth breathers and electromyography.

Authors	Year	Title	Journal	State	Sample	Gender	Age range
Tomé and Marchiori [19]	1998	Estudo eletromiográfico dos músculos orbiculares superior e inferior da boca em crianças respiradoras nasais e bucais durante o repouso com e sem contato labial	J. Bras. Ortodon. Ortop. Facial	Paraná	30	Both	4 to 6 years and 8 months
Tomé and Marchiori [24]	1999	Análise eletromiográfica dos músculos orbiculares superior e inferior da boca em crianças respiradoras nasais e bucais durante a emissão de sílabas	Pró-Fono	São Paulo	30	Both	4 to 6 years and 8 months
Schievano, Rontani and Bérzin [23]	1999	Influence of myofunctional therapy on the perioral muscles. Clinical and electromyographic evaluations	J. Oral Rehabil	São Paulo	13	Both	5 to 10 years
Ribeiro and Marchiori [17]	2002	Electromyographic analysis of trapezius and sternocleidomastoideus muscles during nasal and oral inspiration in nasal- and mouth-breathing children.	J.Electromyogr Kinesiol	Rio Grande do Sul	46	Both	8 to 12 years
Povh et al. [27]	2003	Estudo eletromiográfico do músculo orbicular da boca, segmento superior (região medial) em crianças com má oclusão Classe I e modo respiratório bucal	Rev. Dent. Press Ortodon. Ortop. Maxilar	Paraná	88	Both	Mean of 6 years and 11 months
Fronza et al. [20]	2004	Estudo morfofuncional do segmento medial, porção superior, do músculo orbicular da boca em crianças com má oclusão de Classe II, divisão 1 de Angle e com modos respiratórios predominantemente nasal ou bucal	Rev. Dent. Press Ortod. Ortop. Facial	Paraná	50	Both	6 to 9 years
Ribeiro, Marchiori and Silva [25]	2004	Electromyographic muscle EMG activity in mouth and nasal breathing children	Journal of craniomandibular practice CRANIO	Rio Grande do Sul	46	Both	8 to 12 years
Vieira et al. [28]	2005	Estudo da função muscular peribucal, do grau de inclinação vestíbulo-lingual e da discrepância de modelo dos incisivos inferiores permanentes em crianças respiradoras nasais e bucais com oclusão normal e má oclusão de Classe I.	Rev. Dent. Press Ortodon. Ortop. Facial	Paraná	88	Both	6 to 8 years and 2 months
Correa et al. [21]	2007	Efficacy of physical therapy on cervical muscle activity and on body posture in school-age mouth breathing children	Journal of Pediatric Otorhinolaryngology	Rio Grande do Sul	19	Both	Mean of 10.6 years
Correa et al. [22]	2008	Mouth Breathing Syndrome: Cervical muscles recruitment during nasal inspiration before and after respiratory and postural exercises on Swiss Ball	Journal of Pediatric Otorhinolaryngology	Rio Grande do Sul	19	Both	Mean of 10.6 years
Ferla, Silva and Corrêa[15]	2008	Electrical activity of the anterior temporal and masseter muscles in mouth and nasal breathing children.	Brazilian Journal of Otorhinolaryngology	Rio Grande do Sul	29	Both	8 to 12 years
Hennig et al. [14]	2009	Deglutição de respiradores orais e nasais: avaliação clínica fonoaudiológica e eletromiográfica	CEFAC	Rio Grande do Sul	16	Both	6 to 11 years
Boton et al. [18]	2011	Estudo eletromiográfico dos músculos faciais de respiradores nasais, respiradores orais viciosos e obstrutivos	CEFAC	Rio Grande do Sul	59	Both	7 to 11 years and 11 months
Busanello-Stella et al. [26]	2015	Fadiga eletromiografica dos musc. orbiculares da boca durante exercícios em crianças orais e nasais	CoDAS	Rio Grande do Sul	70	Both	6 to 12 years

Figure 2. Main findings in the literature on the use of surface electromyography in mouth breathing children

