

Influence of resistance training on cardiac autonomic modulation: literature review

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Among the benefits provided by resistance training, its influence on cardiac autonomic modulation draws attention, given the importance of the autonomic nervous system in the control of the internal functions of the body. The objective of this narrative review was to gather information about the effects of resistance training on autonomic modulation in healthy young adults, assessed through heart rate variability. This search was performed in May 2013 in the following databases: Medical Literature Analysis and Retrieval System Online (MEDLINE/PubMed), Physiotherapy Evidence Database (PEDro), Scientific Electronic Library Online (SciELO) and Literature and Latin American and Caribbean Health Sciences (LILACS), with articles published between January 2003 and March 2013. The keywords used were: “resistance training,” “lifting,” “exercise therapy” cross-referenced with “autonomic nervous system” and “parasympathetic nervous system” and also the term “heart rate variability”. Of the 1,940 titles found, 3 complete articles were selected to compose the review. Data were analyzed qualitatively. The analysis of these studies suggests that resistance training can change the heart rate variability indices in the population of healthy young adults and that this change is due to increased vagal activity, provided by the practice of this type of training.

KEYWORDS: Resistance training; Exercise therapy; Autonomic nervous system; Parasympathetic nervous system.

Barbosa MPCR, Silva AKF, Bernardo AFB, Souza NM, Junior JN, Pastre CM, Vanderlei LCM. Influence of resistance training on cardiac autonomic modulation: literature review. MEDICALEXPRESS. 2014 Oct;1(5):284-288.

Received for publication on July 28 2014; First review completed on August 13 2014; Accepted for publication on September 6 2014

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■ INTRODUCTION

Resistance training involving exercises in which voluntary contractions of skeletal muscles of a given body segment occur against some external resistance¹ is currently recommended by several medical organizations for health promotion as well as for primary and secondary prevention of cardiovascular diseases.^{2,3}

When performed regularly and in a systematic way this type of training promotes, among other benefits, increases in muscle strength and mass, increased bone mineral density and basal metabolic rate, helping to maintain body weight and improving quality of life.^{2,4} Furthermore, when incorporated into a comprehensive program of fitness it is also capable of promoting weight loss, increasing the sense of well-being, preserving functional capacity and improving cardiovascular function and cardiac autonomic modulation.^{5,6}

Among the benefits provided by resistance training, its influence on cardiac autonomic modulation draws our attention because the autonomic nervous system controls some of the internal functions of the body and, accordingly, deserves detailed attention in interpreting the findings.

One way of assessing autonomic modulation is heart rate variability (HRV), a simple and non-invasive technique which describes the fluctuations in the intervals between consecutive heart beats (R-R interval), demonstrating the influence of the autonomic nervous system on the sinus node.^{7,8} This technique has been widely used to understand the phenomena involved in the autonomic nervous system in normal and pathological conditions.⁹

While recognizing the importance of the autonomic nervous system to the organism, studies that describe the effects of resistance training on autonomic modulation are scarce when it comes to resistance training in a healthy young adult population.

Therefore, this review aimed to collect information on the effects of resistance training on autonomic modulation in healthy young adults, evaluated through HRV, in order to enhance elements in the literature and contribute to a better understanding of this topic by researchers and professionals working with this population.

■ METHODS

Search strategy

This is an update of the literature with articles selected in May 2013, from queries to the databases *Medical Literature*

DOI: 10.5935/MedicalExpress.2014.05.13

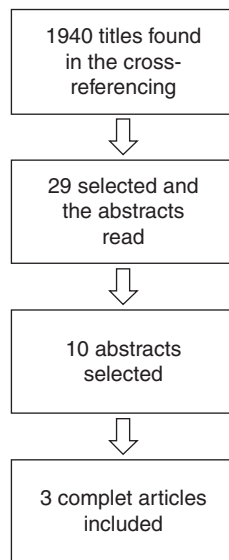


Figure 1 - Flowchart of the strategy for selecting the articles.

