International Journal of Pediatric Otorhinolaryngology (2008) **72**, 1335—1343

International Journal of Pediatric Otorhinolaryngology

www.elsevier.com/locate/ijporl

Mouth Breathing Syndrome: Cervical muscles recruitment during nasal inspiration before and after respiratory and postural exercises on Swiss Ball

Eliane C.R. Corrêa [a,*], **Fausto Bérzin** [b]

[a] *Department of Physical Therapy, Faculty of Physical Therapy, Federal University of Santa Maria, Rio Grande do Sul, Brazil*
[b] *Department of Morphology of Dental School of Piracicaba, Campinas State University, São Paulo, Brazil*

Received 18 March 2008; received in revised form 16 May 2008; accepted 19 May 2008
Available online 7 July 2008

KEYWORDS
Mouth breathing;
Respiratory muscles;
Cervical muscles;
Electromyography;
Physical therapy;
Swiss Ball;
Diaphragmatic breathing

Summary

Objective: This study aimed to evaluate the recruitment of cervical muscles during nasal inspiration before and after breathing and postural exercises on the Swiss Ball in children with Mouth Breathing Syndrome (MBS).
Method: Surface electromyography from the sternocleidomastoid (SCM), sub-occipitals and upper Trapezius muscles was recorded during nasal inspiration, before and at the end of three months of the treatment. A physical therapy program consisting in muscular stretching and strengthening exercises along with naso-diaphragmatic breathing on the Swiss Ball were carried out for body posture realignment and respiratory training. Nineteen mouth breathing children, mean age of 10.6 years, both genres, were the subjects of this study. In order to establish a comparison between the eletromyographic results (normalized values) obtained from pre and post-physical therapy program it was used the Wilcoxon non-parametric test for dependent data.
Results: It was found a significant decrease ($p < 0.01$) in the electromyographic activity during nasal inspiration in all tested muscles after treatment (11.3—3.6% in the SCM, 22.4—11.7% in the sub-occipitals and 8.9—3.1% in the upper Trapezius). At the end of the treatment, the assessed muscles reached lower activity electromyographic levels during nasal inspiration and they became closer of those in the quiet position.

* Corresponding author at: Rua Tuiuti 2462 apt 803, Santa Maria, RS, CEP 97050420, Brazil. Tel.: +55 32251382; fax: +55 32208018.
E-mail address: eliftrs@yahoo.com.br (E.C.R. Corrêa).

0165-5876/$ — see front matter © 2008 Elsevier Ireland Ltd. All rights reserved.
doi:10.1016/j.ijporl.2008.05.012

Conclusion: The lower activity after the physical therapy program in these muscles indicates a less effort of the accessory inspiratory muscles, probably due to a better performance of diaphragm muscle with the improvement of the body posture.
© 2008 Elsevier Ireland Ltd. All rights reserved.

1. Introduction

Mouth breathing results from an insufficient nasal respiration and it is a mechanically incorrect form of respiration, affecting 26.6—53.3% of school-age children in Brazil [1—3]. Due to its multiple consequences it deserves more concern [4,5]. The failure in filtering, humidifying and warming inspired air stimulates an increased presence of white blood cells, increasing the hypersensitivity of the lungs and decreasing their volumes and capacity [6—8]. Besides, there is evidence that the nose obstruction or upper airway blockage determines disturbances in the nasal afferent nerves (sympathic trigeminal and autonomic nerves) with profound effects on respiration and airway caliber in the lungs [9,7,10], negatively affecting the thoracic expansion and alveolo-pulmonary ventilation [7,11].

Additionally, it causes drop in the PaO_2, in the exercise tolerance and, in more severe cases, can be associated with obstructive sleep apnea and Cor pulmonale [4,6].

The dysfunctional pattern of the Mouth Breathing Syndrome (MBS) constitutes a chain reaction of body adaptation to abnormal breathing patterns. Breathing through the mouth facilitates forward head posture, a low and forward tongue position and increased activity of the accessory muscles of respiration (SCM, scalene and pectorals) [12].

This pattern is perpetuated by the decreased activity of the diaphragm and hypotonicity of the abdominal musculature [12,13].

The patient with MBS has higher activity of accessory musculature of inspiration and, as a consequence, an increased energetic consumption and improper lung ventilation [14]. They also develop hypertrophy in these muscles with impairment in the diaphragm muscle because of its inactivity and lack of synergism with abdominal muscles [15].

It has been recommended the treatment for mouth breathing approaching postural changes, specifically the forward head posture, since it is related with the overuse of primary and secondary muscles of respiration [15].

More normal breathing pattern can be facilitated by altering the head and neck posture [12].

The nasal breathing training is justified because the nasal obstruction can induce neuromuscular changes that remain even after the original stimulus has been removed [16].

