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Revision articles

Implications of mouth breathing on the pulmonary function and respiratory muscles

Implicações da respiração oral na função pulmonar e músculos respiratórios

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ABSTRACT

The mouth breathing syndrome is characterized by a set of signs and symptoms, which may be present in subjects who replace an adequate and efficient nasal breathing mode by the mouth or mist breathing mode, for a period equal or superior of six months. The mouth or mist breathing mode may be associated to changes in the ventilatory function and mechanics. This review has the objective of investigating more deeply the consequences of the mouth breathing in the lung function and respiratory muscles, emphasizing the development of such changes since childhood to adult age. Eighteen articles were selected through data basis PubMed and Web of Science and they were grouped in the text, comprehending the follow topics:1) Implications of mouth breathing on the lung function and 2)Implications of mouth breathing on the respiratory muscles. From the information derivate of the analyzed articles, it may realized that few studies reject or did not find some relation between pulmonary changes and mouth breathing. It was suggested that the muscular unbalance produced by these changes may contribute for the mechanic disadvantage of the diaphragm muscle and increase of accessory inspiratory muscles work. Nevertheless, studies with more selective method, including objective and reproducible evaluation of the respiratory muscles are still need.

Keywords: Mouth Breathing; Respiratory System; Pulmonary Ventilation; Respiratory Muscles

RESUMO

A Síndrome do Respirador Oral é caracterizada por um conjunto de sinais e sintomas que podem estar presentes em indivíduos que substituem o modo adequado e eficiente da respiração nasal pelo modo respiratório oral ou misto, por um período igual ou superior a seis meses. O modo respiratório oral ou misto pode estar associado a mudanças na função e mecânica ventilatória. Esta revisão tem como objetivo investigar mais profundamente as consequências da respiração oral na função pulmonar e músculos respiratórios, ressaltando o desenvolvimento de tais alterações desde a infância até a idade adulta. Foram selecionados 18 artigos por meio das bases de dados Pubmed e Web of Science e foram agrupados no texto, compreendendo os seguintes tópicos: 1) Implicações da respiração oral sobre a função pulmonar e 2) Implicações da respiração oral sobre os músculos respiratórios. A partir das informações oriundas dos resultados dos artigos analisados, percebe-se que poucos estudos refutam ou não encontram alguma relação entre as alterações pulmonares e a respiração oral. Sugere-se que, o desequilíbrio muscular produzido por estas alterações pode contribuir para a desvantagem mecânica do músculo diafragma e aumento do trabalho dos músculos acessórios da inspiração. Entretanto, são necessários estudos com métodos mais criteriosos, incluindo avaliações objetivas e reprodutíveis dos músculos respiratórios.

Descritores: Respiração Bucal; Sistema Respiratório; Ventilação Pulmonar; Músculos Respiratórios

INTRODUCTION

Breathing is a vital function and is strongly dependent on the adequate permeability of the nasal route, establishing itself as the main function of the body. The physiologic breathing mode in the human being is nasal, regardless of age[1,2]. The nasal cavity has a fundamental role in the physiology of respiration. It promotes filtering, heating and humidification of the inhaled air, causing it to reach the lungs at the ideal temperature and favoring the adequate oxygenation of the body[2].

Any factor leading to the upper airway (UA) obstruction causes nasal breathing to be replaced by mouth breathing, among which mechanical events, allergic and nonallergic inflammatory diseases, congenital malformation and tumoral lesions[1].

Mouth breathing has been studied since the beginning of the twentieth century, with scientific publications directed to the scope of dentistry emphasizing the occlusal consequences[3]. This condition, considered as a public health problem, is attracting growing scientific interest in recent years, and greater coverage in the multidisciplinary aspects surrounding it.

Mouth Breathing Syndrome is defined as a set of signs and symptoms that may be completely or incompletely present in subjects who, for several reasons, replace the correct pattern of nasal breathing by an oral or mixed pattern[4] for mor than six months[5].

Among these signs and symptoms are included daytime sleepiness, headache, agitation and nocturnal enuresis, frequent fatigue, poor appetite, bruxism, school problems and even learning deficits and behavioral problems[6]. Abreu et al.[7] when studying mouth breathing children, detected the following: sleeping with mouth open (86%), snoring (79%), nasal itching (77%), drooling on the pillow (62%), nocturnal breathing difficulty or restless sleep (62%) nasal obstruction (49%) and irritability during the day (43%). Felcar et al.[8] concluded that children under seven years old who drooled and snored at night were more prone to mouth breathing occurrence. Menezes et al.[9] , when verifying the socioeconomic and demographic influences in determining mouth breathing mode, obtained higher prevalence of mouth breathing in public than private schools.

In addition, this syndrome has as main characteristics the lack of lip seal, ogival or high-arched palate, Angle's Class II malocclusion, unilateral or bilateral crossbite, open bite, sleep apnea, everted lower lip, retracted upper lip, generalized facial hypotonia, stomatognathic malfunction and postural changes[10,11]. Other characteristics include the presence of dark circles[12], elongated face[13], lowered mandible and dental alterations[14], abnormal speech[15], habitual tongue position in the oral floor and mentual muscle hyperfunction during lip-closing[16].

