ARTICLE IN PRESS

Autonomic Neuroscience: Basic and Clinical xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Autonomic Neuroscience: Basic and Clinical

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

Review

Effects of inspiratory muscle training on cardiovascular autonomic control: A systematic review

Raphael Martins de Abreu[a], Patrícia Rehder-Santos[a], Vinicius Minatel[a], Gabriela Lopes dos Santos[b], Aparecida Maria Catai[a,*]

[a] Cardiovascular Physical Therapy Laboratory, Department of Physical Therapy, Federal University of São Carlos, São Carlos, São Paulo, Brazil
[b] Laboratory of Neurological Physiotherapy Research, Department of Physical Therapy, Federal University of São Carlos, São Carlos, São Paulo, Brazil

ARTICLE INFO

Keywords:
Breathing exercises
Respiratory muscle training
Cardiovascular oscillations

ABSTRACT

Purpose: To carry out a systematic review to determine if inspiratory muscle training (IMT) promotes changes in cardiovascular autonomic responses in humans.
Methods: The methodology followed the PRISMA statement for reporting systematic review analysis. MEDLINE, PEDro, SCOPUS and PubMed electronic databases were searched from the inception to March 2017. The quality assessment was performed using a PEDro scale. The articles were included if: (1) primary objective was related to the effects of IMT on the cardiovascular autonomic nervous system, and (2) randomized clinical trials and quasi-experimental studies. Exclusion criteria were reviews, short communications, letters, case studies, guidelines, theses, dissertations, qualitative studies, scientific conference abstracts, studies on animals, non-English language articles and articles addressing other breathing techniques. Outcomes evaluated were measures of cardiovascular autonomic control, represented by heart rate variability (HRV) and blood pressure variability (BPV) indexes.
Results: The search identified 729 citations and a total of 6 studies were included. The results demonstrated that IMT performed at low intensities can chronically promote an increase in the parasympathetic modulation and/or reduction of sympathetic cardiac modulation in patients with diabetes, hypertension, chronic heart failure and gastroesophageal reflux, when assessed by HRV spectral analysis. However, there was no study which evaluated the effects of IMT on cardiovascular autonomic control assessed by BPV.
Conclusions: IMT can promote benefits for cardiac autonomic control, however the heterogeneity of populations associated with different protocols, few studies reported in the literature and the lack of randomized controlled trials make the effects of IMT on cardiovascular autonomic control inconclusive.

1. Introduction

The study of cardiovascular autonomic control through indirect measures, such as blood pressure and heart rate variability (BPV and HRV, respectively) can help us to understand cardiac and vascular regulation in healthy subjects and patients with disorders. These non-invasive measures are also used to verify the efficacy of interventions in clinical settings (Montano et al., 2009), and as an independent predictor of mortality for different populations, since they have great reproducibility and feasibility (Task Force, 1996; Vanderlei et al., 2009). Thus, different modalities of physical exercises have been used to improve and/or restore the cardiovascular autonomic control, such as aerobic, resistance and respiratory exercises (Martinez et al., 2011; Ferreira et al., 2013; Caruso et al., 2015).

According to the literature, conventional methods, such as aerobic and resistance exercises at low intensities promote beneficial adaptations in HRV, such as an increase in cardiac parasympathetic modulation and a decrease in sympathetic modulation at rest after training (Murad et al., 2012; Caruso et al., 2015). In the context of cardiovascular rehabilitation, these adaptations represent cardioprotective effects as rest parasympathetic activity predominance induces electrical stability, while sympathetic hyperactivity promotes cardiac overload, increasing the risk of cardiovascular events (Kleiger et al., 1987; Santos-Hiss et al., 2011; Murad et al., 2012; Caruso et al., 2015). On the other hand, respiratory exercises have developed as a complementary non-conventional method of physical activity to also promote benefits for the cardiovascular autonomic responses as changes in respiratory patterns have an influence on this system (Eckberg et al., 1985). During respiratory phases, oscillations occur in tidal volume, intrathoracic pressure and venous return, which promote different stimulation in the

* Corresponding author at: Rodovia Washington Luís, km 235, Monjolinho, São Carlos, São Paulo 13565-905, Brazil.
E-mail address: mcatai@ufscar.br (A.M. Catai).

http://dx.doi.org/10.1016/j.autneu.2017.09.002
Received 3 May 2017; Received in revised form 24 August 2017; Accepted 5 September 2017
1566-0702/

baroreflex activity according to individual respiratory patterns (Eckberg and Orshan, 1997; Bernardi et al., 2001; Joseph et al., 2005; Jones et al., 2015).

Although non-resistant respiratory exercises are able to promote changes in autonomic cardiovascular control, some studies have shown that inspiratory muscle training (IMT) with resistance generate better results on cardiac autonomic modulation compared to the IMT without loads (sham group), demonstrating that resistance may be the key to potentiate the effects of IMT over autonomic control (Ferreira et al., 2013; Kaminski et al., 2015). Moreover, it is well defined in the literature that performing respiratory exercises associated with resistance, such as the IMT, promotes not only strengthening the respiratory muscles, but also improving respiratory muscular endurance in athletes, non-athletes (HajGhanbari et al., 2013; Sales et al., 2016), patients with chronic heart failure (Bosnak-Guclu et al., 2011; Plentz et al., 2012) and patients undergoing cardiac surgery (Cordeiro et al., 2016). This improvement of respiratory muscle function after IMT is associated with enhancing the metaboreflex activation threshold, improving functional capacity and physical performance, which favors a decrease in the cardiac sympathetic output at rest (Dall'ago et al., 2006; Witt et al., 2007; HajGhanbari et al., 2013).