Title	Purpose	Methodology	Assessment Protocols	Muscles Assessed	Results
Estudo eletromiográfico dos músculos orbiculares superior e inferior da boca em crianças respiradoras nasais e bucais durante o repouso com e sem contato labial	To study the muscle activity of the upper and lower orbicularis oris muscles in the two lip resting positions in nasal and mouth breathing children.	30 children of both genders, aged between 4 and 6 years and 8 months, and distributed according to breathing mode, were evaluated in two groups of 15 individuals. Electromyographic recordings were obtained for all children in the upper and lower orbicularis oris muscles during rest with and without lip contact.	Not reported	Upper and lower orbicularis oris muscles	The activity of both muscles assessed was higher in mouth breathing children than in nasal breathing children during the evaluation tests at rest with and without lip contact and in the maintenance of effort test.
Análise eletromiográfica dos músculos orbiculares superior e inferior da boca em crianças respiradoras nasais e bucais durante a emissão de sílabas	To study the activity of the upper and lower orbicularis oris muscles in nasal and mouth breathing children through electromyographic recordings.	30 children of both genders, aged between 4 and 6 years and 8 months, and distributed according to breathing mode, were evaluated in two groups of 15 individuals. Electromyographic recordings were obtained for all children in the upper and lower orbicularis oris muscles during the production of the following syllables: /pa/,/ba/,/ma/,/sa/,/ fa/,/va/.	Not reported	Upper and lower orbicularis oris muscles	The electromyographic activity of both muscles assessed was lower in mouth breathing children than in nasal breathing children during the evaluation tests of syllables production.
Influence of myofunctional therapy on the perioral muscles. Clinical and electromyographic evaluations	To analyze the influence of the myofunctional therapy on the upper and lower orbicularis oris (UOO and LOO) and mentalis muscles in mouth breathers at rest and with closed lips.	Clinical and electromyographic evaluations were conducted before and after treatment (myofunctional therapy).	Not reported	Upper and lower orbicularis oris and mentalis muscle	The results showed that muscles ($P<0.05$) and functions ($P<0.01$) improved after therapy, which can be noticed on clinical evaluations. The increase in the electrical activity between resting and closed lip position was statistically significant.
Electromyographic analysis of trapezius and sternocleidomastoideus muscles during nasal and oral inspiration in nasal- and mouth-breathing children.	To assess the sternocleidomastoid (SCM) and trapezius (upper fibers) muscle activity patterns in mouth breathing children and compare them with nasal breathing children.	Group I consisted of 26 mouth breathing children, while Group II consisted of 20 nasal breathing children. The electromyographic recordings were obtained through surface electrodes on the sternocleidomastoid (SCM) and trapezius muscles bilaterally during oral and nasal inspiration.	Not reported	Sternocleidomastoid (SCM) and trapezius muscles bilaterally	There was a significant difference in the muscle activity between the groups, with increased activity during nasal inspiration in the mouth breathing group. On the other hand, there was no significant difference between the groups during oral inspiration.
Estudo eletromiográfico do músculo orbicular da boca, segmento superior (região medial) em crianças com má oclusão Classe I e modo respiratório bucal	To study by electromyography the upper (medial region) orbicularis oris muscle in children with Class I malocclusion and mouth breathing pattern.	Children were divided into subgroups according to the type of dental occlusion and breathing pattern.	Not reported	Upper (medial region) orbicularis oris muscle	There was no statistically significant difference between the subgroups for all electromyographic variables.
Estudo morfofuncional do segmento medial, porção superior, do músculo orbicular da boca em crianças com má oclusão de Classe II, divisão 1 de Angle e com modos respiratórios predominantemente nasal ou bucal	To conduct a morphofunctional evaluation of the upper medial region of the orbicularis oris muscle, investigating possible associations with mouth breathing.	Morphofunctional evaluation of the upper medial region of the orbicularis oris muscle, investigating the associations with mouth breathing. Use of lateral cephalometric radiographs and functional evaluation with electromyographic analysis.	Not reported	Upper medial region of the orbicularis oris muscle	There was no statistically significant difference between the two groups regarding the shape of the upper lip, as well as to the function.