Mouth breathing may be associated with genetic factors, inadequate oral habits (pacifier and finger sucking, baby bottle) and nasal obstruction with variable intensity and duration [7]. Rhinitis is one of the main causes of nasal obstruction with a high prevalence in the population[17]. Mouth breathing in children is a frequent complaint in the pediatrician, allergist and otorhinolaryngologist's practice[18].

The altered breathing mode can also be associated with changes in the ventilatory function and mechanics. The respiratory tract can be considered a single morphofunctional entity extending from nose to the alveoli and any change can affect the rest[19]. It is well-known the coexistence between mouth breathing and asthma, highlighting the high prevalence of mouth breathing among asthmatic children[20]. However, studies explaining the complex relationship between the mouth breathing mode and changes in the ventilatory function and mechanics are still scarce.

According to Correa and Bérzin[21], the persistence of mouth breathing even after the resolution of the initial functional abnormality (increased nasal resistance) has been described in the literature. This can be attributed to neural adaptations, changes in the central control of the upper airway and the muscular function and skeletal changes. Therefore, it is important to emphasize that the effects of mouth breathing can be perpetuated into the adulthood [22,23].

Currently, most studies regarding the mouth breathing mode address ENT, dental and of orofacial motricity aspects[23]. A few studies focus on the respiratory changes, the main ones being targeted to mouth breathing in children. In addition, some of these studies are inconsistent and present controversies. Based on the abovementioned, this review aims to investigate further the consequences of mouth breathing for pulmonary function and respiratory muscles, emphasizing the development of such alterations from childhood to adulthood.

METHODS

Initially, the study problem was defined: What is the actual association between mouth breathing and the pulmonary function and ventilatory mechanics measures? After this stage, from December 2014 to March 2015, work began with the search and selection of published studies, without restriction regarding the publication period, in PubMed and Web of Science databases. In both databases, the survey was conducted by crossing the keywords "oral breathing" or "mouth breathing" and "spirometry" or "ventilatory function" or "respiratory muscles" or "respiratory mechanics" or "respiratory muscular strength" or "ventilatory muscular strength" or "maximal respiratory pressure" or "maximal inspiratory pressure" or "maximal expiratory pressure" or "accessory inspiratory muscles" or "diaphragm excursion".

The survey resulted in a total of 378 abstracts, with 354 of them referring to PubMed and 24 related to Web of Science databases. The titles and abstracts were analyzed and all articles written in Portuguese, English or Spanish and with potential relevance to achieve the proposed objectives, as well as for resolving the study problem were selected. Thus, articles analysing some measure of pulmonary function and/or ventilatory mechanics in mouth breathers were included. The articles found in both databases were counted only once. Twenty-two articles were selected to read the full text and of these, 4 were excluded for not having information compatible with the purpose of this review. (Figure 1)