A precocious multidisciplinary evaluation has been recommended in the children with MBS in order to avoid the development of complications and to reduce the treatment costs and time. The EMG recordings in the head and neck muscles are utilized as an evaluation method of the muscle activity and its intensity and changes in the contraction—relaxation mechanism in these patients [5,14,17].

The consulted literature depicts the presence of a number of changes concerning the body posture and breathing pattern as a consequence of the mouth-breathing mode [13,14,18]. Additionally, it has been stated that Physical Therapy may contribute for a more integral and effective therapeutic approach of the multi-disciplinary team to assist children with MBS [5,18]. In other study with Physical Therapy for postural realignment and breathing training, the authors obtained a reduction on cervical muscles activity in the quiet position and in an aligned posture, as well the improvement of forward head posture and abduted scapula [5].

Therefore, given the need of investigation regarding the Physical Therapy in this dysfunction, this study aimed to evaluate the recruitment of cervical muscles, by means of electromyography recordings, during nasal inspiration. The EMG recordings were collected before and after a physical therapy program of breathing and postural exercises on the Swiss Ball in children with MBS.

2. Methods

Nineteen children, 11 boys and 8 girls, with a mean age of 10.6 (SD = 1.0) participated in this study. The children were recruited either from a public school or from a speech-therapy service. All of them were submitted a nasopharyngoscopy and oroscopy in order to confirm the upper airway obstruction diagnosis. Allergic rhinitis, septum deviation, adenoid hypertrophy and residual mouth breathing post-adenoidectomy were the diagnoses found in these children (Table 1). All of them were with controlled symptoms, so that they could breathe through the nose when asked. Children with neurological diseases or other medical diagnoses were excluded.

Table 1 Otorhinolaryngologic diagnosis of the children participants in the study

Otorhinolaryngologic diagnosis	*N*	(%)
Adenoid hypertrophy	1	5
Adenoid hypertrophy + allergic rhinitis	3	16
Allergic rhinitis	7	37
Allergic rhinitis + septum Deviation	4	21
Residual mouth breathing post-adenoidectomy	2	11
Residual mouth breathing post-adenoidectomy + allergic rhinitis	2	11

The Ethical Committee of the Health Science Center, Federal University of Santa Maria, RS, Brazil approved the study. Children's parents were informed about the potential risks and benefits and signed an inclusive informed consent form prior to their children's participation in the study.

Cervical muscle EMG activity was recorded bilaterally during nasal inspiration and isometric contraction before and at the end of 12-week physical therapy program.

Surface EMG was recorded bilaterally from the sternocleidomastoid (SCM), upper Trapezius (UT) and Sub-occipital (SOC) muscles. Recordings were made during the following activities: (1) nasal inspiration, (2) during habitual breathing in quiet position and (3) during an isometric contraction while sitting in an adapted chair. Previously to EMG acquisition during nasal inspiration test, it was observed the nasal airflow, which is the absence of audible nasal congestion, in order to verify whether the child was able to inhale through the nose [19]. The EMG signal collection started with child in a quiet position and in the middle of the EMG tracing (after 5 s), he/she was asked to inspire slowly through the nose until the end of the recording. The duration of EMG signal acquisition for this test was 10 s. In the isometric tests, an adapted chair was used to provide resistance to head flexion, head extension, and shoulder elevation during 5 s of EMG signal acquisition [5]. The EMG data from isometric contractions was used for the normalization procedure. Six active single differential surface electrodes were placed on the right and left SCM muscles, UT muscles and the SOC muscles. The placement of the electrodes and skin preparation followed Cram's recommendations [20]. A reference electrode was placed on the wrist of the subjects. The electrodes (Lynx Electronic Technology Ltda), used in the acquisition of EMG signals have a contact diameter 10 mm $\times$ 2 mm, parallel bars of pure silver 10 mm apart, gain of 100$\times$, input impedance of 10 GΩ and CMRR of 130 dB. The EMG signals were amplified and conditioned using Myosystem Br-1 equipment, with a gain of 50$\times$, band pass filtering from 20 Hz to 1000 Hz, and sampled using a 12 Bit A/D converter board set to a 4 KHz sampling frequency. This equipment is in accordance with the international standardization [21].

The data was analyzed in the EMG amplitude domain. The root mean square (RMS) values, a relatively popular and acceptable method for EMG data processing [22] were calculated by the Myosystem Br-1 software. The absolute EMG amplitude values (expressed in μV) were normalized following some authors' recommendation [20,22] in order to enable comparison of data collection within a subject, as a function of experimental conditions.

The normalized values (expressed in %) resulted from the division of the amplitude parameters obtained from recordings in the quiet position and during nasal inspiration by the largest amplitude value obtained in the isometric contraction [5].

