Journal of Electromyography and Kinesiology 22 (2012) 961–967

Contents lists available at SciVerse ScienceDirect

Journal of Electromyography and Kinesiology

journal homepage: www.elsevier.com/locate/jelekin

Influence of forward leaning and incentive spirometry on inspired volumes and inspiratory electromyographic activity during breathing exercises in healthy subjects

Thalita Vilaboim Santos, Gualberto Ruas, Luciane Aparecida Pascucci Sande de Souza, Marcia Souza Volpe *

Physiotherapy Department, Federal University of Triângulo Mineiro, Uberaba, Minas Gerais, Brazil

ARTICLE INFO

Article history:
Received 30 June 2011
Received in revised form 6 May 2012
Accepted 7 May 2012

Keywords:
Electromyography
Breathing exercises
Incentive spirometry
Physical therapy modalities

ABSTRACT

Breathing exercises (BE), incentive spirometry and positioning are considered treatment modalities to achieve lung re-expansion. This study evaluated the influence of incentive spirometry and forward leaning on inspired tidal volumes (V_T) and electromyographic activity of inspiratory muscles during BE. Four modalities of exercises were investigated: deep breathing, spirometry using both flow and volume-oriented devices, and volume-oriented spirometry after modified verbal instruction. Twelve healthy subjects aged 22.7 ± 2.1 years were studied. Surface electromyography activity of diaphragm, external intercostals, sternocleidomastoid and scalenes was recorded. Comparisons among the three types of exercises, without considering spirometry after modified instruction, showed that electromyographic activity and V_T were lower during volume-oriented spirometry ($p = 0.000$, $p = 0.054$, respectively). Forward leaning resulted in a lower V_T when compared to upright sitting ($p = 0.000$), but electromyographic activity was not different ($p = 0.606$). Inspired V_T and electromyographic activity were higher during volume-oriented spirometry performed after modified instruction when compared with the flow-oriented device ($p = 0.027$, $p = 0.052$, respectively). In conclusion BE using volume-oriented spirometry before modified instruction resulted in a lower work of breathing as a result of a lower V_T and was not a consequence of the device type used. Forward leaning might not be assumed by healthy subjects during situations of augmented respiratory demand.

1. Introduction

Expansion pulmonary therapy is considered an essential component of physiotherapy in the management of patients with decreased pulmonary compliance caused by reversible conditions such as retained airway secretions or atelectasias (Gosselink, 2003). Physiotherapists have available different treatment modalities to achieve lung re-expansion which mainly can be obtained by increasing inspiratory volume and/or functional residual capacity (FRC) (Gosselink et al., 2008).

In order to augment inspiratory volume, breathing exercises (BE) and incentive spirometry (IS) are the most simple treatment interventions (Parreira et al., 2005; Agostini and Singh, 2009). According to some authors to fulfill the physiological requirements of re-expansion, BE should be characterized by a long, slow inspiration, followed by an inspiratory hold (Agostini and Singh, 2009). Maintaining large inflating volumes and transpulmonary pressures for several seconds are necessary to achieve alveolar recruitment since obstructed areas have longer time constants.

In contrast IS involves the use of incentive spirometers which are instrumental devices that offer the additional benefit of visual feedback, in terms of flow or volume, giving the patient a measurable goal while performing the BE (Weindler and Kiefer, 2001; Agostini and Singh, 2009). Since 1980's, IS became widely used in the postoperative of thoracic and abdominal surgeries for the prevention and treatment of pulmonary complications (O'Donohue, 1985). Several studies have been conducted to evaluate its efficacy and to compare this technique with other treatment programs (Dias et al., 2011; Tomich et al., 2010). However, until today there are some controversies regarding IS benefits in relation to BE performed without it or even related to the device type used, volume or flow-oriented (Agostini et al., 2008).

Before applying the indicated treatment, physiotherapists should always position the patient in order to optimize their goals (Gosselink et al., 2008). Upright sitting is usually selected during BE, because at this position higher maximal inspiratory pressure (MIP) and inspired volumes can be generated increasing therapy effectiveness (Heijdra et al., 1994).

* Corresponding author. Address: Rua Irmão Afonso, 507-AP102, Bairro São Sebastião, CEP 38060-360, Uberaba, MG, Brazil. Tel.: +55 3491999824 (home), +55 3433185925 (work).

E-mail address: marciasvolpe@gmail.com (M.S. Volpe).

1050-6411/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jelekin.2012.05.001

Interestingly, forward leaning is a frequently assumed position by patients with chronic obstructive pulmonary disease (COPD) during episodes of dyspnea (O'Neill and McCarthy, 1983; Gosselink, 2003; Bott et al., 2009). O'Neill and McCarthy showed that MIP values were higher in COPD patients during forward leaning when compared to other positions, while this result was not observed in healthy adults (O'Neill and McCarthy, 1983). The superiority of this position as a generator of MIP and its association with relief of dyspnea in COPD patients is probably due at least in part to compression of abdominal contents and stretching of the diaphragm, thereby improving its length-tension relationship.