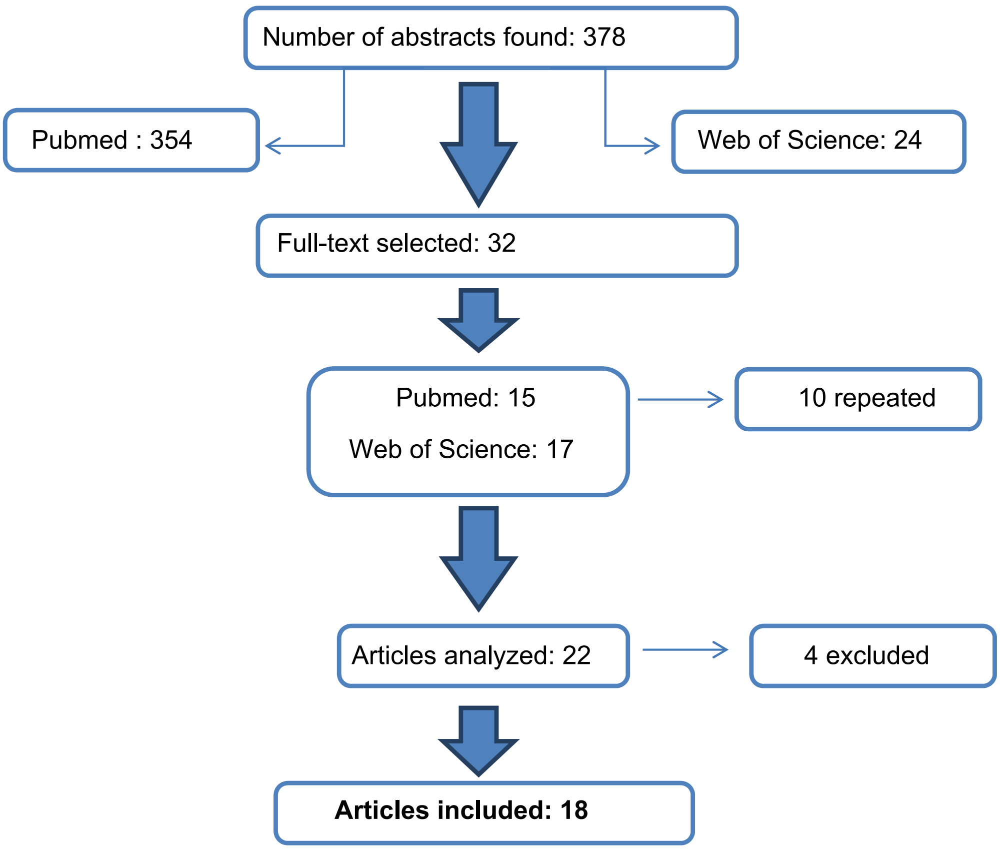

Figure 1. Flow chart of search and selection of studies analyzed in the review.

LITERATURE REVIEW

Table 1 shows the articles included in this review, in chronological order, describing the author and date, objectives and key results. It is observed that the articles found date from the last 11 years, with higher concentration of publications in 2008. In recent decades, there has been a growing interest in understanding the pathophysiological mechanisms involved in mouth breathing, however the relationship between pulmonary function and ventilatory mechanics seems to be recent and have not yet been fully elucidated.

The discussion of the articles in the text was organized in chronological order and divided into topics as follows: 1) Implications of the mouth breathing for the pulmonary function and 2) Implication of the mouth breathing for the respiratory muscles.

Table 1. Objectives description and main results of the studies selected for the review.

Author	Objective	Main results
Dugan et al., 2004	To measure the total respiratory resistance in tidal ventilation in seated and supine position during breathing through the mouth or nose in normal and asthmatic subjects.	Airflow resistance was 2-3 times higher through nasal route and in supine position in normal and asthmatic subjects, compared to mouth breathing and seated position.
Chaves et al. 2005	To evaluate and correlate TMD and cervical dysfunction in asthmatic and non-asthmatic children with and without mouth breathing mode.	Accessory muscle shortening and mouth breathing might explain the correlation between TMD and cervical dysfunction in asthmatics.
Barbiero et al., 2007	To evaluate the effects of respiratory biofeedback (RB) associated with quiet breathing pattern on the thoracic perimetry, pulmonary function, respiratory muscles strength and habits of functional mouth breathing (FMB)	Therapy improves the respiratory muscle strength in FMB, and can be used in this scope.
Barbiero et al., 2008	To evaluate the effect of lung expansion ventilatory pattern associated with respiratory biofeedback on the pulmonary function, respiratory muscles strength and habits in functional mouth breathing subjects.	Therapy improves the vital capacity, Tiffenaeau index and respiratory muscle strength.
Corrêa et al., 2008	To evaluate the cervical muscles recruitment during nasal inspiration before and after breathing and postural exercises on Swiss ball in MB children.	Decreased EMG activity of sternocleidomastoideus, suboccipitals and upper trapezius muscle during nasal inspiration in MB after therapy.
Hallani et al., 2008	To explore the impact of mouth breathing compared to nasal breathing in a mild asthmatic group at rest.	Induced MB caused reduction of pulmonary function in subjects with mild asthma, contributing to the asthma exacerbation.
Yi et al., 2008	To verify the relationship between the excursion of diaphragm muscle and curvatures of vertebral spine in mouth breathing children.	MB group presented decreased cervical lordosis, increased thoracic kyphosis, increased lumbar lordosis and decreased diaphragmatic excursion. There was no relatioship between the curves of vertebral spine and diaphragmatic excursion.
Belli et al., 2009	To evaluate body posture changes in children with asthma compared with a control group of non-asthmatic children paired by sex, age, weight and height.	Children with asthma did not show postural changes compared to non-asthmatic children.
Baltar et al., 2010	A systematic review analyzing the association between asthma and static posture.	Insufficient articles to draw a conclusion. Rigorously designed studies needed.
Silveira et al., 2010	To evaluate the posture of mouth breathing children and study the existence of correlation between posture and lung volumes.	Reduced spirometric values in MB and negative correlation with forward head posture.
Campanha et al., 2010	To detect the impact of speech therapy on asthma and allergic rhinitis control in mouth breathing children and adolescents.	Speech therapy combined with intra-nasal beclomethasone diproprionate promoted more lasting control of asthma, rhinitis and mouth breathing.
Okuro et al., 2011a	To evaluate exercise tolerance and respiratory muscle strentgh in relation to forward head posture and the respiratory type in mouth and nasal breathing children.	MB children showed changes in cervical spine posture and reduction in the respiratory muscle strength compared to NB.
Okuro et al., 2011b	To evaluate exercise tolerance, respiratory muscle strength and body posture in mouth and nasal breathing children.	Respiratory mechanics and the exercise capacity were negatively affected by MB. Forward head posture acted as a compensatory mechanism.
Ferreira et al., 2012	To evaluate the effect of physical therapy on ventilatory parameters and thoracoabdominal dinamics in mouth breathing children.	The physical therapy program produced positive effects on the ventilatory function of MB children.
Cunha et al., 2013	To develop a review to investigate studies using evaluation methods of respiratory muscle strength.	There are few studies evaluating respiratory muscle strength in MB with low methodological rigor.
Gutierrez et al., 2014	To compare the EMG activity in primary and accessory respiratory muscles in subjects with different types of breathing.	Higher EMG activity in subjects with upper thoracic breathing pattern.
Milanesi et al., 2014	To evaluate the consequences of mouth breathing during childhood on the ventilatory function and quality of life in adulthood.	Decrease in respiratory muscle strength and exercise capacity in adults with MB record.
Trevisan et al., 2015	To evaluate the electrical activity of inspiratory accessory muscles and diaphragm ROM in MB and NB adults.	Lower recruitment of inspiratory acessory muscles and diaphragmatic amplitude in MB compared to NB.

