Influence of respiratory biofeedback associated to re-expansive ventilation patterns in individuals with functional mouth breathing

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Summary

Objectives: Assess the effect of re-expansive respiratory patterns associated to respiratory biofeedback (RBF) on pulmonary function, respiratory muscle strength and habits in individuals with functional mouth breathing (FMB).

Methods: Sixty children with FMB were divided into experimental and control groups. The experimental group was submitted to 15 sessions of re-expansive respiratory patterns associated to RBF (biofeedback pletsmovent; MICROHARD® V1.0), which provided biofeedback of the thoracic and abdominal movements. The control group was submitted to 15 sessions using biofeedback alone. Spirometry, maximum static respiratory pressure measurements and questions regarding habits (answered by parents/guardians) were carried out before and after therapy. The Student’s t-test for paired data and non-parametric tests were employed for statistical analysis at a 5% level of significance.

Results: Significant changes were found in forced vital capacity, Tiffeneau index scores, maximum expiratory pressure, maximum inspiratory pressure and habits assessed in FMB with the use of RBF associated to the re-expansive patterns. No significant differences were found comparing the experimental and control groups.

Conclusions: The results allow the conclusion that RBF associated to re-expansive patterns improves forced vital capacity, Tiffeneau index scores, respiratory muscle strength and habits in FMB and can therefore be used as a form of therapy for such individuals.

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1. Introduction

Respiration is a vital function for human beings, who primarily breathe through the nose [1]. Replacing the correct nose breathing pattern with an inadequate pattern, such as mouth breathing or mouth/nose breathing, is defined mouth-breathing syndrome (MBS) [2]. The main cause of MBS is nasal obstruction, but the condition may also occur due to acquired habits, such as pacifier sucking, bottle feeding or finger sucking [3,4]. Individuals with no obstructive etiological factors are denominated functional mouth breathers, as there is no obstruction impeding nasal respiration [5].

Mouth breathing may trigger a number of problems, such as facial, postural and behavioral alterations [4,6,7]. Such problems can compromise the quality of sleep, thereby directly affecting physical development, scholastic performance, family relationships and quality of life as a result of the deterioration of physical/psychological conditions and social relationships [3,8].

As functional mouth breathing (FMB) produces multiple problems, multidisciplinary follow up is important [6]. Physiotherapy plays a fundamental role in the treatment of FMB, working directly on respiratory and postural alterations, helping to reestablish a correct breathing pattern; prevent and correct thoracic and postural alterations; and reeducate the musculature involved in these alterations. For such, physiotherapy methods such as kinesiotherapy, functional respiratory reeducation, respiratory biofeedback (RBF) are employed [9,10]. RBF has also been used effectively on patients with cystic fibrosis, chronic obstructive pulmonary disease and asthma [11—13].

RBF was developed to demonstrate to patients a number of physiological events, such as respiratory rate, tidal volume, respiratory flow and movement of the thorax and abdomen, through the amplification and exhibition of visual and auditory signals. The aim of RBF is to help individuals learn to manipulate these events for therapeutic benefits and the improvement of respiratory performance [14]. Barbiero et al. [10] evaluated the effectiveness of RBF associated to the “quiet breathing” pattern in 20 children with functional mouth breathing and found a significant increase in maximum inspiratory pressure (PImax) and significant alterations in the habits and behavior of these individuals after administering the method. The authors demonstrate that individuals with functional mouth breathing may have a restrictive ventilation disorder and that RBF associated to quite breathing produced no alterations in thoracic cirtometry, forced expiratory volume in the first second (FEV1), forced vital capacity (FVC), peak expiratory flow (PEF), Tiffeneau index (IT) or maximum expiratory pressure (PEmax).

