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Effects of inspiratory muscle training on autonomic control: systematic review

Efeitos do treinamento muscular inspiratório no controle autonômico: revisão sistemática

Los efectos del entrenamiento muscular inspiratorio en el control autonómico: la revisión sistemática

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ABSTRACT | The autonomic nervous system dysfunction has an important role on the physiopathology of some diseases. A possible option to improve the autonomic control is the inspiratory muscle training (IMT). The aim of this study was to systematically review the available literature about the effects of this training modality on autonomic control. A search was performed for controlled and randomized clinical trials on database MEDLINE, PEDro, SciELO and LILACS by two independent reviewers, who also evaluated the methodologic quality (PEDro scale). 181 articles were found and, after elegibility criteria analysis, four studies were included. The included studies showed good methodological quality and assessed the effect of IMT on the autonomic control of participants with risk factors for cardiovascular disease. The autonomic control was evaluated by heart rate variability (HRV) analysis and by noradrenaline plasma levels. The IMT improved autonomic control in 3 studies, reducing the sympathetic nervous system (noradrenaline plasma levels; LF nu – HRV) and increasing the vagal nervous system (HF un – HRV). It is concluded that IMT may be a therapeutic alternative to improve the autonomic control.

Keywords | Breathing Exercises; Exercise; Autonomic Nervous System; Physiopathology.

RESUMO | A disfunção do sistema nervoso autônomo tem papel importante na fisiopatologia de diversas doenças. Uma possível maneira de melhorar o controle autonômico é o treinamento muscular inspiratório (TMI), sendo o objetivo deste estudo revisar sistematicamente a literatura disponível sobre os efeitos desta modalidade. Dois revisores buscaram ensaios clínicos controlados e randomizados nas bases de dados MEDLINE, PEDro, SciELO e LILACS, avaliando também sua qualidade metodológica (escala de PEDro). Foram encontrados 181 artigos e, após verificar os critérios de elegibilidade, foram incluídos quatro pesquisas que avaliaram o efeito do TMI sobre o controle autonômico de participantes com fatores de risco para doenças cardiovasculares, por meio da variabilidade da frequência cardíaca (VFC) e dos níveis plasmáticos de noradrenalina. O TMI melhorou o controle autonômico em três estudos, reduzindo a atividade nervosa simpática (níveis plasmáticos de noradrenalina; LF u.n. – VFC) e aumentando a atividade nervosa vagal (HF u.n. – VFC). Conclui-se que o TMI parece ser uma alternativa terapêutica para melhorar o controle autonômico.

Descritores | Exercícios Respiratórios; Exercício; Sistema Nervoso Autônomo; Fisiopatologia.

RESUMEN | La disfunción del sistema nervioso autonómico tiene el papel importante en la fisiopatología de diversas enfermedades. Una posible manera de mejorar el control autonómico es el entrenamiento muscular inspiratorio (TMI), siendo el objetivo del presente estudio revisar sistemáticamente la literatura disponible sobre los efectos de esta modalidad de entrenamiento sobre la función autonómica. Ha sido realizada la búsqueda por ensayos

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clínicos controlados y aleatorizados en las bases de datos MEDLINE, PEDro, SciELO y LILACS por dos revisores independientes, que también han evaluado la cualidad metodológica (escala de PEDro). Han sido encontrados 181 artículos y, después de certificar los criterios de elegibilidad, han sido incluidos cuatro estudios. Los estudios que han sido incluidos han presentado buena cualidad metodológica y han evaluado el efecto del TMI sobre el control autonómico de los participantes con factores de riesgo para las enfermedades cardiovasculares. El control autonómico ha sido evaluado por el análisis de la variabilidad de la frecuencia cardíaca (VFC) y por medio de los niveles plasmáticos de noradrenalina. El TMI ha mejorado el control autonómico en tres estudios, reduciendo la actividad nerviosa simpática (los niveles plasmáticos de noradrenalina; LF u.n. – VFC) e incrementando la actividad nerviosa vagal (HF u.n. – VFC). Se concluye que el TMI parece ser alternativa terapéutica para mejorar el control autonómico.
Palabras clave | Ejercicios Respiratorios; Ejercicio; Sistema Nervioso Autónomo; Fisiopatología.