Legend: MB: mouth breathing; TMD : temporomandibular disorder; EMG: eletrocmyography; NB: nasal breathing ; ROM: range of movement.

Implications of mouth breathing for the pulmonary function

The respiratory system is an assembly of tubular and alveolar organs situated in the head, neck and chest cavity. Under the command of the Central Nervous System, it performs functions such as gas exchange, acid-basic balance and phonation. The primary function of the respiratory system is diffusion, which is the gas exchange between the alveolar air and the pulmonary capillary blood, culminating with the oxygen supply required for the tissue metabolism[24].

The upper airways are the most responsible for the increased resistance with increasing airflow, therefore factors that modify the airways diameter (as nasal obstruction) may alter their resistance[25]. The failure in the filtration, humidification and heating of the inhaled air stimulates increased presence of leukocytes in the blood, increasing the lung hypersensitivity and decreasing its volumes and capacity. In addition, there is evidence that the nasal or upper airways obstruction determines disturbances in the afferent nerves with profound effects on breathing and airway caliber of the lungs, negatively affecting chest expansion and alveolo-pulmonary ventilation[21].

The relationship between asthma and rhinitis does not seem to be fully established, since both disorders may represent two distinct entities or a disease involving both airways [17]. Chaves et al. [26] reported that the association between both diseases can lead to the development of a series of postural changes and in the primary and accessory muscles of inspiration.

In 2004, Duggan et al.[27] observed that patients with asthma or rhinitis showed reduced forced expiratory volume in one second (FEV1), vital capacity (VC) and FEV1/VC% ratio. In addition, they showed increased residual volume (RV) and RV/TLC (total lung capacity) ratio compared to normal controls. Another study by Hallani et al.[28], investigated the effect of forced mouth breathing in mild asthma patients, since nasal breathing provides a protective influence against exercise-induced asthma. The volunteers were instructed to breath only by oral or nasal route for an hour each at separate days. The pulmonary function was measured by spirometry and breathing difficulty was evaluated by Borg scale at the end of each period. The authors concluded that forced mouth breathing leads to decreased pulmonary function in mild asthmatic patients at rest, including the iniciation of asthma symptoms in some of them. Therefore, mouth breathing may play a role in the pathogenesis of acute asthma exacerbations.

In 2008, Barbiero et al.[29] conducted a randomized clinical study with 60 functional mouth breathing children to evaluate the efficacy of respiratory therapy by means of reexpansive ventilatory exercises and respiratory biofeedback (RBF). Considering the possibility of restrictive ventilatory alterations in mouth breathers, the authors utilized measures of pulmonary function and maximal respiratory pressures. The results showed a significant increase of the forced vital capacity (FVC), maximal expiratory and inspiratory pressures (PEMáx and PIMáx), besides the reduction in the FEV1/ FVC ratio in subjects with functional mouth breathing undergoing reexpansive ventilatory exercises associated with respiratory biofeedback. The reexpansive ventilatory exercises promote an increase of inspiratory reserve volume, expiratory reserve volume, functional residual capacity and total lung capacity, also producing an increase of FVC. Respiratory muscular training performed with RBF associated with breathing exercises generated an increase of respiratory muscles strength evidenced by alterations in the respiratory pattern of children from control and study group, inducing changes in the dynamics of the respiratory movements and consequent improvement of respiratory mechanics.

In order to analyze the posture of mouth breathing children and to study the possible correlations between posture and lung volumes, Silveira et al. [30] showed a significant reduction of the pulmonary function values in mouth breathers compared to nasal breathers. They also found a negative correlation between the forced vital capacity and the anterior projection of the head in the mouth breathing group, explained by the fact that this anterior projection of the head acts with the purpose of facilitating the air entry through the mouth, resulting in postural changes that determine the worsening of pulmonary function. Therefore, the researchers report that postural changes (especially the anterior projection of the head) may contribute to the worsening of the respiratory dysfunction criating a feedback system that generates a progressive respiratory and musculoskeletal worsening .