The Physical Therapy Program (PTP) comprised stretching and strengthening exercises on the Swiss Ball, in combination with breathing exercises. Therapeutic exercises on the Swiss Ball consisted in 15 directed movements to restore postural alignment, primarily through stretching of the anterior muscles and strengthening of the posterior muscles of the trunk. The dynamic surface of the ball demands greater muscular activation levels and require good body posture alignment for balancing [23]. The exercises were performed in sitting, supine and prone positions using the Swiss Ball as described in Table 2. The program also included manual stretching in the SCM and Scalene muscles and naso-diaphragmatic breathing through manual stimulus. The subjects participated of the 30-min training sessions twice a week for 12 consecutive weeks (total of 24 sessions). Attention was focused towards correcting head position, since this is the most important postural disturbance found in mouth breathers [6,13,24,25] and the EMG evaluation was addressed to the cervical muscles.

Normalized EMG levels presented by each of tested muscles were organized in tables that show the mean and respective standard deviation values obtained before and after PTP. First, Shapiro—Wilk test was used to verify the normality of the data. Next, to establish a comparison between the results pre and post-PTP it was used the Wilcoxon non-parametric test for dependent data, with statistical analysis system (SAS) release 8.2. The significance level was set at 1%.

3. Results

The EMG recordings acquired from cervical muscles (SCM, sub-occipitals and upper Trapezius) during

Table 2 Description of the Swiss Ball exercises of the Physical Therapy Program

Exercise	Description	Repetitions
1 Shell on the ball	Child in prone on the SB (plank position), move forward with your hands on the floor while bending his hips and knees above the SB	3
2 Back extension	In prone position, knees extended and feet on the floor, with hands behind the neck, lift the chest and hold the position during 10 s	3
3 Back extension (rocket)	Variations of ex. 2: arms extended out, with the inner arm in line with the ears	3
4 Back flye	Variations of ex. 2: lift arms out to the sides	3
5 Alternating superman	Knell on the floor, resting the body over the ball with hands on the floor, raise the right leg out behind and the left arm out in front. Hold the position for 10 s and repeat on other side	3
6 Lat stretch	Knell on the floor, bend forward at the hips and roll the ball forward during expiration with abdominal contraction	3
7 Shell	Variation of ex 6: knell in front the ball, roll the ball from side to side, rotating the body and looking under the arm. Exhale during rotation	3/each side
8 Pelvic seated	Seated on the center of the ball, moving the pelvis back and forward	3
9 Variations of pelvic tilt	Lift up the right arm while moving the pelvis forward, return back the pelvis and repeat with the left arm Lift both arms while moving the pelvis forward and return the arms while moving the pelvis back	3
10 Abdominal curl	In a seated position, lower the body back, contract abdominal muscles to curl forward and lift the shoulder blades	10
11 Abdominal stretch	Supine on the ball, with the ball rest under the lower back and hips, walk from seated to lying, taking the arms overhead	3
12 Bridge on the ball	Supine on the ball with the head and shoulder blades on the ball, lift the lower back and hips, taking the arms out to the sides. Hold the position for 10 s	
13 Manual stretch	Variations of ex. 12: the physiotherapist apply manual stretch, with traction during exhalation, on the scalene and SCM muscles in this position, with one hand on the child's head behind it and the other on the sternum	
14 Naso-diaphragmatic breathing	Child in supine position with the legs on the ball (knees and hips bended), breathing wide and full into the lower ribcage and upper abdominal with a hand of the physiotherapist as a proprioceptive stimulus for diaphragm muscle action	
15 Bridge on the floor	Supine on the floor. Legs on top of the ball, lift the hips off the floor into a bridge position. Hold the position for 10 s	

nasal inspiration showed a high level in these muscles activity in children with MBS, which significantly decreased after PTP. Normalized values (%) of pre and post-EMG measurements of the 19 children are shown in Table 3. Comparative results between pre and post-PTP of normalized EMG data and the significant level are presented in Table 4.

The EMG raw signals of the SCM muscles during nasal inspiration, before and after PTP, are shown in Fig. 1.

The EMG recordings obtained pre treatment demonstrated an important muscular unbalance with "hyperactivity" levels, since they are higher than 10% of MVC, except the right UT muscle.

The post-treatment recordings showed that the muscle activity was adjusted in SCM and UT, but not in the SOC muscles. The lower EMG activity in the SCM and UT means that the muscle recruitment of the inspiratory accessory muscles reduced with the PTP.