INTRODUCTION

The autonomic nervous system (ANS) works on the control of human physiological homeostatic mechanisms, at every moment, through its sympathetic and vagal branches[1]. Its operation can be assessed by invasive and non-invasive methods, most commonly through measuring circulating plasma catecholamines, muscle sympathetic nervous activity, baroreflex sensitivity, heart rate variability (HRV), and arterial pressure[2].

ANS disfunction can adversely affect health, being associated to the physiopathology of cardiac, metabolic, and lung diseases, such as arterial hypertension[3], heart failure[4], diabetes mellitus[5], and chronic obstructive pulmonary disease[6]. In this sense, many studies have been developed aiming to investigate the effect of therapeutic measures that can revert the autonomic alterations[7] and, consequently, reduce the morbimortality risk for these populations.

In the context of non-pharmacologic treatments, it is well stablished in literature that changing into healthy life habits can improve the autonomic function, such as adopting food patterns and practicing aerobic exercises regularly[8]. Besides, inspiratory muscle training (IMT) is another modality of physical training that had been indicated as an adjuvant therapy in the control of many diseases, having, in some cases, positive responses in the ANS[9,10]. The IMT consists on performing inspirations against a resistance through many mechanisms, it is an easily applied and low-cost intervention, which is also considered clinically significant in the rehabilitation scenario[11]. Studies with different populations point out the improvement of inspiratory muscle force after performing the IMT[9-15]. In addition, functional capacity and blood pressure also seem to be favored by this training modality[9,13]. Considering that the IMT promotes the increase in the respiratory metaboreflex activation threshold and that changes in the respiratory pattern encourage baroreflex activity, it is believed that improving the autonomic control may be one of the physiologic mechanisms for such results[13,16,17]. However, the studies assessing IMT effects on the autonomic function were performed with heterogenous samples and diverse methodology, making it important to assess these studies' level of evidence and the effectiveness of applying the IMT on the ANS. Thus, this study's aim was to systematically review evidences pointing out the effects of inspiratory muscle training on the autonomic function.

METHODOLOGY

The systematic review study was performed according to the guidelines by the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA)[18].

A search in the databases MEDLINE, PEDro, SciELO, and LILACS was performed and included articles published until January 2017, written in Portuguese and English. We also adopted as inclusion criteria articles with randomized controlled trials (RCT) and that used the IMT as intervention.

The strategy for searching in the database was as follows: the intervention descriptors "breathing exercises" or "inspiratory muscle training" or "respiratory muscle training" were associated to the outcome descriptors "autonomic nervous system" or "sympathetic nervous system" or "parasympathetic nervous system" or "baroreflex" or "heart rate variability" or "autonomic function" or "autonomic control".

Articles that performed IMT associated to another physical therapy technique or to aerobic/resistance