Campanha et al.[31] utilized peak expiratory flow (PEF) and forced expiratory volume in one second (FEV1) measures, among other variables, to analyze the efficacy of speech therapy in children presenting with mouth breathing, asthma andallergic rhinitis. Therapy to achieve nasal breathing awareness and automation, in conjunction with intranasal beclomethasone dipropionate, improved significantly the respiratory capacity as compared to the use of medication alone. Thus, speech therapy contributed for the respiratory pattern adequacy and facilitated early and lasting control with favorable impact on functional and clinical management of asthma and allergic rhinitis in the mouth breathers studied.

In order to evaluate the effect of physical therapy on ventilatory parameters and on the thoracoabdominal dynamics, Ferreira et al.[32] verified the maximal inspiratory (MIP) and expiratory (MEP) pressures, inspiratory capacity (IC), peak expiratory flow (PEF) and thoracoabdominal mobility in mouth breathing children. The authors observed a considerable increase in lung volumes, evidenced by the significant increment of the IC. This finding was explained by the increasedinspiratory muscle strength, also obtained with treatment. Higher values of MIP were also observed after treatment and may indicate, according to the authors, that children developed better use of diaphragm, which may have favored its strengthening. After treatment, they showed better distribution of the ventilatory pattern in upper chest and abdomen regions, with preference of costo-diaphragmatic pattern. Furthermore, there was an increase in the Charpy angle, atributted by the authors to the release of the chest cavity through manual diaphragmatic stimulation and by stretching the inspiratory accessory muscles, since the diaphragmatic muscle recruitment provides greater mobility in the lower ribs and the increase of lower transverse diameter of the rib cage.

Although the relashionship between mouth breathing mode and its consequences in adulthood still remains poorly addressed in the literature, Milanesi et al.[33] evaluated the impact of mouth breathing on ventilatory function and quality of life of 24 adults, from 18 to 30 years old, diagnosed as mouth breathers in childhood compared with nasal breathers. Maximal respiratory pressures, peak expiratory flow, 6-minute walk test and quality of life were assessed. The results showed that values obtained in MIP, MEP and the distance covered on the 6-minute walking test were statistically lower in mouth breathers compared to the control group.

Implications of mouth breathing on the respiratory muscles

Breathing is a process that involves neural, chemical and muscular components and its main agents are the diaphragm, intercostal and abdominal muscles[33]. The breathing process occurs due to movements that increase and decrease the chest size causing air to be inspired into the lungs and subsequently expired. The thoracic movement only becomes possible when there is sufficient effort to overcome the elastic retraction and airflow resistance[25]. The diaphragm, the main muscle of breathing, contracts during inspiration together with the accessory muscles, including external intercostal, sternocleidomastoid and scalene. This contraction promotes chest expansion and reduction of intrathoracic pressure, thus allowing the air to enter the lungs. The expiration occurs by relaxing the diaphragm and other activated muscles and, predominantly, by the lung elastic recoil[34].

The effectiveness of diaphragm depends, above all, on the stability of the abdominal wall, which promotes the visceral support during inspiration and also depends on the stability of the lumbar paraspinal muscles, the site of vertebral insertion of the diaphragm. Thus, these muscles prevent en bloc elevation of thoracic cage, characterizing the synergistic antagonistic relationship[2].

The prominent inspiratory movement on the upper chest influences the thoracoabdominal mechanics by changing the diaphragm muscle position and its apposition zone due to reduced intra-abdominal pressure. This fact could lead to the development of thoracic deformities, such as elevation of last ribs, upper displacement of thoracic cage and increased lumbar lordosis[2].

Nasal obstruction can lead to decreased olfactory stimuli, increased pulmonary hyperresponsiveness and nasal congestion[5,7]. Therefore, the upper airway obstruction can bring as consequence mouth breathing, impaired ventilation and chest expansion, subsequently resulting in developmental disorders of the thoracic cage. Changing the breathing pattern by MBS also implies adaptative postural needs.

In 2005, Chaves et al.[35] compared and correlated the clinical signs of Temporomandibular Disorder (TMD) and cervical dysfunction in asthmatic and non-asthmatic children with and without mouth breathing mode. The authors speculated that the increased resistance in the respiratory tract could lead to changes in head posture, dysfunction of respiratory mechanics associated with hyperactivity of the neck muscles and the development of cervical abnormalities. A positive correlation between the scores of TMD and cervical dysfunction was found only in the asthmatic children group and 90% of these were mouth breathers.

Yi et al.[2] analyzed, by means of fluoroscopy, the diaphragmatic excursion in nasal and mouth breathing children and found a decrease in the diaphragm amplitude caused by mouth breathing. The authors also report that, when there is a significant nasal obstruction (as in mouth breathing mode), an attempt to overcome this obstruction occurs through conscious effort, by increasing the inspiratory effort through the accessory muscles of inspiration.