Taking these aspects into consideration, we hypothesize that the administering of re-expansive respiratory muscle patterns associated with RBF could produce changes in lung volume and capacity as well as an improvement in expiratory muscle strength, which was not found when using RBF with the quite breathing pattern. This will open up new possibilities in the rehabilitation of mouth breathing and reduce the consequences of this dysfunction. A search of the pertinent literature revealed no reports on the influence of re-expansive muscle patterns in individuals with mouth-breathing habits. Thus, the aim of the present study was to assess the effect of re-expansive respiratory patterns associated with RBF in individuals with functional mouth breathing on pulmonary function (ventilation distribution, FEV1, FVC and IT) and respiratory muscle strength as well as the habits and behavior that are common to such individuals.

2. Methods

2.1. Study population

The present study was a controlled clinical trial involving 60 children with functional mouth breathing. The children were divided into two groups through simple manual randomization by lots—30 in the experimental group and 30 in the control group. Table 1 displays the age, weight, height and percentage distribution by gender of the children who participated in the study.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Experimental group</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>10.41 ± 1.46 (7.5—13.1)</td>
<td>9.45 ± 1.59 (6.7—12.5)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>35.47 ± 10.36 (20.2—75.5)</td>
<td>35.76 ± 11.40 (19.8—67.0)</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.41 ± 0.10 (1.18—1.63)</td>
<td>1.38 ± 0.15 (1.10—1.71)</td>
</tr>
<tr>
<td>Male gender</td>
<td>56.7% (17)</td>
<td>50% (15)</td>
</tr>
<tr>
<td>Female gender</td>
<td>43.3% (13)</td>
<td>50% (15)</td>
</tr>
</tbody>
</table>
The study received approval from the Research Ethics Committee of the School of Medicine of the Universidade de São Paulo (process no. 418/05). The parents/guardians of the children were invited to a lecture clarifying MBS and the proposal of the study. Those interested in participating received detailed explanations regarding the study and signed terms of informed consent.

The children were selected at the Núcleo Regional de Ensino de Maringá, PR, Brazil. For this selection, a questionnaire was first administered regarding the characteristic signs and symptoms of MBS in order to identify children with possible functional mouth breathing. Those who exhibited indicative signs and symptoms of MBS were submitted to an individual clinical evaluation carried out by a pediatrician (accompanied by the parents/guardians) for the confirmation of the diagnosis. The clinical examination included clinical history, rhinoscopy, otoscopy and Altman mirror analysis. Radiography was then performed on the rhinopharynx profile to certify the absence of hyperplasia of the adenoids and pharyngea as well as deviated septum or other nasal-pharyngeal alterations of an obstructive nature. These procedures ensured that all those selected exhibited functional MBS.

Children with no mechanical obstruction of the airways, regardless of having undergone de-obstruction surgery, and those not having begun any physiotherapy intervention for respiratory reeducation were included in the study. The following were the exclusion criteria: (a) children with allergic rhinitis in an acute phase associated to any other respiratory pathology; (b) those with neurological conditions, orthopedic deformities and/or craniofacial deformities that restricted respiratory function; (c) those with seeing and/or hearing impairments; (d) those with a history of chronic pulmonary or heart disease; and (e) those who developed a lung condition, viral or otherwise, during the treatment period.

2.2. Experimental procedure

The experimental procedure was executed in three phases:

(a) **Pre-treatment phase**: The children were assessed for the identification of ventilation distribution; a questionnaire was administered for a subsequent analysis of habits and behavior; respiratory function (FEV<sub>1</sub>, FVC, TI) and respiratory muscle strength (P<sub>I</sub><sub>max</sub> and P<sub>E</sub><sub>max</sub>) were assessed.

(b) **Treatment phase**: The children attended 15 sessions of the proposed treatment. The experimental group was submitted to RBF associated to re-expansive respiratory muscle patterns and the control group was submitted to RBF associated to the quiet breathing pattern.

(c) **Post-treatment phase**: The children were reevaluated following the same protocol as the initial assessment.