Analysis and Retrieval System Online (MedLine/Pubmed), Physiotherapy Evidence Database (PEDro), Scientific Electronic Library Online (SciELO) and Literature and Latin American and Caribbean Health Sciences (LILACS), with articles published between January 2003 and March 2013.

For the search the following keywords were used: “resistance training”, “lifting”, “exercise therapy” cross-referenced using the Boolean operator “and”, with the descriptors “autonomic nervous system” and “parasympathetic nervous system”, which were defined based on the *Medical Subject Headings (MeSH)* and their counterparts in the Portuguese language, *Descritores em Ciências da Saúde (DeCS)*. Additionally, the term “heart rate variability” was used, which, although not considered a descriptor by the MeSH, was included because of its wide use as a keyword.

All references from the selected studies were also reviewed to complement the research. The entire search was performed by a single co-author (MPCRB), with the supervision of a senior co-author (LCMV).

Inclusion and exclusion criteria

We selected studies performed on young adult humans (between 18 and 45 years), who did not present any kind of disease or abnormal physiological conditions and who had performed some type of resistance training. We restricted the search to articles published in the ten preceding years in both English and Portuguese. Randomized and nonrandomized clinical trials, available as free text on the internet, were included.

The following were excluded: letters to editors; abstracts; dissertations or academic theses; studies performed on animals, children, adolescents, elderly, or individuals with any type of pathology; studies which only evaluated the acute effect of exercise after a session of resistance training or even training that combined resistance with aerobic exercise.

Selection strategies

For the selection of articles, an initial screening of titles related to the subjects cited above was performed. This selection was based on titles which addressed the effects of

resistance training on the autonomic nervous system, which referred to the idea of resistance training and autonomic evaluation or contained information relating to the words “heart rate variability”, “autonomic control” and “training”. At the end of the search the repeated titles, which were held in various databases, were excluded.

The next step was the detailed reading of the article summaries in order to select those that exclusively addressed the effects of resistance training on the autonomic nervous system, assessed through heart rate variability in healthy adults. After excluding the abstracts which did not deal with the issue, the full texts were evaluated and those which did not fit the exclusion criteria were included in the final result of the search.

Data Analysis

The data were analyzed qualitatively and presented in table form with a description of the following characteristics: author and year, characteristics of the population/groups, the assessment tool/collection position/training protocol used, HRV indices assessed and conclusions found.

■ RESULTS

The search in the databases, through the selected descriptors resulted in 1,940 articles: 1,662 from the PubMed database, 264 from SciELO, 12 from PEDro and one article from the Lilacs database. The articles were submitted to the selection strategies for eligibility in this study as shown in Figure 1.

Three articles were selected, which were read in their entirety and composed this update as shown in Table 1. Of the three articles included, two used an electrocardiogram^{10,11} to capture the series of R-R intervals and one used the Suunto T6 Wristop heart rate monitor.¹²

■ DISCUSSION

The results of the articles selected for this review indicated that resistance training improves cardiac autonomic function, assessed through HRV. In general terms, two of the three articles evaluated found a statistically significant improvement in at least one HRV index after resistance training.

Heffernan et al.¹¹ observed 39 healthy adult men, divided into 2 groups: African-American group (18 volunteers) and Caucasian group (21 volunteers), and found that 6 weeks of training sessions performed for 60 minutes, three days per week brought improvements in cardiac autonomic function. The protocol used for resistance training was divided into two stages and applied on alternate days: one of the stages worked muscles in the legs, back and biceps, and the other the muscles in the chest, shoulders and triceps. Each session consisted of five exercises.

From the R-R intervals series captured using an ECG recording during 15-min of rest in the supine position, Heffernan et al. found no statistically significant differences between the indices in (a) the time domain, determined through RMSSD (the square root of the mean square of differences between adjacent normal R-R intervals and pNN50, the percentage of adjacent R-R intervals with a

Table 1 - Description of the characteristics of the population, evaluation instrument, collection position, training protocol, indices evaluated and the conclusions of the three articles selected for this study.