Title	Purpose	Methodology	Assessment Protocols	Muscles Assessed	Results
Electromyographic muscle EMG activity in mouth and nasal breathing children	To compare by electromyography (EMG) the activity pattern of the sternocleidomastoid and upper trapezius muscles in mouth and nasal breathing children.	Group I consisted of 26 mouth breathing children, while Group II consisted of 20 nasal breathing children. EMG recordings were made using surface electrodes bilaterally in the areas of the sternocleidomastoid and upper trapezius muscles while relaxed and during maximal voluntary contraction.	Not reported	Sternocleidomastoid and upper trapezius muscles	Results suggested greater activity during relaxation and decreased activity during maximal voluntary contraction in mouth breathers.
Estudo da função muscular peribucal, do grau de inclinação vestíbulo-lingual e da discrepância de modelo dos incisivos inferiores permanentes em crianças respiradoras nasais e bucais com oclusão normal e má oclusão de Classe I	To check the association between the mouth breathing pattern, the behavior of the lower orbicularis oris and mentalis muscles and the determination of specific occlusal characteristics in the anterior region of the lower dental arch.	The sample was divided into 4 subgroups relating to breathing pattern and type of occlusion. 22 electromyographic tests were conducted, in addition to the assessment of the buccolingual inclination degree (FMIA) and the model discrepancy (MD) of the permanent lower incisors.	Not reported	Orbicularis oris and mentalis muscles	There was no statistically significant difference when comparing the subgroups for the dental variables and for most of the electromyographic variables evaluated.
Efficacy of physical therapy on cervical muscle activity and on body posture in school-age mouth breathing children	To evaluate the effectiveness of a combined postural exercise and breathing program on cervical muscles and body posture in mouth breathing children of school age.	The children in the sample were recruited from a public school or a speech-language pathology therapy. The evaluation procedures included electromyographic recordings of the sternocleidomastoid (SCM), suboccipital (SOC) and upper trapezius (TU) muscles and digital photographic analysis before and after treatment.	Not reported	Sternocleidomastoid (SCM), suboccipital (SOC) and upper trapezius muscles	There was a significant reduction ($p<0.05$) in the electrical activity in the muscles assessed while in relaxed position. The improvement of postural deviation was shown in the digital photographic analysis, especially the reduction of anterior head posture and abducted scapula.
Mouth Breathing Syndrome: Cervical musclesrecruitment during nasal inspiration beforeand after respiratory and postural exerciseson Swiss Ball	To assess the cervical muscle recruitment during nasal inspiration before and after breathing and postural exercises on the Swiss ball in children with Mouth Breathing Syndrome (MBS).	The surface electromyography of the sternocleidomastoid (SCM), suboccipital, and upper trapezius muscles was recorded during nasal inspiration in the baseline and at the end of three months of treatment.	Not reported	Sternocleidomastoid (SCM), suboccipital (SOC) and upper trapezius muscles	At the end of the treatment, the muscles assessed reached lower electromyographic levels during nasal inspiration and became closer to those in a relaxed position.
Electrical activity of the anterior temporal and masseter muscles in mouth and nasal breathing children	To study, through the electromyographic analysis, the pattern of electrical activity of the anterior temporal and masseter muscles in mouth breathing children, comparing them with nasal breathing children.	Patients were divided into two groups: mouth breathers (n=17), and nasal breathers (n=12). Children underwent bilateral electromyographic test of the anterior temporal and masseter muscles in the maximal intercuspidal position and during normal chewing.	Not reported	Bilateral anterior temporal and bilateral masseter muscles	The observed level of electrical activity in the mouth breathing group was lower in all analyzed muscles; however, a statistical significance was found only in the left temporal muscle.
Deglutição de respiradores orais e nasais: avaliação clínica fonoaudiológica e eletromiográfica	To assess and compare the swallowing of mouth and nasal breathing subjects, through clinical and electromyographic assessment of the upper and lower orbicularis oris muscles.	The speech-language pathology assessment included the structures and functions of the stomatognathic system, while the electromyographic assessment consisted in capturing the electrical activity of the upper and lower orbicularis oris muscles during isometry and swallowing.	Not reported	Upper and lower orbicularis oris muscles	Swallowing changes were observed in the mouth breathers in the clinical evaluation. On the other hand, electromyographic evaluation showed higher muscle activity in mouth breathers when compared to nasal breathers.