2.3. Assessment of ventilation distribution

The assessment of ventilation distribution was performed through a visual analysis of the RBF screens. The child was initially placed at rest for 10 min. The biofeedback cuffs were then positioned and the child was placed with his/her back to the equipment screen in a 90° Fowler position, with arms resting on the thighs, legs relaxed and feet resting on the ground. With the child duly positioned and maintaining spontaneous breathing, the screen permitting the identification of ventilation distribution was recorded. For this analysis, the predominance of ventilation distribution between the thorax and the abdomen was determined. Thoracic ventilation distribution was a predominance of movement in the upper thorax or upper rib region. Diaphragmatic ventilation distribution was a predominance of movement in the lower thorax or lower rib region.

2.4. Spirometry

A computerized spiography — AM 4000PC system — was used following the criteria described by the Brazilian Consensus on Spirography [15] and the Brazilian Pulmonary Function Test Guidelines [16]. The child was seated at 90° hip flexion, with no back support to the trunk, arms relaxed and spine erect. The child was allowed to lean forward during the test in order to exhale the greatest possible amount of air.

2.5. Manovacuometry

Maximum and static respiratory pressure measurements were performed using a digital manovacometer (MVD300<sup>®</sup>), following the criteria described by the American Thoracic Society/European Respiratory Society [17]. The children were informed of the test procedures and positioned in the same manner as during the spirometry exam. A nasal clip was used during the execution of the test. To measure P<sub>I</sub><sub>max</sub>, the child was instructed to perform maximum inhalation starting with the residual volume. To measure P<sub>E</sub><sub>max</sub>, the child was instructed to perform maximum exhalation starting with total lung capacity (TLC). The measurements were performed three times, with only the largest value considered for analysis.
2.6. Assessment of habits and behavior

A questionnaire was used for the analysis of the habits of the mouth-breathing children. The questionnaire was duly filled out by the parents/guardians prior to and following training with RBF and was drafted to determine changes related to the main habits that mouth-breathing children present. Regarding habits of daily living, the following factors were investigated: mouth open during waking hours; mouth open while sleeping; drool on the pillow; difficulties in waking; and restless sleep.

2.7. Treatment protocol

RBD was used during the treatment for the detection of thoracic–abdominal movements (Pletsmovent MICROHARD® V1.0, developed by GLOBAL-MED, RS, Brazil), coupled to a Pentium II—133 MHz microcomputer for analysis. This equipment provided the children with feedback by mean of visual signals, revealing the respiration behavior in the thoracic and abdominal regions. These visual signals were shown on the computer screen, which was divided into three parts (one above the other) for the visualization of how the respiration was behaving in the thoracic region (upper line) and abdominal region (center line) as well as the difference between thoracic and abdominal respiration (lower line).

RBF calibration was performed by inflating the cuffs positioned in the axillary and epigastric regions by means of a rubber bulb until reaching zero on the manometer coupled to the equipment.

2.8. Treatment protocol procedures

Fifteen 30-min treatment sessions were carried out, with a frequency of three times per week, a 1-day interval between sessions and no sessions on Saturday or Sunday. Prior to the sessions, the child remained at rest for 10 min in order to establish quiet breathing. Nasal hygiene was performed with a saline solution and the Altman mirror was used to confirm the absence of nasal obstruction prior to each session.

After positioning the thoracic and abdominal cuffs in the axillary and epigastric regions, respectively, the child was placed in front of the computer screen in 90° Fowler position, with arms resting on thighs, legs relaxed and feet resting on the ground (Fig. 1). The calibration of the equipment and the entire therapy was performed with the child in this position. All children were accompanied by a physiotherapist throughout the sessions.

For the quiet breathing pattern, which is characterized by calm, mild respiration with an amplitude near the basal tidal volume and respiratory rate within normal values (control group) [14], the child breathed in such a way as to leave the lower line on the computer screen flat. Through the visualization of the screen, the child could make any necessary corrections in breathing.