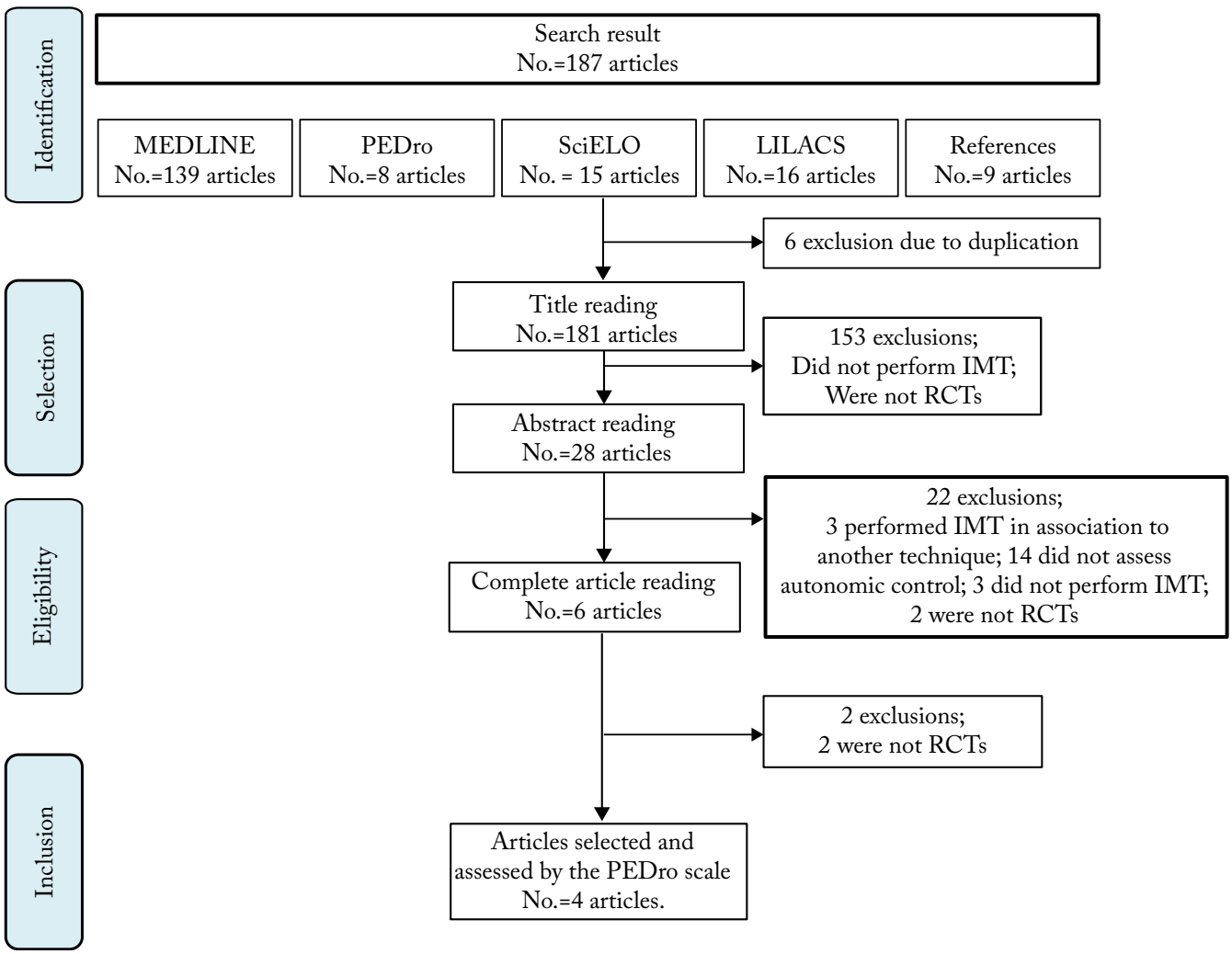
physical training were excluded, besides the ones that did not describe the training protocol in detail .

Article search and selection was performed by two independent reviewers (LBA and MBS), and disagreements during the process were decided through consensus. Initially, the titles of the studies were read and the ones mentioning IMT and autonomic nervous system were selected. Later on, the abstracts were read in order to identify the previously stablished inclusion and exclusion criteria. A search for other articles based on the references of the selected studies was also performed. Following, the selected articles were read entirely to extract interest data for the review and final evaluation of the study by the PEDro scale. This scale has 11 criteria and aims to assess the RCT quality. The studies evaluated by the PEDro scale may score from 1 to 10, given that the criteria number 1 is not added to the score.

OUTCOMES

Description of the study search and systematic review

The initial search selected 178 articles found in the databases, and six articles were excluded for being duplicated. Other nine articles from another source were selected, based on the references of the articles elected for complete reading. Therefore, the search selected 181 articles for title reading. From them, 153 were excluded after reading the titles and, sequentially, 22 other were excluded after reading the abstracts. Thus, six articles were considered eligible for the complete reading. Two of those were excluded due to the study's outline. By the end, four articles were considered for the current systematic review (Figure 1).



IMT: inspiratory muscle training; RCT: randomized controlled trial.

Figure 1. Flowchart of the article search and selection.

Studies' characteristics

All selected studies have verified the IMT effects on the experimental group, comparing it to the control group, which performed the same training protocol, but without the resistance load or with the minimum resistance load offered by the mechanism used. The articles were assessed regarding the methodological quality, as indicated in Table 1, and scored 4[14] or 6[12,13,15].

The included studies observed the IMT effects performed with linear load on the autonomic control of patients with risk factors for cardiovascular diseases. The total evaluated sample gathered 72 patients, aging, in average, between 55 and 65 years-old (Table 2).

Autonomic modulation was assessed in three studies by the indirect HRV technique[12-14] and in another study by dosing plasmatic levels of plasma catecholamines[15].

The description of IMT protocols performed in each study is presented in Table 3.

Table 1. Methodological quality of the studies based on the PEDro scale.