Table 3 Normalized values (%) of pre and post-EMG measurements of the 19 children

Subjects	Muscles											
	SCM right pre	SCM left pre	SCM right post	SCM left post	OCC right pre	OCC left pre	OCC right post	OCCleft post	UT right pre	UT left pre	UT right post	UT left post
1	8	6	3	1	22	12	13	10	5	6	1	2
2	3	4	3	7	36	23	8	10	3	4	1	1
3	26	17	2	4	32	26	14	18	7	12	3	4
4	11	12	3	4	25	18	10	11	5	14	2	5
5	12	12	4	9	8	15	18	15	4	7	2	4
6	4	8	4	9	47	52	9	42	7	6	2	2
7	3	3	4	3	52	43	5	10	8	8	2	2
8	9	16	2	1	23	14	8	4	4	8	3	1
9	13	44	5	9	18	10	13	6	23	26	6	8
10	32	19	2	2	25	22	12	18	8	12	5	3
11	4	9	3	6	17	15	15	31	6	14	3	4
12	6	4	5	3	18	25	10	7	8	8	5	6
13	6	4	3	8	22	19	15	7	4	7	5	5
14	10	43	3	3	32	24	16	17	4	8	2	1
15	9	8	1	3	17	10	7	5	5	9	3	1
16	11	11	3	2	25	10	6	6	19	4	3	3
17	7	8	3	2	20	14	5	4	5	6	2	2
18	6	4	2	2	23	18	11	10	12	12	4	2
19	6	10	2	3	12	9	6	12	8	23	6	3
Mean	11.3		3.6		22.4		11.7		8.9		3.1	

The results also demonstrated that the EMG activity levels during nasal inspiration became closer of those obtained in quiet position after PTP, mainly in the SCM and UT muscles. Fig. 2 shows the normalized EMG values in the quiet position and during nasal inspiration pre and post-PTP, in the evaluated muscles.

4. Discussion

The present study evaluated the recruitment of cervical muscles during nasal inspiration before and after physical therapy program of breathing and postural exercises on the Swiss Ball in children with Mouth Breathing Syndrome. The results evidenced a positive effect of this intervention, since all muscles presented a significant reduction on the EMG activity levels after PTP. In order to inspire through the nose, the children presented high levels of muscular activity on SCM, SOC and UT before PTP. These EMG levels, with exception of UT muscle, are considered "hyperactivity", according to Finsterer [26] because they are higher than 10% of MVC.

After PTP, all muscles decreased significantly the EMG activity, despite SOC remain with hyperactivity muscular levels. The SOC muscles presented the highest levels of EMG activity, probably because of their function as cervical extensor in the posterior cranial rotation induced by the nasal obstruction. [12,15,20,24] However, the greatest difference after PTP was observed on SCM muscles, which is justified by their action as inspiratory accessory muscles [27,28]. The results also demonstrated that, after treatment, the activity levels during nasal inspiration were closer of those observed in the quiet position on SCM, SOC and UT muscles. Such results are in accordance with some authors who stated that SCM has a minor role in respiration and 70% of inspiratory capacity is achieved with no activity of SCM muscle [20,29], yet SCM recruitment increases when the diaphragm decreases activity owing a low mechanical advantage [15]. Thus, the lower recruitment of SCM muscles observed in this study, indicates that the diaphragm muscle became able to assume a greater muscular work in the

Table 4 Mean values and standard deviation of normalized EMG levels (%) during nasal inspiration in the SCM, SOC and UT muscles pre- and post-PTP

Muscles	Pre		Post		*P*-value
	Mean	S.D.	Mean	S.D.	
SCM (%)	11.3	10.3	3.6	2.3	0.0001*
SOC (%)	22.4	16.1	11.7	10.0	0.0018*
UT (%)	8.9	9.3	3.1	2.8	0.0002*

* Statistically significant at 1% level ($P < 0.01$).