In the experimental group, the following re-expansive respiratory patterns were performed [14]:

(a) Inspiratory hiccups: Short, successive, energetic inhalations with no post-inspiratory apnea until reaching maximum inspiratory capacity and TLC. This was done to re-expand the pulmonary basal zones and strengthen the diaphragm.

(b) Fractioned inspiration in repetitions: Smooth, short, nasal inhalations, interrupted by short periods of post-inspiratory apnea and programmed for two, three, four or six repetitions.

The child began treatment first performing the inspiratory hiccups for 10 min, followed by 10 min of the quiet breathing pattern, the aim of which was to obtain minimal respiratory work for the child, with a rest between two re-expansive patterns. In the final 10 min, the child performed the fractioned inspiration in repetitions.

![Fig. 1 Position of the patient during the treatment protocol procedures.](image-url)
2.9. Statistical analysis

For the analysis of pulmonary function and the measurement of the maximum static respiratory pressures prior to and following the experimental protocol, the Kolmogorov–Smirnov was used to determine the normality of the data. When normal distribution was accepted, the paired Student’s t-test was used (FEV₁, FVC, TI, and PEₘₐₓ). In situations in which normal distribution was not accepted, the Wilcoxon test was used (Pₑₘₐₓ). The Wilcoxon test was also used in the analysis of the influence of the RBF on mouth-breathing habits and in the comparative analysis between the experimental and control groups. Differences on these tests were considered statistically significant when the p-value was less than 0.05.

3. Results

The results demonstrate that the use of RBF associated to re-expansive respiratory patterns produced significant changes in the FVC and TI (Student’s t-test; p < 0.05; Table 2). Regarding FEV₁ and all other spirometric parameters in the control group, no significant changes were found (Student’s t-test; p > 0.05; Table 2). No significant changes were found in FVC, TI, and FEV₁ values when comparing the post-treatment values of the experimental group with those of the control group (Wilcoxon test; p > 0.05).

Statistically significant differences were found in Pₑₘₐₓ (Wilcoxon test; p < 0.05) and PEₘₐₓ (Student’s t-test; p < 0.05) when comparing pre-treatment and post-treatment values (Table 3). However, no statistically significant changes were found when comparing values between groups.

Table 4 displays the percentage and numeric distribution of the ventilation distribution patterns in the experimental and control groups prior to and following therapy with respiratory patterns associated to biofeedback.

Mixed and thoracic ventilation distribution predominated in the pre-treatment period. The mixed pattern was found in 56.7% of the children in the experimental group and 43.3% of the children in the control group, whereas the thoracic pattern was predominant in 30% of the children in the experimental group and 50% of the children in the control group.

In the post-treatment period, both the experimental and the control groups exhibited changes in the ventilation distribution pattern. 13.3% and 50% increases occurred in the mixed ventilation distribution pattern for the experimental and control groups, respectively. No statistically significant differences were found when compared to the pre-treatment value (Student’s t-test; p > 0.05).
groups, respectively, and a 14.4% increase occurred in the predominately abdominal distribution pattern in the control group. Following treatment, the predominately thoracic ventilation pattern was present in just 3.3% of the children in the experimental group.

There were statistically significant differences (Wilcoxon test; \( p < 0.05 \)) in the following habits in the experimental and control groups: mouth open while sleeping, mouth open during waking hours and drool on the pillow (Tables 5 and 6). Regarding restless sleep, only the control group exhibited a statistically significant change (Wilcoxon test; \( p < 0.05 \)).

4. Discussion

The results demonstrate that the use of RBF associated to re-expansive respiratory patterns in children with functional mouth breathing produced significant changes in FVC and TI following treatment (\( p < 0.05 \)); the same did not occur with regard to FEV\(_1\) (\( p > 0.05 \)). The administering of RBF associated to quiet breathing did not produce changes in FVC, TI and FEV\(_1\) (\( p > 0.05 \)) values and the comparison of post-treatment values between groups also revealed no significant changes (\( p > 0.05 \)).