Articles evaluated	Criteria											
	1	2	3	4	5	6	7	8	9	10	11	Total
Corrêa et al., 2011[12]	✓	✓		✓	✓		✓			✓	✓	6/10
Ferreira et al., 2013[13]	✓	✓	✓	✓	✓					✓	✓	6/10
Kaminski et al., 2015[14]	✓	✓			✓					✓	✓	4/10
Vranish et al., 2016[15]	✓	✓		✓	✓			✓		✓	✓	6/10

Criteria: 1: specified eligibility criteria; 2: randomized alocation; 3:secret alocation; 4: comparison of basal characteristics; 5: blind subject; 6: blind therapists; 7: blind evaluators; 8: subject follow-up description; 9: treatment intention analysis; 10: inter-group comparison; 11: variability and precision measurement. Item 1 does not contribute to the total score.

Table 2. Included studies' characteristics.

Study	Studied sample (diagnosis; age; sex)	No.	Measure used to assess autonomic control	Result
Corrêa et al.[12]	Diabetes Mellitus type 2 with inspiratory muscle weakness; 63.0 years-old; 48% men.	Total=25 EG=12 CG=13	HRV assessed for 24 hours (time domain) and for 5 minutes during rest and after passive postural maneuver (frequency domain).	No changes in cardiac autonomic control were observed.
Ferreira et al.[13]	Essential hypertension; 56.9 years-old; 38% men.	Total=13 EG=6 CG=7	HRV assessed in a short interval (frequency domain).	LF and HF spectral bands, in normalized unites, have reduced and increased, respectively, only in the EG, differing from CG.
Kaminski et al.[14]	Diabetic autonomic neuropathy; 55.5 years-old; participant gender was not reported.	Total=10 EG=5 CG=5	HRV assessed in a short interval (frequency and time domain).	LF spectral band, in normalized units, reduced only in the EG.
Vranish et al.[15]	Obstructive sleep apnea; 65.3 years-old; participant gender was not reported.	Total=24 EG=12 CG=12	Circulating plasma catecholamines.	Noradrenaline levels reduced only in the EG.

EG: experiment group; CG: control group; HRV: heart rate variability; LF: low frequency band of the potency spectral density; HF: high frequency band of the potency spectral density.

Table 3. Characteristics of the inspiratory muscle training performed with the EG.

Study	Intensity (% MIP)	Duration/ repetitions	Frequency (days/week)	Duration (weeks)	Supervision (days/weeks)
Corrêa et al.[12]	30	30 minutes	7	8	Yes (1)
Ferreira et al.[13]	30	30 minutes	7	8	Yes (1)
Kaminski et al.[14]	30	30 minutes	7	8	Yes (1)
Vranish et al.[15]	75	30 repetitions	7	6	Yes (1)

EG: experiment group; MIP: maximal inspiratory pressure.

IMT effects on autonomic control

In three studies, the IMT improved autonomic control[13-15]. From them, one observed the reduction of sympathetic nervous activity (SNA), evinced by the reduction of noradrenaline blood levels after the training period[15]. Two other studies have showed an increased in vagal modulation[13] and reduction in the SNA[13,14], which were pointed out, respectively, by the increase in spectral density in the high frequency band and by the reduction of low frequency band assessed by the HFV (Table 2). In one study[12], no changes in autonomic control assessed by HFV measurements with the performance of IMT were observed (Table 2).

DISCUSSION

This was the first study to systematically review the effects of IMT on ANS. The selected studies have showed that this training modality, which firstly aims to improve inspiratory muscle strength and resistance, is also capable of promoting benefits on the autonomic control, specially on risk factors for cardiovascular diseases.

It is known that autonomic disfunction is a striking characteristic in the physiopathologic path of cardiovascular diseases[3-6]. Because of that, measures that can revert or lessen these alterations deserve to be highlighted, among them is the aerobic training[19] and, as aforementioned, IMT. Indeed, many studies in this review pointed out the improvement of autonomic control with IMT, regardless of prescription or the manner of evaluating the ANS. Besides, one of the studies[10] that were excluded form this systematic review, for not being a RCT, has assessed the IMT effect on SNA through microneurography in heart failure patients. Although the study was not selected for this review, we considered its finding significant, pointing to a reduction in the number of sympathetic bursts after the intervention.

