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Diaphragmatic amplitude and accessory inspiratory muscle activity in nasal and mouth-breathing adults: A cross-sectional study

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The purpose of this study was to evaluate the electromyographic activity of the accessory inspiratory muscles and the diaphragmatic amplitude (DA) in nasal and mouth-breathing adults. The study evaluated 38 mouth-breathing (MB group) and 38 nasal-breathing (NB group) adults, from 18 to 30 years old and both sexes. Surface electromyography (sEMG) was used to evaluate the amplitude and symmetry (POC%) of the sternocleidomastoid (SCM) and upper trapezius (UT) muscles at rest, during nasal slow inspiration at Lung Total Capacity (LTC) and, during rapid and abrupt inspiration: Sniff, Peak Nasal Inspiratory Flow (PNIF) and Maximum Inspiratory Pressure (MIP). M-mode ultrasonography assessed the right diaphragm muscle amplitude in three different nasal inspirations: at tidal volume (TV), Sniff and inspiration at LTC. The SCM activity was significantly lower in the MB group during Sniff, PNIF ($p < 0.01$, Mann–Whitney test) and MIP ($p < 0.01$, *t*-test). The groups did not differ during rest and inspiration at LTC, regarding sEMG amplitude and POC%. DA was significantly lower in the MB group at TV ($p < 0.01$, Mann–Whitney) and TLC ($p = 0.03$, *t*-test). Mouth breathing reflected on lower recruitment of the accessory inspiratory muscles during fast inspiration and lower diaphragmatic amplitude, compared to nasal breathing.

1. Introduction

Nasal breathing is innate to human beings due to its important function of preparing the air to reach the important structures of the respiratory system. In addition, it is essential for development and functionality of the craniofacial and stomatognathic systems (Armijo-Olivo et al., 2006; Cuccia et al., 2008).

Nasal breathing can be partially or totally replaced by mouth breathing, regardless of the factors that block the passage of the air through the nasopharynx. These factors can be obstructive, mainly the enlarged adenotonsilar tissues, or functional, caused by transient edema of nasal mucosa, muscular flaccidity or by the maintenance of this habit even after surgical correction (Berwig et al., 2011). Mouth supplying is considered an abnormal and inefficient adaptation of breathing mode and it may induce functional, postural, biomechanical and occlusal imbalances (Barros et al., 2006; Okuro et al., 2011).

Mouth-breathing (MB) mode, as obstructive as functional, may produce postural adaptations and muscular imbalances in the attempt of reducing nasal resistance and facilitating airflow through the nasal–pharyngeal airway. Forward head posture is commonly found in MB people (Chaves et al., 2010; Cuccia et al., 2008; Okuro et al., 2011; Yi et al., 2008), reflecting on the diaphragm (Lima et al., 2004; Yi et al., 2008) and rib cage kinetics (Okuro et al., 2011; Pires et al., 2007). Additionally, studies found higher accessory inspiratory muscle activity at rest (Ribeiro et al., 2002; Corrêa and Bérzin, 2008), respiratory muscle weakening (Milanesi et al., 2014; Okuro et al., 2011; Pires et al., 2005, 2007) and predominant inspiratory movement in the upper thorax (Yi et al., 2008). The lower functional exercise capacity and the reduced quality of life in the domain of general health were also consequences of the mouth-breathing mode (Milanesi et al., 2014).

Sternocleidomastoideus and upper trapezius muscles are described as inspiratory accessory muscles, acting as head and

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neck stabilizers and helping to elevate the thoracic cage, respectively, during deep inspiration (Kendall, 2005). Studies conducted with sEMG found higher activity of the accessory inspiratory muscles at rest, and lower activity during maximal contraction, in MB children compared to the nasal breathers. It was suggested that this activity pattern may occur due to muscular imbalance, resulting from postural changes in mouth-breathing children (Ribeiro et al., 2002). In another study carried out with MB children (Corrêa and Bérzin, 2008), the EMG activity levels of the accessory inspiratory muscles, previously to physiotherapeutic intervention, were compatible with muscular hyperactivity.

Diaphragmatic amplitude (DA) in MB children, investigated by means of fluoroscopy (Yi et al., 2008), was lower than in nasal-breathing children. Traditionally diaphragm evaluation is accomplished by fluoroscopy (gold pattern); however, ultrasound has shown advantages due to absence of radiation and portability (Boussuges et al., 2009; Nason et al., 2012). Despite the different approaches, either directly attained at the posterior surface of the diaphragm (Kim et al., 2010) or indirectly (craniocaudal displacement of the left branch of the portal vein) (Grams et al., 2014; Yamaguti et al., 2007), there is a consensus that ultrasound is a reproducible and easy to use method (Boussuges et al., 2009; Grams et al., 2014; Kim et al., 2010; Nason et al., 2012).

Currently, most studies regarding mouth-breathing mode address otorhinolaryngological, dental and orofacial motricity aspects, however, some of them concentrate on the postural changes, mainly in children. Nevertheless, morphofunctional sequelae of these changes may remain at adult age, even after treating the nasal obstruction during youth.

The evaluation and treatment of mouth breathing, by a physical therapist, should comprehend postural and ventilatory changes. However, there is scarcity of studies regarding ventilatory function and respiratory muscles in mouth-breathing children and adults.