The increase in FVC values in the experimental group in the post-treatment period may be due to the re-expansive ventilation patterns associated to RBF. According to Azeredo [14], the aim of such patterns is to increase inspiratory reserve volume, expiratory reserve volume, functional residual capacity and total lung capacity, which produces an increase in FVC. According to Silva et al. [18], the TI is obtained from the division of FEV\(_1\) by FVC. Therefore, its reduction in the post-treatment period is related to the increase in FVC. According to Stout et al. [19], FEV\(_1\) is a parameter indicative of obstruction in the airways. The FEV\(_1\) values in the present study demonstrate that the children did not have airway obstructions.

The comparison of maximum static respiratory pressure reveals statistically significant differences in \( P_{Imax} \) and \( P_{Emax} \) between pre-treatment and post-treatment values with RBF associated to re-expansive patterns and quiet breathing. Barbiero et al. [10] found an increase in \( P_{Imax} \) values in individuals with functional mouth breathing with the use of RBF associated to the quiet breathing pattern. After treatment, significant differences (Student’s \( t \)-test, \( p < 0.05 \)) were also found with regard to \( P_{Emax} \) in both groups. This may also be due to the respiratory
Variations in respiratory muscle strength produce changes in the dynamics of respiratory movements, with consequent changes in respiratory mechanics [20]. This was evidenced by the changes in the respiratory pattern of the children in the experimental and control groups. According to Costa [21], patients who do not have a good level of awareness of respiratory movements can be sensitized through functional respiratory reeducation methods, which promote learning and the automatization of respiratory movements. The fundamental basis of these methods is sensory integration or reintegration of the movements performed by the thorax and abdomen in the respiration phase. From the awareness of details of inspiratory and expiratory movements, an individual can learn to control the rhythm, frequency and depth of his/her breathing, which appears to have been induced in these children with the administering of RBF in both groups.

In the post-treatment period, both the experimental and control groups underwent changes in the ventilation distribution pattern. 13.3% and 50% increases in the mixed ventilation pattern (both the thoracic musculature as well as diaphragm muscle) occurred in the experimental and control groups, respectively. There was also a 14.4% increase in the predominately abdominal distribution in the experimental group following treatment. The re-expansive respiratory patterns worked predominately on the diaphragm muscle, which explains the response found in this group. The predominately thoracic ventilation distribution was only present in 3.3% of the children in the experimental group following treatment.

There were significant changes following treatment (Wilcoxon test; \( p < 0.05 \)) in the following habits initially presented by the experimental and control groups: mouth open during waking hours, mouth open while sleeping and drool on the pillow. Regarding restless sleep, a significant change (Wilcoxon test, \( p < 0.05 \)) only occurred in the control group. No significant changes were found in either group with regard to difficulty waking (Wilcoxon test, \( p > 0.05 \)).

Table 4   Percentage and numeric distribution of respiratory pattern in the pre-treatment and post-treatment period in patients with functional mouth breathing from the experimental (\( N = 30 \)) and control (\( N = 30 \)) groups

<table>
<thead>
<tr>
<th>Ventilation pattern</th>
<th>Experimental group</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-treatment</td>
<td>Post-treatment</td>
</tr>
<tr>
<td>Mixed</td>
<td>56.7 (17)\textsuperscript{a}</td>
<td>70 (21)</td>
</tr>
<tr>
<td>Abdominal predominance</td>
<td>13.3 (04)</td>
<td>27.7 (08)</td>
</tr>
<tr>
<td>Thoracic predominance</td>
<td>30.0 (09)</td>
<td>3.3 (01)</td>
</tr>
</tbody>
</table>

\( \textsuperscript{a} \) Number of cases.