In 2008, Corrêa and Bérzin[21] evaluated the cervical muscles recruitment during nasal inspiration, by means of electromyography, before and after a physical therapy program with breathing and postural exercises using Swiss ball in children presenting with Mouth Breathing Syndrome. Suboccipitals muscles showed the highest levels of electromyographic activity, probably due to their function as extensors of the upper cervical spine in the forward head posture, induced by the nasal obstruction. However, the biggest difference observed after physical therapy program was found in the sternocleiodomastoid muscle, which is justified by its action as an accessory muscle of inspiration, because 70% of inspiratory capacity is obtained with no activity of this muscle, but its recruitment increases with the decrease of diaphragm activity due to low mechanical advantage. The lower activity obtained for this muscle with the intervention suggests advantageous postural changes, with restriction in mouth breathing due to forward head posture and the excessive use of accessory muscles of breathing. The findings of this study may be the result of a better postural alignment and muscular balance and, consequently, a reduced recruitment of cervical muscles in these children during nasal inspiration.

Based on the belief that the excessive use of the accessory muscles of breathing and mouth breathing mode in children presenting with asthma might cause changes in head, shoulders and chest posture, Belli et al.[20], conducted a study investigating the presence of postural changes in asthmatic children. The authors found no differences between children from 7 to 12 years old with mild to moderate asthma when compared to non-asthmatic, attributing the results to the absence of children with severe asthma and most modern treatement strategies of the disease. Baltar et al.[36] investigated in their literature review the relationship between asthma and postural changes. The authors speculated that the obstruction, present in asthmatic subjects, might cause muscle shortening that, by compensation, would promote postural changes and the consequent impairment of respiratory mechanics. Nevertheless, after analyzing the studies found in the literature, they concluded that data were still insufficient to draw a conclusion.

Based on the assumption of a possible relationship between body posture and breathing muscles, Okuro et al.[37] compared the maximal respiratory pressures and head posture among mouth and nasal breathing children. The authors observed a decrease in maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) in mouth breathers. Another important and surprising finding relates to the fact that forward head posture (flexion of the lower cervical spine and extension of the upper cervical spine) acted in this case as a compensation mechanism for better performance of the respiratory muscles strength[37].

Cunha et al.[38] point out that further studies are needed to assess respiratory muscle strength in mouth breathers, including a comparison with other instruments with the same purpose, as these studies are scarce in the literature.

The recruitment of the diaphragm and sternocleidomastoid muscles appears to significantly increase during breathing with resistence[39]. However, with the maintenance of large loads, the contribution of these muscles to the respiratory effort varies over time, so that the diaphragm decreases its activity and increases the sternocleidomastoid muscle recruitment. In addition, it is assumed that the diaphragm does not have the sensory receptors required to mediate the sensation of dyspnea, which reinforces the theory that the receptors present in the accessory muscles of inspiration may be involved in generating the sensation of dyspnea[39].

Gutierrez et al.[40] showed a significantly higher muscle activation in the diaphragm and external intercostal muscles by comparing individuals with upper thoracic breathing and costo-diaphragmatic patterns during tasks such as tidal and deep breathing, speech, swallowing and clenching. The research team demonstrated the participation of respiratory muscles during other stomatognathic functions noting that the upper thoracic breathing pattern can be a decisive factor in the capacity of differentiated muscle adaptation. More recently, Trevisan et al.[23] evaluated the activity of the sternocleidomastoid and upper trapezius muscles, using surface electromyography and the amplitude of diaphragmatic movement, by means of ultrasound, in mouth and nasal breathing adults. The authors observed lower recruitment of accessory muscles of inspiration during fast inspiration andsmaller amplitude of the diaphragmatic movement in mouth breathers. The increased workload required during rapid inspiration and the burden imposed by a possible transient edema of the nasal mucosa were the reasons attributed by the authors to the electromyographic findings. The lower diaphragmatic amplitude was explained by the biomechanical disadvantage of the diaphragm due to the excessive use of accessory muscles in mouth breathers.

FINAL CONSIDERATIONS

From this analysis perspective, it seems to be important to consider pulmonary function and respiratory mechanics in the approach of the mouth breather. Mouth breathing leads to musculoskeletal impairment requiring a comprehensive intervention to prevent pathological compensatory mechanisms that can be perpetuated into adulthood[33].

It can be seen that the articles found in the databases used for research on oral breathing and respiratory changes were written mainly in the last 10 years. In recent decades there has been a growing interest in understanding the etiological and pathophysiological mechanisms involved in mouth breathing, although controversies remain related to their definition and diagnosis. Regarding respiratory muscle strength, Cunha et al.[38] point out the absence of studies on this topic, while it is necessary to evaluate the respiratory muscles and the consequences of mouth breathing on the respiratory system. Another relevant observation, also confirmed by the authors above mentioned, refers to the fact that most of these studies were conducted by Brazilian researchers. It seems that there are still many gaps to be filled regarding this topic.

Based on the information from the results of the analyzed articles (shown in Table 1), it is observed that few studies refute or do not find any relationship between mouth breathing and postural changes. The muscle imbalance produced by these changes may contribute to the mechanical disadvantage of the diaphragm and the increased effort of the accessory muscles of inspiration. In the presence of a significant nasal obstruction, an effort occurs to overcome this resistance by increasing the work of accessory muscles of inspiration[2]. Moreover, the forward head posture, common among mouth breathers, facilitates the air to enter the mouth which could lead to a deterioration of the pulmonary function [30]. In the long run, the hyperactivity of the neck muscles may be associated with cervical changes that, as a result, can cause temporomandibular disorders (TMD) and spine cervical disorders[21]. Considering all these aspects, a cycle seems to be established where mouth breathing alters the respiratory function and mechanics and produces postural compensations, which in turn perpetuate the respiratory changes.