The knowledge obtained concerning diaphragmatic motion and accessory inspiratory muscles recruitment, in mouth-breathing adults, may contribute to a more global and interdisciplinary diagnostic and therapeutic approach, from childhood to adult age.

The objective of this study was to evaluate the electrical activity of accessory inspiratory muscles and the amplitude of diaphragmatic movement in mouth and nasal-breathing adults.

2. Methods

This exploratory, cross-sectional, controlled study was approved by the local Research Ethics Committee (protocol number 04039912.7.0000.5346) and a Consent Form was signed by the participants. Adult male and females between 18 and 30 years of age with mouth-breathing (MB group) and nasal-breathing mode (NB group), body mass index (BMI) between 18.5 and 24.9 kg/m^2 (WHO, 2013), normal spirometry according to European Respiratory Society (Stocks and Quanjer, 1995) and without evidence of respiratory and neuromuscular diseases, thoracic deformities, tobacco history and/or exposure to risk environment, took part in the study. Subjects using topical or systemic corticosteroids, muscle relaxants and/or barbiturates were excluded. Those with report of flu in the last three weeks or allergic rhinitis attack on the assessment day, chest and/or abdominal surgery, abdominal hernia and those who were physically active were excluded. The diagnosis of the breathing mode was based on the anamnesis, signs and symptoms and physical characteristics related to mouth breathing, such as absence of lip seal, hypotonic lips, elongated face, report of snoring, drooling on the pillow, or having the mouth open most part of the day and/or during sleep (Milanesi et al., 2014; Yi et al., 2008). The otorhinolaryngologic evaluation included nasofibroscopy, which assessed the presence of upper airway obstruction by tonsillar and or adenoidal hypertrophy or rhinitis and classified the participants as organic or functional mouth breathers, namely with or without mechanical obstruction.

The anamnesis consisted of collecting signs and symptoms, history of surgery, consumption of drugs, demographic and anthropometric data, stature, body mass index (Digital Scale *CAMRY*, model EB9013), physical activity level (International Physical Activity Questionnaire – IPAQ) (Matsudo et al., 2001) and spirometry (*One Flow FVC KIT, Clement Clark International*, United Kingdom). Subsequently, participants were evaluated by sEMG and diaphragm ultrasound.

During examination the subjects were seated with an upright trunk, relaxed arms, hands on lap, eyes open, head in the Frankfurt plane, and the feet flat on the floor. For the sEMG, an adapted chair was used (Corrêa and Bérzin, 2008).

Electrical activity of Sternocleidomastoideus (SCM) and upper trapezius (UT) muscles was recorded bilaterally. Signal acquisition was based on the *Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles* (SENIAM) (Hermens et al., 2000). In order to reduce signal interference, the collection site was equipped with a rubber floor, and all bulbs and mobile phones were switched off. Any metal accessories were also removed from the participants.

Prior to attaching the electrodes the participants skin was cleaned with gauze soaked with 70% alcohol and, whenever necessary, trichotomy was carried out on the muscle surface.

Preamplifier sensors with differential output were connected to adhesive disposable silver/silver chloride bipolar surface electrodes (interelectrode distance 20 mm; Hall Industry and Comerce Ltda). A reference electrode (Meditrace 100) was applied to the sternal manubrium (Hermens et al., 2000).

The SCM electrodes were positioned longitudinally to the muscle fibers at the midpoint of the muscular belly, located by muscle palpation during manually resisted neck flexion. The UT electrodes were positioned at the midpoint between the spinous process of the seventh cervical vertebra and the acromion (Hermens et al., 2000).

An sEMG signal was acquired using a 14-bit Surface Electromyograph (Miotool 400, Miotec®, Porto Alegre, Brazil), 110 dB Common Mode Rejection and 2000 Hz sampling frequency per channel. Butterworth and band-pass filters (20–500 Hz) were used (Hermens et al., 2000). A signal was recorded by Miograph (Miotec®, Porto Alegre, Brazil) and stored in a portable computer (HP 420 Intel Celeron). Both devices were connected to battery without connection to a power system.

Muscle activity was recorded at rest (tidal volume – TV), during 10 s, and during four inspiratory tests: Sniff, Lung Total Capacity (LTC), Peak Nasal Inspiratory Flow (PNIF) and Maximum Inspiratory Pressure (MIP). These tests started after expiration at Functional Residual Capacity (FRC), except the MIP, which started from Residual Volume (RV). From these expiratory levels, the subjects performed fast and abrupt nasal inspiration (Sniff), slow and complete nasal inspiration (LTC), fast nasal inspiration through a facial mask (PNIF) and fast, forced and sustained inspiration through the mouthpiece (MIP) (Kjærgaard et al., 2008; Montemezzo et al., 2012; Neder et al., 1999; Ottaviano et al., 2008). Each of these activities was performed at least three times with a 2-min interval. To normalize the EMG signal, muscle activity during Maximal Voluntary Contraction (MVC) was collected during anterior head flexion (SCM muscle) and shoulder elevation (UT), and with resistance offered by existing boards in the adapted chair (Corrêa and Bérzin, 2008). These activities were recorded during five seconds and repeated at least twice, with 2-min intervals (Figs. 1 and 2).

From all recordings, the most uniform signal that was visually verified and confirmed by the Fast Fourier Transform (FFT) curve was selected for further quantitative analysis (Corrêa and Bérzin,