Table 5   Percentage values of the presence, improvement and absence of functional mouth-breathing habits before and after treatment in the experimental group (\( N = 30 \)) submitted to therapy with biofeedback

<table>
<thead>
<tr>
<th>Habits</th>
<th>Pre-treatment</th>
<th>Post-treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Mouth open while sleeping</td>
<td>76.6 (23)\textsuperscript{a}</td>
<td>6.7 (02)</td>
</tr>
<tr>
<td>Mouth open during waking hours</td>
<td>70.0 (21)</td>
<td>13.3 (04)</td>
</tr>
<tr>
<td>Drool on pillow</td>
<td>50.0 (15)</td>
<td>16.7 (05)</td>
</tr>
</tbody>
</table>

\( \textsuperscript{a} \) Number of cases with absent, present or sometimes present habits.

Table 6   Percentage values of the presence, improvement and absence of functional mouth-breathing habits before and after treatment in the control group (\( N = 30 \)) submitted to therapy with biofeedback

<table>
<thead>
<tr>
<th>Habits</th>
<th>Pre-treatment</th>
<th>Post-treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Mouth open while sleeping</td>
<td>76.6 (23)\textsuperscript{a}</td>
<td>3.3 (01)</td>
</tr>
<tr>
<td>Mouth open during waking hours</td>
<td>93.3 (28)</td>
<td>3.3 (01)</td>
</tr>
<tr>
<td>Drool on pillow</td>
<td>73.3 (22)</td>
<td>20.0 (06)</td>
</tr>
<tr>
<td>Restless Sleep</td>
<td>60.0 (18)</td>
<td>13.3 (04)</td>
</tr>
</tbody>
</table>

\( \textsuperscript{a} \) Number of cases with absent, present or sometimes present habits.
Regarding the mouth remaining open during waking hours, 70% and 16.7% (experimental group) and 76.6% and 20% (control group) either always or nearly always exhibited this habit, respectively. These data are similar to those described by Andrade et al. [22] for 40 mouth-breathing children between 6 years and 10 years 11 months, 67.5% of whom exhibited partially open lips. After training in both the experimental and control groups, the majority of children exhibited lip closure without effort by the perioral musculature both during waking hours as well as when sleeping. This demonstrates a change in the type of respiration and, consequently, an improvement in pulmonary ventilation.

Significant differences were found in the experimental and control groups (Wilcoxon test; \( p < 0.05 \)) following treatment with regard to drool on the pillow. This differs from the results described by Bottero et al. [23], who found that 51.4% of the subjects in their study were mouth breathers/mouth—nose breathers and found no significant difference between respiratory mode and sleep alterations, snoring or moist pillow upon waking. In a study with 20 children with FMB submitted to 15 sessions of RBD associated to the quiet breathing pattern, Barbiero et al. [10] found significant changes in the following habits after treatment: mouth open while sleeping, mouth open during waking hours, drool on the pillow, difficulty waking, snoring and restless sleep.

In mouth-breathing individuals, the alveolar hyperventilation that may occur eventually pulls them out of the REM sleep phase, fragmenting it for a long period of time and giving the individuals a restless sleep [24]. The individuals in the control group reported a significant improvement in the quality of sleep (Wilcoxon test, \( p < 0.05 \)); 66.7% of the individuals exhibited an absence of restless sleep after training. Through the questionnaire administered in the present study, an improvement in the quality of sleep was observed, with a reduction in drool on the pillow (both experimental and control groups) and a reduction in restless sleep (control group), which may be attributed to the change in breathing pattern and consequent improvement in ventilation, thereby reducing hyperventilation.

Silva et al. [25] carried out a respiratory physiotherapy program with six mouth-breathing children and administered a quality of life questionnaire addressing psychological limitations and nose-breathing impairment as well as performing spirometry prior to and following respiratory physiotherapy. The authors found a reduction in nose-breathing impairment, significant increases in FVC, FEV, and tidal volume, the child’s perception regarding an improvement in quality of life and changes in mouth-breathing pattern, indicating the effectiveness of treatment.

5. Conclusions

The results of the present study suggest that re-expansive respiratory patterns administered in association with RBF were effective as a form of therapy for individuals with MBS and offer physiotherapists an additional method for treating their patients in an increasingly satisfactory manner.

References