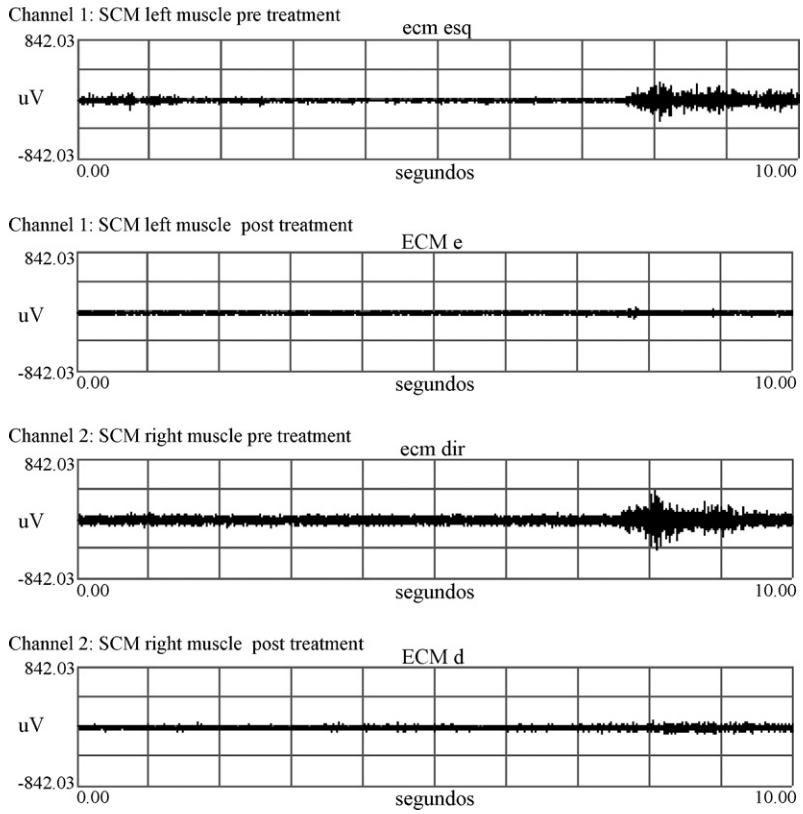

Fig. 1 EMG raw signal of the right and left SCM muscles of a mouth breathing child pre and post-treatment.

breathing. Breslin et al. [30] observed an increase of diaphragm and SCM muscles activity during resistance breathing, however over time, the diaphragm decreased activity and SCM recruitment increased. Other authors also considered that SCM should be active only in the maximal inspiration, and its activity may be increased due to visceral and mechanical restrictions to respiration [15,20,28].

During a quiet position, it is highly unusual to see large recruitment patterns associated with respiration in the UT, SCM and scalene muscles. The mayor exceptions to this rule are with COPD or patients who breathe in a paradoxical fashion [20]. The nose obstruction, which leads to an abnormal and inefficient breathing through the mouth causes drop in the PaO_2 and in the exercise tolerance [6]. It also determines profound effects on respiration and airway caliber in the lungs due to the disturbances in the nasal afferent nerves [9,10]. Additionally, it has shown the association of mouth breathing with obstructive sleep apnea and Cor pulmonale [4].

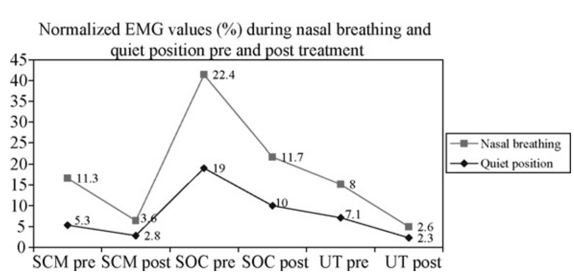

Fig. 2 Comparison between normalized EMG values obtained on cervical muscles during quiet position and nasal inspiration pre and post-PTP.

According to Basmajian and De Luca [27], the increase of electrical activity of respiratory accessory muscles in patients with respiratory deficiency is probably some form of compensatory stimulation via the respiratory center of CNS. When the diaphragm is not able to assume the mayor portion of the muscular respiratory work, there is a raise in the proprioceptive impulses to the inspiratory accessory muscles, producing the sensation of dyspnea because of the highest activity in these muscles [15]. In a long-term, the hyperactivity of neck muscles could be associated to cervical alterations, which as a consequence may cause temporo-mandibular (TMD) and cervical spine disorders [25].

Muscle shortness may be a substantial contributor to problems in Trapezius and scalene muscles, which may be linked to respiration. Therefore, relaxation of resting tone is considered essential to successful outcomes. Teaching a relaxed respiratory pattern involves teaching the patient to breathe abdominally [20]. This was confirmed by

Costa et al. [28] that verified SCM muscle was inactive during deep nasal inspiration in individual with diaphragmatic breathing pattern and active during nasal and oral inspiration in individuals with thoracic breathing pattern. In a study with respiratory biofeedback associated with quiet breathing pattern, in a tidal volume and normal respiratory rate, mouth-breathing children increased the PIMax, which indicated that they improved the use of diaphragm muscle by re-educating it. They also modify the respiratory pattern with more balance in the thoracoabdominal movement after this intervention [18].

Ribeiro-Corrêa et al. [14] also found higher activity of the sternocleidomastoideus and upper Trapezius muscles in children with MBS than in children with nasal breathing mode, indicating that the head posture modifies with the nasal obstruction. As a consequence, these muscles stay in a contracted state without relaxation or rest. Besides, nasal obstruction requires a larger inspiratory effort and, consequently, increases the inspiration accessory musculature EMG activity. Barbiero et al. observed, in a biofeedback pletsmovent, an irregular pattern with predominance of thoracic movement in 50% of twenty mouth-breathing children [18].

A head extension is considered a compensatory mechanism to increase the pharyngeal airway space, whereas it was demonstrated not be enough for providing a normal breathing pattern [24].