Author and year	Characteristics of the population/groups	Evaluation instrument /collection position/ training protocol	Evaluated Indices	Conclusions
Cooke & Carter, 2005	22 volunteers divided into 2 groups: Resistance exercise group: 12 volunteers (11 men; 21 ± 0.3 years; 82 ± 0.4 Kg; 180 ± 0.2 cm; Control group (without exercise): 10 volunteers (7 men; 22 ± 0.7 years; 78 ± 6 Kg; 176 ± 4.3 cm)	EKG; 5 minutes at rest breathing spontaneously; 3 x a week (~45 min) for 8 weeks	SDNN; LF(ms ²); HF(ms ²); LF(n.u.); HF(n.u.)	Resistance training for the whole body increased muscle strength and reduced resting blood pressure, but did not increase vagal autonomic activity
Heffernan et al., 2009	39 men divided into 2 groups: 18 African-American individuals (22 ± 1 years; 88.0 ± 4.4 Kg; 27.3 ± 1.2 Kg/m ²); 21 Caucasian individuals (24 ± 1 years; 85.4 ± 4.3 Kg; 26.6 ± 1.0 Kg/m ²)	EKG; 15 minutes in silence at rest in the supine position; 3 x a week (~60 min) for 6 weeks +4 weeks of detraining	RMSSD; pNN50; LF(ms ²); HF(ms ²); LF(n.u.); HF(n.u.); LF/HF; Sample Entropy	Resistance training improved cardiac autonomic function and reduced systemic inflammation (white cell count and C-reactive protein) in African-American men, but not in Caucasians. These adaptations remained after cessation of training (after 4 weeks of detraining).
Hu et al., 2009	69 volunteers between 20-45 years, divided into 2 strength training groups and a control group: 48 volunteers in the training groups (32 ± 2 years; 81.5 ± 10.2 Kg; 179 ± 4.8 cm); 21 volunteers in the control group (31 ± 7.5 years; 79.4 ± 9.7 Kg; 179.6 ± 6.7 cm)	Suunto T6 Wristop; During the entire VO ₂ max test; 2/3 x a week for 10 weeks	SD1; SD1n	Strength training increased the exercise capacity and improved vagal modulation of heart rate in intensity submaximal exercise in young and middle-aged men with low initial levels of physical activity

Abbreviations: Kg = kilograms; cm = centimeters; min = minutes; m² = meters squared; VO₂ max = maximum oxygen consumption; ECG = electrocardiogram; SDNN = standard deviation of all normal R-R intervals; LF = low frequency component; HF = high frequency component; LF/HF = ratio between the components of low and high frequency; n.u. = normalized unit; ms² = milliseconds squared; TP = total power in ms²; RMSSD = square root of the mean square of differences between adjacent normal R-R intervals; pNN50 = percentage of adjacent R-R intervals with a difference greater than 50ms; SD1 = standard deviation of the instantaneous beat-to-beat variability; SD1n = standard deviation of the instantaneous beat-to-beat variability in normalized units.

difference greater than 50 ms) or (b) through the frequency domain (LF = low frequency component, HF = high frequency component [in ms^2 and n.u.] and LF/HF ratio). However, when these same series were analyzed by the index sample entropy, a nonlinear analysis method, the series presented themselves as more complex, indicating that the training had improved cardiac autonomic function.

This result suggests that the nonlinear indices may have greater sensitivity to express the changes produced in the autonomic nervous system, even in subjects without autonomic dysfunctions. Studies show that the techniques of nonlinear analysis are capable of describing the processes generated by biological systems more efficiently when compared to linear techniques¹². Furthermore, there is evidence that the mechanisms involved in cardiovascular regulation interact with each other in a nonlinear way¹³.

Heffernan et al.¹¹ also observed that 4 weeks after the end of the training, in the African-American volunteer group, the entropy values of the sample remained above those found before the start of training.