When analyzing these studies from the methodological point of view, many differences remain regarding not only the diagnosis of oral breathing, but also the variables related to respiratory mechanics. When addressing mouth breathing, the utilization of a uniform classification, including the same terminology and the same laboratory tests, is desirable. Further studies are needed with more detailed methods, including objective and reproducible parameters in the evaluation of the respiratory muscles.

REFERENCES

1. Brant TCS, Parreira VF, Mancini MC, Becker HMG, Reis AFC, Brito RR. Breathing pattern and thoracoabdominal motion in mouth-breathing children. Rev Bras Fisioter. 2008;12(6):495-501.
2. Yi LC, Jardim JR, Inoue DP, Pignatari SSN. The relationship between excursion of the diaphragm and curvatures of the spinal column in mouth breathing children. J Pediatr. 2008;84(2):171-7.
3. Hartsook JT. Mouth breathing as a primary etiologic factor in the production of malocclusion. J Dent Child. 1946;13(4):91-4.
4. Barbiero EF, Vanderlei LCM, Nascimento PC, Costa MM, Neto AC. Influência do biofeedback respiratório associado ao padrão Quiet Breathing sobre a função pulmonar e hábitos de respiradores bucais funcionais. Rev Bras Fisioter. 2007;11(5):347-53.
5. Conti PBM, Sakano E, Ribeiro MAGO, Schivinski CIS, Ribeiro JD. Assessment of the body posture of mouth-breathing children and adolescents. J Pediatr. 2011;87(4):357-63.
6. Menezes VA, Tavares RLO, Granville-Garcia AF. Síndrome da respiração oral: alterações clínicas e comportamentais. Arq Odontol. 2009;45(3):160-5.
7. Abreu RR, Rocha RL, Lamounier JA, Guerra AFM. Etiology, clinical manifestations and concurrent findings in mouth-breathing children. J Pediatr. 2008;84(6): 529-35.

8. Felcar JM, Bueno IR, Massan ACS, Torezan RP, Cardoso JR. Prevalence of mouth breathing in children from an elementary school. Ciênc Saúde Coletiva. 2010;15(2):437-44.
9. Menezes VA, Leal RB, Moura MM, Granville-Garcia AF. Influence of socio-economic and demographic factors in determining breathing patterns: a pilot study. Rev Bras Otorrinolaringol. 2007;73(6):826-34.
10. Cattoni DM, Fernandes FDM, Di Francesco RC, Latorre MRDO. Quantitative evaluation of the orofacial morphology: anthropometric measurements in healthy and mouth-breathing children. Int J Orofacial Myology. 2009;35:44-54.
11. Posnick JC, Agnihotri N. Consequences and management of nasal airway obstruction in the dentofacial deformity patient. Curr Opin Otolaryngol Head Neck Surg. 2010;18(4):323-31.
12. Menezes VA, Leal RB, Pessoa RS, Pontes RMES. Prevalência e fatores associados à respiração oral em escolares participantes do projeto Santo Amaro-Recife. Rev Bras Otorrinolaringol. 2006;72(3):394-9.
13. Falcão DA, Grinfeld S, Grinfeld A, Melo MVR. Oral breathers clinically diagnosed and by autodiagnosed. Body posture consequences. Int J Dent. 2003;2(2):250-6.
14. Motonaga SM, Berte LC, Anselmo-Lima WT. Respiração bucal: causas e alterações no sistema estomatognático. Rev Bras Otorrinolaringol. 2000;66(4):373-9.
15. Bicalho GP, Motta AR, Vicente LCC. Evaluation of Swallowing in Mouth Breathing Children. Rev CEFAC. 2006;8(1):50-5.
16. Cattoni DM, Fernandes FDM, Di Francesco RC, Latorre MRDO. Características do sistema estomatognático de crianças respiradoras orais: enfoque antroposcópico. Pró-Fono R Atual Cient. 2007;19(4):347-51.
17. Menezes VA, Barbosa AMF, Souza RMS, Freire CVC, Granville-Garcia AF. Ocorrência de rinite, respiração oral e alterações orofaciais em adolescentes asmáticos. Rev CEFAC. 2013;15(3):663-71.
18. Costa Jr EC, Sabino HAC, Miura CS, Azevedo CB, Menezes UP, Valera FCP et al. Atopia e hipertrofia adenoamigdaliana em pacientes respiradores bucais em um centro de referência. Braz J Otorhinolaryngol. 2013;79(6):663-7.
19. Banzatto MGP, Grumach AS, Mello JF, Francesco RCD. Adenotonsillectomy improves the strength of respiratory muscles in children with upper airway obstruction. Int J Pediatr Otorhinolaryngol. 2010;74(8):860-3.
20. Belli JFC, Chaves TC, Oliveira AS, Grossi DB. Analysis of body posture in children with mild to moderate asthma. Euro J Pediatr. 2009;68(10):1207-16.
21. Corrêa ECR, Bérzin F. Mouth Breathing Syndrome: cervical muscles recruitment during nasal inspiration before and after respiratory and postural exercises on swiss ball. Int J Pediatr Otorhinolaryngol. 2008;72(9):1335-43.
22. Milanesi JM, Borin G, Correa ECR, Silva AMT, Bortoluzzi DC, Souza JÁ. Impact of the mouth breathing occurred during childhood in the adult age: biophotogrammetric postural analysis. Int J Pediatr Otorhinolaryngol. 2011; 75(8):999-1004.
23. Trevisan ME, Boufleur J, Soares JC, Haygert CJP, Ries LGK, Correa ECR. Diaphragmatic amplitude and accessory inspiratory muscle activity in nasal and mouth-breathing adults: a cross-sectional study. J Electromyogr Kinesiol. 2015;25(3):463-8.
24. West JB. Fisiologia respiratória. 8ª ed. Porto Alegre: Artmed; 2010.
25. Pires MG, Di Francesco RC, Junior JFM, Grumach AS. Alterações Torácicas Secundárias ao Aumento de Volume de Tonsilas Palatinas e Faríngeas. Arq Int Otorrinolaringol. 2007;11(2):99-105.
26. Chaves TC, Silva TSA, Monteiro SAC, Watanabe PCA, Oliveira AS, Grossi DB. Craniocervical posture and hyoid bone position in children with mild and moderate asthma and mouth breathing. Int J Pediatr Otorhinolaryngol. 2010;74(9):1021-7.
27. Duggan CJ, Watson RA, Pride NB. Postural Changes in Nasal and Pulmonary Resistance in Subjects with Asthma. J Asthma. 2004;41(7):695-701.
28. Hallani M, Wheatley JR, Amis TC. Enforced mouth breathing decreases lung function in mild asthmatics. Respirol. 2008;13:553-8.
29. Barbiero EF, Vanderlei LCM, Neto AC, Nascimento PC. Influence of respiratory biofeedback associated to re-expansive ventilation patterns in individuals with functional mouth breathing. Int J Pediatr Otorhinolaryngol. 2008;72:1683-91.
30. Silveira W, Mello FCQ, Guimarães FS, Menezes SLS. Postural alterations and pulmonary function of mouth-breathing children. Braz J Otorhinolaryngol. 2010;76(6):683-6.
31. Campanha SMA, Fontes MJF, Camargos PAM, Freire LMS. The impact of speech therapy on asthma and allergic rhinitis control in mouth