Title	Purpose	Methodology	Assessment Protocols	Muscles Assessed	Results
Estudo eletromiográfico dos músculos faciais de respiradores nasais, respiradores orais viciosos e obstrutivos	To check the electrical activity of the orbicularis oris, masseter and temporal muscles at rest, in the lip and chewing isometries, in nasal breathing children and vicious and obstructive mouth breathing children, comparing them.	The study assessed 15 nasal breathing children (NB); 23 vicious mouth breathing children (VMB) and 21 obstructive mouth breathing children (OMB). Children underwent otorhinolaryngological and speech-language pathology assessments, as well as to an electromyographic examination at rest, and chewing and lip isometries.	Not reported	Orbicularis oris, masseter and temporal muscles, bilaterally	There was no significant difference in the muscles studied when comparing the three groups, except for the right masseter muscle at rest, when comparing nasal breathers (NB) and vicious mouth breathers (VMB).
Fadiga eletromiográfica dos músculos orbiculares da boca durante exercícios em crianças orais e nasais	To study the orbicularis oris muscles fatigue through the median frequency analysis of the electromyographic signal and the reported time of fatigue, according to the respiratory pattern and the facial growth pattern.	They underwent speech-language pathology, otorhinolaryngological and cephalometric evaluation to be classified into 36 nasal and 34 mouth breathers. For the electromyographic evaluation, the children supported 40, 60 and 100 g lip dumbbells and a lip exerciser until the feeling of fatigue.The median frequency was analyzed in 5, 10, 15 and 20 seconds of activity.	MBGR –Protocol of Orofacial Myofunctional evaluation with scoresMuscle Fatigue Assessment Protocol	Orbicularis oris muscles	Regardless of the comparison between the groups, there was a significant decrease in the median frequency after five seconds of activity. The reported time for the feeling of fatigue was lower in mouth breathers.

Figure 3. Main findings in the literature on the use of surface electromyography in mouth breathing children

Table 1. Frequency of scientific production characteristics of surface electromyography in mouth breathers

	N	%
Year		
1998 a 2004	7	50%
2005 a 2011	6	42.8%
2012 a 2015	1	7.1%
Journal		
Jornal Brasileiro de Ortodontia e Ortopedia facial	1	7.1%
Pró-Fono	1	7.1%
Journal of Oral Rehabilitation	1	7.1%
Journal of Electromyography & Kinesiology	1	7.1%
Revista Dental Press de Ortodontia e Ortopedia Maxilar	1	7.1%
Revista Dental Press de Ortodontia e Ortopedia Facial	2	14.2%
Journal of Craniomandibular Practice - CRANIO	1	7.1%
Brazilian Journal of Otorhinolaryngology	1	7.1%
Journal of Pediatric Otorhinolaryngology	2	14.2%
CEFAC	2	14.2%
CoDAS	1	7.1%
State/Country		
São Paulo/Brazil	2	14.2%
Paraná/Brazil	4	28.5%
Rio Grande do Sul/Brazil	8	57.1%

N: number of studies, %: percentage

Table 2. Frequency of sample population characteristics

	N	%
Number of subjects sampled		
10-20	4	28.5%
21 to 30	3	21.4%
41 to 50	3	21.4%
51 to 60	1	7.1%
61-70	1	7.1%
81-90	2	14.2%
Gender		
Both genders	14	100%
Age range		
4 to 6 years and 11 months	2	14.2%
Mean of 6 years and 11 months	1	7.1%
5 to 10 years	2	14.2%
6 to 12 years	6	42.8%
8 to 12 years	3	21.4%

N: number of studies, %: percentage

Table 3. Frequency of muscles assessed

Muscles Assessed	N	%
M. orbiculares superior e inferior da boca	4	28.5%
M. orbicular de boca segmento superior	2	14.2%
M. orbiculares da boca e mentual	2	14.2%
M.esternocleidomastoideus (ECM) e trapézio	2	14.2%
M. esternocleidomastóideo (ECM), suboccipital (SOC) e músculo trapézio superior	2	14%
M. orbiculares orais, masseteres e temporais	1	7.1%
M. temporal anterior bilateral e masseter bilateral	1	7.1%

M: muscles, N: number of studies, %: percentage

As for publication journals, there is a wide variety of journals. Among the 14 studies, one that stands out was found in the "Journal of Electromyography and Kinesiology"[17], which is the main source of outstanding original articles on the study of muscle contraction and human movement, focused on publishing the best studies in all areas related to electromyography and kinesiology. Two studies were published in the Revista CEFAC, which addresses only articles from the Speech-Language Pathology-related areas[14,18]. Two other studies in the area of Dentistry and Orthodontics were published in the Revista Dental Press de Ortodontia e OrtopediaFacial[19,20] and, finally, two studies in the area of Otorhinolaryngology were published in the Revista de Otorrinolaringologia Pediátrica[21,22].