In the study by Hu et al.,¹⁴ 69 volunteers were divided into 3 groups: two strength training groups and one no-training control group (physically inactive men who participated in regular physical activity no more than once per week during the past 3 years), divided according to their physical characteristics and level of physical activity. The trained groups performed progressive strength training for 10 weeks with a frequency of 2 or 3 sessions per week.

Before and after this trial, several evaluations were conducted, among which the $\text{VO}_{2\text{max}}$ test stands out. During the performance of these tests the R-R intervals series were quantitatively evaluated.

Elevations in both indices were observed in the trained groups in the $\text{VO}_{2\text{max}}$ test during submaximal exercise at an intensity of 100 Watts, while at other exercise intensities, performing the same test, no statistical difference was found. The elevations were observed soon after the initiation of the test, but as the exercise intensity increased during performance of the test, no increases were observed in the SD1 and SD1n indices.

This finding from the work of Hu et al.¹⁴ could be explained by the great amount of sympathetic activity that occurs during the $\text{VO}_{2\text{max}}$ test. At the beginning of the test, though this activity is still not high, it is still possible to observe increases in the SD1 and SD1n indices. However, when the individuals approach their maximum exercise intensity the sympathetic activity rises sharply, preventing an increase in the SD1 and SD1n indices, which reflects the activity of the parasympathetic component, because of this high level of sympathetic activation. Thus, the fact that no statistical differences were found in the moments following the intensity of 100 Watts is entirely understandable.

The only study in which none of the analyzed indices showed significant differences before or after resistance training was that of Cooke et al.¹⁰ which suggested that strength training did not affect the overall magnitude of vagal cardiac control at rest. The authors conducted training for 8 weeks, with a frequency of 3 weekly sessions of 45 minutes, which included both individual and multiple joint exercises, and observed no differences in the SDNN, LF (ms^2), HF (ms^2), LF (n.u.) or HF (n.u.) indices. The R-R intervals were captured on completion of training by means of an ECG during 5 minutes of rest breathing spontaneously.

In summary, the consolidation of these studies suggests that resistance training can change the HRV indices in the population of healthy young adults and that this change is due to increased vagal activity or preventing the high sympathetic activity, provided by the practice of this type of training. The fact that only some of the studied indices indicated an improvement in cardiac autonomic modulation may be related to the population studied. This is because a young healthy adult population, in theory, presented no autonomic dysfunction and had an intact autonomic nervous system.

ACKNOWLEDGEMENTS

Project supported by Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), Brazil.

All authors participated in all stages of the writing of this article.

RESUMO

Entre os benefícios promovidos pelo treinamento resistido, a sua influência sobre a modulação autonômica cardíaca nos chama a atenção, tendo em vista a importância do sistema nervoso autônomo (SNA) no controle das funções internas do organismo. O objetivo da presente revisão narrativa foi reunir informações a respeito dos efeitos do treinamento resistido sobre a modulação autonômica em adultos jovens saudáveis, avaliados por meio da variabilidade da frequência cardíaca (VFC). Para isso foram realizadas consultas em maio de 2013 nas bases de dados: *Medical Literature Analysis and Retrieval System Online* (MedLine/Pubmed), *Physiotherapy Evidence Database* (PEDro), *Scientific Electronic Library Online* (SciELO) e *Literatura Latino-Americana e do Caribe em Ciências da Saúde* (Lilacs), com artigos publicados no período de janeiro de 2003 a março de 2013; as palavras-chaves utilizadas foram: “resistance training”, “lifting”, “exercise therapy” em cruzamento “autonomic nervous system” e “parasympathetic nervous system” e também o termo “heart rate variability”. Dos 1940 títulos encontrados foram selecionados 3 artigos completos para compor esta revisão. Os dados foram analisados de forma qualitativa. A reunião desses estudos sugere que o treinamento resistido pode alterar os índices de VFC na população de adultos jovens saudáveis e que essa alteração ocorre em função do aumento da atividade vagal, proporcionado pela prática deste tipo de treinamento.

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