The forward head posture is influenced by the obstruction of the nasal airways, dyspnea, as well by the short and/or upper thoracic breathing, which increases the SCM activity and induces thoracic elevation, impairing the mechanical effectiveness of diaphragm muscle. This change in head posturing intensifies the inspiratory effort, settling down a vicious cycle of dysfunctional breathing [7,15,31]. The increase in the SCM muscles activity seems to be due to not only to the upper airway resistance but also because of the mechanical disadvantage of the diaphragm muscle caused by the postural changes. The head protraction and the shortening of the posterior muscle chain produces higher thoracic convexity, inspiratory position of the chest and medial rotation of shoulders, confirming the postural disturbances resulted from respiratory obstruction in patients with MBS [13].

There is little evidence about the relationship between specific respiratory muscle recruitment and the sensation of dyspnea, yet it was observed that COPD patients who recruit accessory neck and rib cage muscles in ventilation are more likely to report an increase in the sensation of dyspnea [30].

Breslin et al.'s study [30] showed that a shift in the ventilatory work from the rib cage and accessory muscles to diaphragm may reduce the sensation of dyspnea. The authors reported that resistance breathing resulted in a positive correlation with EMG activity of SCM and dyspnea, which was associated with desynchronized breathing.

A significant mechanical nasal airway obstruction is impossible to overcome by conscious effort, but a person who is mouth breather habitually may benefit by a concerted effort to keep the mouth closed [6]. The mouth-breathing persistence even after resolution of the initial functional abnormality (increased nasal resistance) has been mentioned by some authors [16,31,32]. They attributed this to the reflection of neural adaptations and long-lasting modifications of central control of upper airway, muscle function and the skeletal changes. All of these changes affect the posture and the muscular balance, therefore requiring treatment. Additionally, it is evidenced that some children with adequate upper airways breathe through the mouth due to a habit. The postural and respiratory techniques can influence the respiratory mode as in habitual mouth breathers as in allergic patients. The nasal breathing should be practiced in the inter-crisis period and after the removal of the causative factor of airway obstruction [7,11].

Basmajian and De Luca [27] pointed out the importance of proprioception in driving the respiratory muscles and reported an EMG study of diaphragm and intercostals muscles which evaluated the "abdominal compression reaction" in anesthetized dogs. They observed that such strong abdominal compression determines a caudal movement of diaphragm in the initial phase of inspiration .This is related to sudden inhibition of the abdominal compression reaction and a corresponding decrease in intra-abdominal pressure. Diaphragmatic breathing exercises, which emphasize abdominal rather than the rib cage expansion, are helpful when there is an overuse of the accessory muscles of the neck and upper chest [33].

Practicing slow diaphragmatic breathing in response to all stimuli (emotional situations, walking up hill or exposure to allergens) can reduce the asthmatic and breathlessness symptoms [34]. Diaphragmatic breathing has been reported as a commonly treatment used for dyspnea because it contributes to the reduction in respiratory rate and tidal volume [30].

Besides the proprioceptive stimulus for the adequate diaphragmatic work, the PTP needs to be addressed to the body posture, since it is postulated that optimal breathing capability derives from a posture of optimal muscle balance. The postural re-alignment is beneficial in part by improving the diaphragmatic mechanical advantage [33]. In a previous study, Corrêa and Bérzin obtained a better postural re-alignment in mouth breathing children, which was demonstrated by computerized analysis and lower cervical muscles activity after Swiss Ball exercises [5]. The importance of these results also extends to the ventilatory work. An adequate work of breathing demands liberation of the body tensions and increase of the mobility of thoracic joints. According to Hall and Brody [12], tactile feedback on the abdomen and rib cage along with stretch of the lateral trunk and intercostals muscles should be used in the diaphragmatic re-education. It is also recommended that the diaphragmatic breathing should not be taught, but facilitate with an adequate thoracoabdominal mechanics [31].

The abdominal muscles have a double function during breathing, as a support for the lower thoracic expansion and as in the lowering of ribcage. Therefore, abdominal exercises on the Swiss Ball were included in the PTP program, since abdominal muscles strengthening is also indicated to reestablish the appropriate diaphragmatic position and length [11,15].

Some activity such as gasping, thoracic breathing, breath holding, etc adversely affect the respiratory pattern. Changing the respiratory patterns with effortless diaphragmatic breathing may lead to an improvement in health and performance. The respiratory re-education to correct the mouth breathing is justified because it provides a decrease on the frequency and intensity of dyspnea [7].

The clinical relevance of this study is with respect of the high incidence of Mouth Breathing Syndrome [1—3] and its association with asthma [25], respiratory infections and sleep disordered breathing [4]; the importance of an evaluation including postural and respiratory type [20] to minimize the consequences of the muscular imbalance. Besides a precocious and complete interdisciplinary evaluation and intervention approach are essential for better therapeutic outcomes with positive impact in the quality of life of these patients. It must be also emphasized the need of prophylactic measures as breast-feeding and environment hygiene to diminish the incidence of allergic diseases.