The sample ranged from 13 to 88 individuals, including children of both genders from 4-12 years old, and the largest age group studied was from 6-12 years old. Even in studies with smaller samples[14,21-23], the authors reported an electromyographic evidence of both for the improvement of the muscles evaluated after speech-language pathology therapy[23] and physical therapy[21,22], as for the electrical activity of the upper orbicularis muscle in mouth breathers[14]. No article indicates that a restricted number of subjects may have been a factor that influenced the results.

As for the methodology of the studies, it was found that most studies divided the sample into two groups (mouth and nasal breathers)[14,15,17,19,21-26] with subgroups[18,27,28] to compare the electromyographic findings of the muscles studied in the two populations.

A single study addressed the impact of myofunctional therapy by performing an electromyographic assessment before and after a speech-language pathology therapy[23] , and two other studies assessed muscle electrical activity after months of physical therapy sessions[21,22] , while the other studies used the electromyography to complement the initial clinical assessment, detect the muscle activity pattern[14,15,17,18,20,24,25,27,28] and to assist in the diagnosis[26]. The literature in the speech-language pathology area understands the sEMG as a reliable tool for a reliable assessment, diagnosis and treatment related to speech-language pathology[24,26].

Only three of the 14 studies include the etiology of mouth breathing undergoing nasopharyngoscopy and oroscopy to confirm the diagnosis of upper airway obstruction[21,22] and there are reports that few studies classified mouth breathers according to the etiology as obstructive and vicious, making it difficult to discuss its results[18]. In this study, the authors show the importance of knowing the etiology of mouth breathing in order to assist in therapeutic management, as they believe that children with mouth breathing caused by nasal obstruction are more likely to develop more severe muscle changes than children with vicious mouth breathing[18].

The literature reports that children who have chronic mouth breathing may show significant changes in the craniofacial development, with changes in both bone and muscle tissues, that is, several structural changes of the speech organs, such as: hypotonia of the jaw elevators (masseter muscles) , tongue hypotonia, changes in the tongue resting posture, as well as in the orbicularis oris (the short upper and everted lower lip)[29] and mentalis muscles, all of which impair the stomatognathic functions, such as speech, swallowing and chewing in addition to vocal changes[29-33]. As shown in Table 3, the assessment of the orbicularis oris muscles was included in 9 studies (64.2%)[15,17,20,21,23-25,28,30] and this is due to the fact that the perioral muscles, including the orbicularis oris and mentalis muscles[17,21], will act more actively in order to restore the lip sealing required to adequate breathing[34,35], which arouses the interest of researchers to evaluate both subjectively and quantitatively with electromyographic results, correlating with swallowing[14], chewing[15,18] and speech[24] functions.

There are studies that claim that the compensatory participation of perioral muscles in mouth breathers during the swallowing function, for example, is an adaptation of the stomatognathic system as the chewing muscles do not perform the muscle activity that is required for this function[36,37]. Therefore, two studies among the results of this integrative review evaluated not only the orbicularis oris muscles, but also the temporal and masseter muscles[15,18] in mouth breathers comparing them to the group of mouth breathers. It is believed that the interest of these scholars towards these masticatory muscles in this specific population is due to the fact that the discussions are restricted to chewing development in mouth breathers, and the evaluation is based only on clinical aspects, with the need for a quantitative aspect, through a device to assist in the assessment, diagnosis and a more effective intervention[13].

Other studies decided to evaluate the sternocleidomastoid (SCM) and trapezius muscles in both relaxation and maximal voluntary contraction[25] and during oral and nasal inspiration[18] in order to understand the level of muscle activity since, as mentioned, mouth breathing children change the position of the head and neck[11] to reduce the narrowing of the airways[25], and the SCM muscle is considered a tool for inspiratory movement. These authors found greater SCM muscle activity in mouth breathing children during nasal inspiration, attributing this increased activity to the effort to increase lung volumes[18]. Regarding this action of accessory muscles during nasal breathing in mouth breathers, some authors[17] concluded that the therapy aimed at this population should not be performed only for orofacial changes, as there are also changes in the cervical muscles. Thus, other studies[21,22] using sEMG on cervical muscles (sternocleidomastoid, subocciptal and upper trapezius) were also found to verify the effectiveness of physical therapy sessions after a period of treatment. However, there is a consensus that there are few publications involving these muscles, and the authors suggest the development of further studies to verify the level of cervical muscle activity after postural and respiratory care.