Forward leaning is often associated to arm support on knees or on a surface positioned in front of them (Bott et al., 2009). Some authors have hypothesized that fixation of arms probably helps by optimizing recruitment of accessory muscles, or conversely by promoting relaxation of accessory muscle and, consequently, reducing the use of upper chest muscles (Gosselink, 2003). Although there are some studies reporting the benefits and the physiological mechanisms of forward leaning, there are still conflicting issues about the posture (Bhatt et al., 2009; Bott et al., 2009).

Despite the controversial points, if there is evidence that forward leaning has a positive influence on the activation pattern of inspiratory muscles in COPD patients, the association of this position to BE seems interesting due to its possible benefit – obtaining equal inspired volumes with lower energetic expenditure. Pulmonary expansion therapy is frequently advocated to critical illness patients, like COPD ones, what reinforces the necessity of therapies that achieve their goal without increasing patient's respiratory work. In fact pulmonary expansion therapy is indicated to COPD patients only in specific clinical conditions that predispose to pulmonary compliance reduction, like in the postoperative period of thoracic surgery. During such conditions patients are often even more debilitated and prone to fatigue; what undoubtedly supports that unnecessary energetic expenditure should be avoided.

The main objective of this study was to investigate the influence of forward leaning on inspired tidal volume (V_T) and inspiratory muscular activity during different BE with and without IS, using both flow and volume-oriented devices. Since the physiological mechanisms of forward leaning are not clearly comprehended we decided to first investigate its effects on healthy subjects.

2. Methods

The Ethics Research Committee of the University approved the protocol used. The volunteers were informed about the procedures and signed the written informed consent.

3. Subjects

Healthy volunteers of both genders were selected from a sample of university students. The inclusion criteria were: being 18–25 years old, without smoking history and reporting the absence of respiratory diseases. The exclusion criteria were: presenting altered respiratory function detected by functional analysis of lung volumes, having previous knowledge of BE and IS, incomprehension and/or inability to perform the BE and having visual deficit.

4. Procedures

4.1. First assessment

All volunteers were submitted to a pulmonary function test, an interview and collection of anthropometric measurements. Function analysis of lung volumes was carried out as recommended in the literature at the pulmonary function laboratory of the University (Pereira, 2002). During the interview, they were questioned by previous and/or current pulmonary diseases, smoking habits and the International Physical Active Questionnaire (IPAQ) was applied (accessed at http://www.ipaq.ki.se).

4.2. Electromyography

Surface electromyographic activity of the following inspiratory muscles was recorded: diaphragm (DI), external intercostals (EI), sternocleidomastoid (SCM) and scalenes (SCA). For data collection, a pair of bipolar surface electrodes was placed on the cleaned, abraded skin at each investigated muscle group. The electrodes to capture DI activity were placed on the 7th or 8th anterior intercostal space in accordance to the best signal captured between the axillary and hemiclavicular line (de Andrade et al., 2005). To record EI activity, the electrodes were placed in the 2nd or 3rd intercostal space at the midclavicular line (Chien et al., 2008). In the case of SCM, the electrodes were placed on the muscular body, at 5 cm from the mastoid process and the electrodes for recording SCA were placed 1–2 cm above the clavicle, just behind SCM clavicular fibers (De Troyer et al., 1994; Hug et al., 2006). A reference electrode was placed on the coracoid process of the right scapula.

The influence of the ECG on the electromyographic signal was minimized by recording from the right side of the body. The confirmation of the proper position of the electrodes was assured by requesting the individuals to take a deep breath, to perform an isometric neck flexion and an isometric neck inclination for confirmation of DI and EI, SCM and SCA, respectively.

Data acquisition was carried out using an eight-channel biological signal acquisition system (EMG System Ltda., São José dos Campos, SP, Brazil) consisting of a signal conditioner with a gain of 1000, a high-pass filter of 20 Hz and a low-pass filter of 500 Hz. All data were processed using specific software for acquisition and analysis (Windaq, São José dos Campos,SP, Brazil) and a 12-bit analogue-to digital converter, with a sample frequency of 2000 Hz. Windaq is a program which allows the storage of data in files and mathematic process to calculate the root mean square (RMS). In all procedures the capture and analysis of electromyographic signals were carried out as recommend by the International Society Electrophysiology Kinesiology.

For an adequate comparison of the electromyographic activities during the steps of the protocol, data collected during MIP measurements were used to calculate the percentage of muscle activation during each BE related to the electromyographic activity recorded during MIP measurements.

4.3. Ventilometry

Inspired V_T was obtained using a ventilometer (Wright®, British Oxygen Company, London, England) attached to a mouthpiece. While performing the BE, the volunteers breathed through the mouthpiece connected to the ventilometer. During the exercises with the spirometers, a tube of polyvinyl chloride in its shortest length was used to connect the ventilometer to the incentive spirometer.

4.4. Intervention protocol

MIP measurements were obtained with a manovacuometer (GeRar®, São Paulo, SP, Brazil) from FRC with the volunteer seated. MIP was taken from the best values, after at least three measurements with one-min interval between them, according to a specific protocol (Souza, 2002). After MIP measurements, the subjects stayed seated comfortably in a chair and were instructed on how to perform the BE.