Most of the criticism in the present study is regarding the lack of a clinical assessment of the ventilatory pattern and mechanics along with the EMG evaluation of cervical muscles, even though this was not its purpose. Authors reported some methods for the assessment of the dysfunction resulting from the mouth breathing as measurement of maximal inspiratory pressure and peak flow, which still can be adapted to be used through the nose [7,35]. It was also recommended the evaluation of spirometric parameters, thoracic expansibility by means of the diameter measurement of the thorax and abdomen, and a pletsmovent for respiratory biofeedback [8,18].

The reduced activity in these muscles brings advantageous changes since it can reduce the amount of mouth breathing reinforced by the forward head posture and the overuse of the accessory muscles of respiration.

The results of the current study evidenced a significant decrease on the EMG activity on tested muscles after treatment in children with MBS. These findings can be a result of a better postural alignment, specifically regarding the head forward posture, and an adequate respiratory pattern with less participation of inspiratory accessory muscles obtained with the treatment. Moreover, the improvement on the muscular balance seems to contribute for a reduction of the recruitment of cervical muscles in these children during nasal inspiration. Since the children learn how to breathe with diaphragmatic musculature and to keep an aligned posture and they have their muscle in a better balance for that, it is possible that the effect of this treatment can be permanent or maintained for a long-term.

The short-term data of the present study do not offer this conclusion and may not reflect a long-term non-surgical solution to Mouth Breathing Syndrome. Thus, further studies are required to demonstrate this more objectively, with validated quality of life surveys before/after therapy, short-term and long-term. The EMG analysis can be considered a reliable method for this sort of analysis, yet with careful measures regarding to instrumentation for an EMG signal acquisition with quality and for a proper data processing.

Acknowledgments

The authors would like to thank CAPES for their financial support, and the following individuals for their valuable contributions: Aline Ferla, MSc, Speech Therapist for data collection, Jovana Milanesi, PT undergraduate student for PTI sessions, Otolaryngologist Pedro Coser, MD for the clinical trial, Serge Roy, ScD, PT for scientific advising at the NeuroMuscular Research Center (Boston University) and Maria Beatriz Silveira, MD for her critical review of this manuscript.

We would also like to graciously thank the children for having participated in this study.

References

[1] S.A. Araújo, J.R. Moura, L.A. Camargo, Main Otolaryngological Symptoms Among School Children @rquivos de otorrinolaringologia, 8 (2004), Available in: URL http://www.arquivosdeorl.org.br/conteudo/acervo_port_print.asp?id=262.

[2] D. Solé, I.C. Camelo-Nunes, A. Thereza Vana, E. Yamada, F. Werneck, L. Solano de Freitas, M.J. Sologuren, M. Brito, N.A. Rosário Filho, R.T. Stein, C.K. Naspitz, Prevalence of rhinitis and related-symptoms in schoolchildren from different cities in Brazil, Allergol. Immunopathol. 32 (2004) 7—12.

[3] V.A. De Menezes, R.B. Leal, R.S. Pessoa, R.M.E.S. Pontes, Prevalence and factors related to mouth breathing in school children at the Santo Amaro project-Recife, Revista Brasileira de Otorrinolaringologia 72 (2005) 394—399.

[4] F.C.P. Valera, L.V.V. Travitzki, S.E.M. Mattar, M.A.N. Matsumoto, A.M. Elias, W.T. Anselmo-Lima, Muscular, functional and orthodontic changes in pre school children with enlarged adenoids and tonsils, Int. J. Otorhinolaringol. 67 (2003) 761—770.

[5] E.C.R. Corrêa, F. Bérzin, Efficacy of physical therapy on cervical muscle and on body posture in school-age mouth breathing children, Int. J. Pediatr. Otorhinolaringol. 71 (2007) 1527—1535.

[6] T. Weimert, Airway obstruction in orthodontic practice, JCO (1986) 96—104.

[7] D. Costa, Fisioterapia Respiratória na Correção da Respiração Bucal, Revista Fisioterapia em Movimento (1997) 111—120.

[8] E. Ribeiro-Corrêa, L.M. Soares, Avaliação Espirométrica de crianças portadoras de respiração bucal, Fisioterapia Brasil (2003) 163—167.

[9] J.G. Widdicombe, The physiology of the nose, Clin. Chest Med. (1986) 159—170.

[10] B.J. Canning, Neurology of allergic inflammation and rhinitis, Curr. Allergy Asthma Rep. (2002) 210—215.

[11] L.C. Yi, S. Amaral, C.E. Capela, Z.C.F. Guedes, S.S.N. Pignatari, Abordagem da reabilitação fisioterapêutica no tratamento do respirador bucal, Reabilitary (2004) 43—48.

[12] C.M. Hall, L.T. Brody, Therapeutic Exercise: Moving Towards Function, second edition, Williams & Wilkins, Lippincott, 2005.