The following category of analysis refers to the evaluation protocols used for both the evaluation, especially of the stomatognathic system, as for the use of the surface electromyography. None of the 14 studies mentioned any of the various types of surface electromyography protocols created by the Professor Hilton Justino da Silva[38] and other authors of the book "*Protocolos de Eletromiografia de Superfície em Fonoaudiologia*", published by Pró Fono[38] This book has electromyographic assessment protocols in phonation, an electromyographic assessment protocol

for cervical muscles, among others, that could and should be present in studies using surface electromyography as a complementary tool for evaluation, diagnosis and clinical intervention. Only one speech-language pathology study[30] reported the use of the MBGR protocol (Protocol of Orofacial Myofunctional evaluation with scores)[39] that addresses general aspects of the stomatognathic system, as well as breathing, chewing and swallowing functions, for the clinical evaluation of the study population.

Referring to the results analyzed in the studies included in this integrative review, it was found that there were data showing the increased electrical activity of the orbicularis oris muscles with and without lip contact in mouth breathers when compared to nasal breathers, with a statistically significant difference[19] in line with the findings of another study[29]. However, the electromyographic activity was lower[24] during the speech test (production of syllables with bilabial and labiodental phonemes) in the same muscles evaluated, and it is believed that this is due to the hypotonia of the speech organs. Two of the studies assessed only the upper orbicularis oris muscle and found that there was no statistically significant difference between the subgroups[27] evaluated, as well as for the shape of the upper lip in relation to function[20]. On the other hand, the literature shows an increase in the activity of the lower orbicularis oris muscle due to the joint action of the mentalis muscle, in order to compensate the hypofunctionality observed in mouth breathers[40]. This activation of the lower orbicularis oris muscle seen in the literature is in line with the results reported also in the study that composes this integrative review, in which when evaluating the vicious mouth breathing (VMB) and the obstructive mouth breathing (OBM) at rest, the authors found that the lower orbicularis oris muscle in OBMs were electrically more active than in nasal breathers[18].

Finally, regarding the electromyographic findings of the temporal muscles evaluated, there was also an increased electrical activity of the left temporal muscle in OMBs during masticatory isometry[18], similar result was found in another study[14] that evaluated the maximum intercuspidal position and during habitual chewing[1814] In this regard, the literature explains that due to the anterior head posture in mouth breathers, which occurs in order to facilitate the air flow through the oropharynx, the temporal muscles have increased electrical activity in an attempt to compensate the lower activity of the masseter muscles. In addition, the greater activity of the left temporal muscle in relation to the right one may be related to the chewing lateral preference pattern[18]. As for the SCM, suboccipital and trapezius muscles, the studies found a significant reduction in the electrical activity of the muscles evaluated during the relaxed position, aligned posture[21] and nasal breathing[22] of mouth breathers after physical therapy treatment

FINAL CONSIDERATIONS

Given all of the above, the study contributes to the area of Orofacial Motricity as well as other areas of health, such as physical therapy, since only a few studies have been published in the last 20 years including the use of surface electromyography to complement the clinical evaluation, assist in the diagnosis and, mainly, in the therapeutic intervention of mouth breathing children within the age group of the inclusion criteria. Specifically in the field of speech-language pathology, only one study focused on using sEMG in orofacial muscles, in order to demonstrate the therapeutic efficacy. Similarly, only two papers, among the physical therapy studies, included the use of sEMG in cervical muscles in the study population, after postural exercise sessions, suggesting that the main purpose of the instrument would be the initial assessment of myofunctional and postural changes caused by mouth breathing, and not as a therapeutic biofeedback.

Therefore, the researchers recommend the publication of further longitudinal studies including the use of sEMG, in order to understand the electrical activity of various muscle groups a given time after the surgical and/or therapeutic intervention, in mouth breathers, that may assist professionals in the therapeutic planning.

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