breathing children and adolescents. J Pediatr. 2010;86(3):203-8.
32. Ferreira FS, Weber P, Correa ECR, Milanesi JM, Borin GS, Dias MF. Efeito da fisioterapia sobre os parâmetros ventilatórios e a dinâmica tóraco-abdominal de crianças respiradoras bucais. Fisioter Pesq. 2012;19(1):8-13.
33. Milanesi JM, Weber P, Berwig LC, Ritzel RA, Silva AMT, Correa ECR. Childhood mouth-breathing consequences at adult age: entilator function and quality of life. Fisioter Mov. 2014;27(2) 211-8.
34. Nason LK, Walker CM, McNeeley MF, Burivong W, Fligner CL, Godwin JD. Imaging of the diaphragm: anatomy and function. Radiographics. 2012;32(2):E51–E70.
35. Chaves TC, Grossi DB, Oliveira AS, Bertolli F, Holtz A, Costa D. Correlation between signs of temporomandibular (TMD) and cervical spine (CSD) disorders in asthmatic children. J Clin Pediatr Dent. 2005;29(4):287-92.
36. Baltar JÁ, Santos MSB, Silva HJ. Does asthma promote changes in static posture? – Systematic review. Rev Port Pneumol. 2010;16(3):471-6.
37. Okuro RT, Morcillo AM, Ribeiro MAGO, Sakano E, Conti PBM, Ribeiro JD. Mouth breathing and forward head posture: effects on respiratory biomechanics and exercise capacity in children. J Bras Pneumol. 2011;37(4):471-9.
38. Cunha RA, Cunha DA, Assis RB, Bezerra LA, Silva HJ. Evaluation of Respiratory Muscle Strength in Mouth Breathers: Clinical Evidences. Int Arch Otorhinolaryngol. 2014;18(3):289-93.
39. Breslin EH, Garoutte BC, Kohlman-Carrieri V, Celli BR. Correlations between dyspnea, diaphragm and sternomastoid recruitment during inspiratory resistance breathing in normal subjects. Chest. 1990;98(2):298-302.
40. Gutiérrez MF, Valenzuela S, Miralles R, Portus C, Santander H, Fuentes AD et al. Does breathing type influence electromyographic activity of obligatory and accessory respiratory muscles? J Oral Rehabil. 2014;42(11):801-8.