[13] L.C.O. Lima, M.A. Barauna, M.J.J. Sologurem, R.S.T. Canto, A.C. Gastaldi, Postural alterations in children with mouth breathing assessed by computerized biophotogrammetry, J. Appl. Oral Sci. (2004) 232—237.

[14] E. Ribeiro-Corrêa, S.C. Marchiori, A.M.T. Silva, Electromyographic analysis of trapezius and sternocleidomastoideus muscles during nasal and oral inspiration in nasal and mouth breathing children, J. Electromyogr. Kinesiol. (2002) 302—316.

[15] R.J. Hruska, Influences of dysfunctional respiratory mechanics on orofacial pain, Dent. Clin. N. Am. (1997) 211—227.

[16] A.J. Miller, K. Vargervik, G. Chierici, Experimentally induced neuromuscular changes during and after nasal airway obstruction, Am. J. Orthod. (1984) 385—392.

[17] C.H. Biscioni, J.C. Couto, C. Guma, J. Harfin, C. Morandi, D.S. Pina, R. Sampaolesi, A.D. Vasallo, P.H. Vigneau, Evaluación multidisciplinaria del paciente respirador bucal, Sociedad Argentina de Ortodoncia (1994) 57—69.

[18] E.F. Barbiero, L.C.M. Vanderlei, P.C. Nascimento, M.M. Costa, A. Sacalabrini Neto, Influence of respiratory biofeedback associated with a quiet breathing pattern on the pulmonary function and habits of functional mouth breathers, Rev. Bras. Fisioter. (2007) 347—353.

[19] M. Rappai, N. Collop, S. Kemp, R. de Shazo, The nose and sleep-disordered breathing—what we know and what we do not know, Chest (2003) 2309—2323.

[20] J.R. Cram, G.S. Kasman, J. Holtz, Introduction to Surface Electromyography, An Aspen Publication, Gaithersburg, MD, 1998.

[21] R. Merletti, Standards for reporting EMG data, J. Electromyogr. Kinesiol. 9 (1999) III—IV.

[22] C.J. De Luca, The use of surface electromyography in biomechanics, J. Appl. Biomech. (1997) 135—163.

[23] P.W. Marshall, B. Murphy, Core stability exercises on and off a Swiss Ball, Arch. Phys. Med. Rehab. (2005) 242—249.

[24] J.A.V. Huggare, M.T. Laine-Alava, Nasorespiratory function and head posture, Am. J. Orthod. Dentofac. Orthop. (1997) 507—511.

[25] T.C. Chaves, D.B. Grossi, A.S. Oliveira, F. Bertolli, A. Holtz, D. Costa, Correlation between signs of temporomandibular disorder (TMD) and cervical spine (CSD) disorders in asthmatic children, J. Clin. Pediatr. Dent. (2005) 287—292.

[26] J. Finsterer, EMG-interference pattern analysis, J. Electromyogr. Kinesiol. (2001) 231—246.

[27] J.V. Basmajian, C.J. De Luca, Muscles Alive: Their Functions Revealed by Electromyography, fifth edition, Williams & Wilkins, 1985.

[28] D. Costa, M. Vitti, D.O. Tosello, R.P. Costa, Participation of the sternocleidomastoid muscle on deep inspiration in man. An electromyographic study, Electromyogr. Clin. Neurophysiol. (1994) 315—320.

[29] E.J.M. Campbell, The role of the scalene and sternocleidomastoid muscle in breathing in normal subjects: an electromyographic study, J. Anat. (1955) 378—386.

[30] E.H. Breslin, B.C. Garoutte, V. Kolhman-Carrieri, B.R. Celli, Correlations between dyspnea, diaphragm and sternomastoid recruitment during inspiratory resistance breathing in normal subjects, Chest (1990) 298—302.

[31] E.C.R. Corrêa, F. Bérzin, Temporomandibular disorder and dysfunctional breathing, Braz. J. Oral Sci. (2004) 498—502, Available in:URL:www.fop.unicamp.br/brjorals.

[32] J.C. Leiter, G.L. Baker, Partitioning of ventilation between nose and mouth: the role of nasal resistance, Am. J. Orthodont. Dentofac. Orthoped. (1990) 432—438.

[33] F.P. Kendall, E.K. McCreary, P.G. Provance, Muscles Testing and Function, fourth edition, Williams & Wilkins, Baltimore, 1993.

[34] E. Peper, V. Tibbetts, Effortless diaphragmatic breathing. electromyography: applications in physical therapy. Reprint from Institute for Holistic Healing Studies, San Francisco State University, CA.

[35] M.G. Pires, R.C. Di Francesco, A.S. Grumach, J.F. Mello Jr., Evaluation of inspiratory pressure in children with enlarged tonsils and adenoids, Rev. Bras. Otorrinolaringol. (2005) 598—602.

Available online at www.sciencedirect.com
ScienceDirect