Corrêa et al.[12] did not observe positive effects of IMT on the autonomic control of mellitus diabetes type 2 patients and weakness in the respiratory musculature. On the other hand, Kaminski et al.[14] have verified that IMT improved the ANS action on patients with the same disease, but with no diagnosis of respiratory muscle weakness. Unlike the interaction between inspiratory muscle weakness and IMT for the maximal inspiratory pressure (MIP) outcome, which indicates that the lower the pre-intervention MIP is, the higher the improvement observed after the training[21,22], possibly, for these patients with bigger respiratory muscle force damage, the intensity and time of IMT application may have been insufficient to create the positive autonomic adaptations observed in other populations.

We observed that most selected studies[12-14] have applied IMT protocols at 30% of the MIP for 30 minutes daily, for eight weeks. Many other works have shown that this training protocol promotes not only improvements in the respiratory muscle resistance and strength, but also in the functional capacity and quality of life of chronic disease patients[9,22]. These protocols, with more repetitions and less intensity, seem to elicit less exacerbated hemodynamic responses during the inspiratory muscle exercise, offering more safety for cardiovascular patients. In fact, Dempsey et al.[23] have verified that inspiratory muscle exercise, when done in high intensity, may cause inspiratory muscle fatigue, causing an abrupt increase in the SNA. Considering that the SNA increase is related to an increase in the myocardium operation, in peripheral vascular resistance, and in arterial pressure[24], in high intensities, the patients would be exposed to higher risk of acute cardiovascular events.

On the other hand, one of the analyzed works[15] has applied IMT with high intensity (75% of MIP) and short sessions (30 respirations) in patients with sleep apnea. Still, the authors reported favorable outcomes on the ANS operation. However, it has been already demonstrated that a single session of this exercise modality with high loads caused higher SNA and less parasympathetic activation when compared to the session with lower loads in healthy elderly individuals[25,26], which may confer higher cardiovascular risk to the patients. Thus, new studies should clarify the acute and chronic physiological effects of IMT with high loads and/or high intensity for different populations.

Probable mechanisms that justify the improve in autonomic control with IMT are outside this review's scope. However, it is possible to speculate about some justifications: 1) improvement in peripheral reflexes altered by chronic diseases. The improvement in inspiratory muscle force increases the resistance to fatigue, reducing the release of metabolites by these muscles, which can lessen the stimulus to the respiratory metaboreflex[16]. For animals, it has also been verified an improvement in the sensibility of baroreceptors as a response to the IMT program[27]. Still, the cardiopulmonary reflex, known as vagal "brake", can be stimulated by the increase in pulmonary volume obtained by the sustained inspiration

performed during the IMT[28]; 2) influence of respiration on controlling SNA. The proximity and the neural connections between the cardiovascular and respiratory centers were already described, so that interventions that work on respiratory control may cause responses in cardiovascular variables[29,30].

This study's results should be carefully interpreted, once they present some limitations. Notably, the sample sizes of the studies included in the review, specially of those that used the HRV as an evaluation method, can be considered small. Besides, the heterogeneity in the participants' characteristics makes it difficult to generalize the results for other populations, specially those with respiratory muscle weakness. Lastly, only one study has investigated the effect of IMT prescribed by series and repetitions, making it difficult to draw conclusion on the best indicated protocol for the improvement of autonomic control. Therefore, we suggest that new RCT be performed with different sample characteristics, on participants with and without respiratory muscle weakness and through different IMT prescriptions.

The findings pointing out improvement in the autonomic control are specially significant, since there is evidence showing that, besides the participation of autonomic disfunction in the physiopathology of many diseases, as arterial hypertension[3], autonomic unbalance confers a worse prognosis to individuals[31-34]. It is known that SNA has a toxic effect to the heart, causing cardiomyocyte programed death and increase in the myocardium work[35], while the parasympathetic activity confers a cardioprotective effect[36]. Thus, individuals with autonomic disfunction have higher risks of cardiac decompensation[33] and sudden death[34], and interventions that may enable improvements in this scenario are specially beneficial to these patients' health, representing a relevant implication for clinical practice. In this sense, the most recent guidelines for treating cardiovascular diseases point out IMT as an alternative for the process of cardiovascular rehabilitation[37].

CONCLUDING REMARKS

We have concluded that IMT seems to improve cardiac autonomic and systemic control, specially for cardiovascular patients. It is evident that the heterogeneity in the prescription of IMT may affect the autonomic benefits promoted by this training, being essential to perform new studies on this theme.

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