While respiratory muscle strengthening may be associated with an improvement in resting autonomic modulation, IMT has only been investigated recently as a tool to improve this system. Therefore, the aim of this study was to review the effects of IMT on cardiovascular autonomic responses (HRV and BPV) in humans and the best dose response to cardiovascular autonomic function. This understanding will provide support to use this training modality in a rehabilitation program for patients with clinical characteristics and autonomic imbalance, complementing conventional therapies. In addition, IMT can be considered as a therapeutic resource with better cost-benefit for patients unable to perform dynamic exercises, such as patients at an early stage of rehabilitation.

2. Methods

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement for reporting systematic review analysis (Liberati et al., 2009). Moreover, to assist and systematize the search and data extraction, a standardized electronic tool, called State of the Art through Systematic Review (StArt) (Fabbri et al., 2016) was used (Available from: http://lapes.dc.ufscar.br/tools/start_tool).

2.1. Data sources and search strategy

A literature search was performed in the following electronic databases: MEDLINE 1946 – present with daily updates (Ovid), PEDro (Physiotherapy Evidence Database), SCOPUS (Elsevier) and PubMed (via National Library of Medicine). The following MeSH terms or keywords were used for the intervention type (respiratory muscle training AND inspiratory) and outcomes (blood pressure OR heart rate). Furthermore, the search was limited to humans (population of interest) and the English language. Finally, the additional limits were used: clinical study, clinical trial, controlled clinical trial and randomized clinical trial. The literature search was carried out from inception to March 13th, 2017.

2.2. Eligibility and exclusion criteria

The eligibility criteria to select studies were: (1) the primary objective should be related to the effects of inspiratory muscle training on the cardiovascular autonomic nervous system, and (2) randomized and non-randomized clinical trials with and without the control group. Exclusion criteria were reviews, short communications, letters, case studies, guidelines, theses, dissertations, qualitative studies, scientific conference abstracts, studies on animals, non-English language articles and articles addressing other breathing techniques (expiratory muscle training, yoga, controlled breathing and meditation).

2.3. Selecting the studies

Two independent reviewers (P.·Rehder-Santos and R.M. Abreu) selected the studies according to the inclusion and exclusion criteria. Initially, the papers were screened considering the title and abstract, and when potentially eligible, they were selected for full-text evaluation. If there were some disagreements between these reviewers, a third independent reviewer (V. Minatel) was consulted. In addition, authors were contacted when the articles were not available. References of articles selected were verified in order to search for other relevant studies for reviews.

2.4. Data extraction and quality assessment

From each selected study, the following data were extracted: (1) characteristics of participants and groups (population, sample size, groups, gender, age, peak oxygen consumption and MIP at baseline); (2) characteristics of intervention (type of inspiratory resistor type, start intensity, progression of intensity, number of sessions, session duration, intervention time, supervised intervention and description of sham and/ or control groups); and (3) measurements and main outcomes related to the effects of IMT on cardiovascular autonomic control, represented by HRV and BPV indexes.

Frequency domain indexes consist of decomposition of RR interval time series (RRi) in oscillatory components through the spectral analysis that considers the reciprocity of the two branches of the autonomic nervous system (ANS). The main components are expressed in absolute values (abs) and in normalized unit data (nu). The low frequency absolute values (LFabs) are modulated by both sympathetic and parasympathetic outflows with a predominance of sympathetic (Akselrod et al., 1981), as well as other factors, including baroreceptor activity (Pagani et al., 1986); a low frequency normalized unit (LFnu) is an indicator of sympathetic predominance, and high frequency (HFabs and HFnu) corresponds to parasympathetic modulation (Akselrod et al., 1981; Malliani et al., 1991; Task Force, 1996; Pagani et al., 1986). Approaches in time domain, such as the RMSM of the RRi reflects the overall cardiovascular modulation, i.e., joint action of the sympathetic and parasympathetic modulation; while RMSSD reflect the parasympathetic modulation of the ANS (Task Force, 1996).

All articles included were assessed for methodological quality using the PEDro scale (Moseley et al., 2000). The scales include 11 questions (criteria), however the first criterion (specifying the origin of the subject and eligibility criteria) does not receive any score. Thus, the maximum score of scale is 10 points. The total score was grouped into three levels: good (7 to 10), fair (4 to 6) and poor (0 to 3). Other criteria evaluated by scale include: (2) random allocation, (3) concealed allocation, (4) comparison at baseline, (5) blind participant, (6) blind therapist, (7) blind assessor, (8) key outcome measures > 85% participants (9) intention-to-treat analysis, (10) between group statistical analysis, and (11) variability measures. The articles were classified independently by two researchers (P. Rehder-Santos and R.M. Abreu). When there any disagreement, the researchers discussed the matter to obtain a consensus between them concerning the final score.

3. Results

A total of 729 articles were identified through a database search (SCOPUS = 40, PubMed = 72, MEDLINE = 608, PEDro = 9). No additional records were identified from other sources. Out of the 718 articles screened after duplicates were removed, six articles (full text) were selected for reading and all of them fulfilled the inclusion criteria of this review (Fig. 1).