

## Cardiac Autonomic Modulation and High-Intensity Exercise

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### INTRODUCTION

Recently, new techniques of physical training focusing on health promotion and higher performance have been conveyed. So, the high intensity training been emphasized as an appropriate method to improve physical fitness and optimize cardiorespiratory and metabolic functions of the body. High intensity intermittent training comprises of work at high heart rate for a short period of time. In healthy adults, their oxygen consumption increases significantly<sup>[1]</sup>. Methods of resistive exercises are usually recommended to maintain good physiological health, while improving life quality and preventing chronic degenerative diseases<sup>[2]</sup>.

Heart rate variability (HRV) is considered an alternative method of analysis that provides strong indications of predisposition to develop cardiovascular diseases in individuals. These include cardiac ischemia, arrhythmias and risk factors that may lead to death. Reduction in HRV inevitably occurs with the passing of time, low HRV is considered an etiological state and it is persistently linked to mortality in elderly<sup>[3]</sup>. It is extensively described in the research literature that resistive exercises benefit the musculoskeletal and endocrine systems. Still, the clinical implications in the autonomic cardiac modulation of this brand of exercise are not fully elucidated. The high intensity training protects the autonomic cardiac control against aging, as elderly athletes show similar HRV indices as young adults<sup>[4]</sup>.

Identifying the precise disparities induced by high intensity exercise in HRV is of fundamental importance. Hence, many studies that analyzed the cardiac autonomic modulation through HRV in high intensity exercises were composed to better comprehend the autonomic nervous system modulation when presented with high overload. So, we aimed to describe the effect of the high intensity exercise protocols on cardiac autonomic modulation.

### ABSTRACT

**AIM:** Recently, many new ways of physical training focusing on health promotion and higher performance have been articulated. So, high intensity training has been spotlighted as the best way to improve physical aptitude and to optimize cardiorespiratory and metabolic functions. We intended to describe high intensity training protocols and their effects on cardiac autonomic regulation.

**METHODS:** The studies were selected in the databases PubMed, Medline, Scielo and Lilacs. The keywords cited were: Exercise, Autonomic Nervous System, Cardiovascular System, which were defined based on the MeSH.

**RESULTS:** The selected articles presented vagal withdrawal and increase in the sympathetic modulation during the exercise protocols. It highlighted cardiovascular overload and thus, increases in arterial pressure and heart rate, improving cardiovascular endurance over time.

**CONCLUSION:** The practice of exercise affects the cardiac autonomic modulation according to the level of intensity and volume advocated.

**Key words:** Autonomic Nervous System; Cardiovascular system; Exercise

## METHODS

The articles applied in this study were selected from the databases of PubMed, Medline, Scielo and Lilacs. For this search we applied the following keywords: Exercise, autonomic nervous system and cardiovascular system, which were defined as fundamental keywords in the health sciences (DeCS) and equally in the English language (MeSH).

These readings were gathered based on their titles, analyzed and selected according to the inclusion criteria. The title had to express high intensity exercise as its focus of study, and had to analyze the cardiac autonomic system through HRV. Afterwards, we filtered the results to identify repetitions, as the searches were made in multiple databases.

All the selected titles had their abstracts considered to retain only those that focused on the autonomic heart modulation during resistive exercise. The selected abstracts were re-analyzed to identify relevant studies that were not found in the primary search (between 2003 and 2014).

For the evaluation of the studies' quality, we applied the PEDro scale on the manuscript presented in Table 1. The British Journal of Sports Medicine has published editorials regarding PEDro scale, supporting its use<sup>[5-7]</sup>. They presented a summary of a systematic review indexed on PEDro.

According to the PEDro's information on the website <http://www.pedro.org.au/>: "PEDro is the Physiotherapy Evidence Database, which is an unrestricted database of over 32,000 randomized trials, systematic reviews and clinical practice guidelines in physiotherapy. For each trial, review or guideline, PEDro delivers the citation details, the abstract and a link to the full text, where conceivable. All trials on PEDro are independently quality assessed. These quality ratings are necessary to quickly guide users to trials that are more likely to be valid and to contain sufficient information to guide clinical practice. PEDro is produced by the Centre for Evidence-Based Physiotherapy at The George Institute for Global Health."

The points addressed by the PEDro scale include the following criteria accordingly which are assessed in [http://www.pedro.org.au/wp-content/uploads/PEDro\\_scale.pdf](http://www.pedro.org.au/wp-content/uploads/PEDro_scale.pdf): "eligibility criteria, randomization of subjects allocation, if allocation was concealed, characteristics concerning prognostic indicators, blinding of all

subjects, blinding of all therapists who administered the therapy, blinding of all assessors who measured at least one key outcome, if measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups, if all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analysed by "intention to treat", if the results of between-group statistical comparisons are reported for at least one key outcome, if the study provides both point measures and measures of variability for at least one key outcome". PEDro's scores ranges between 0 and 11 and we standardized only studies up to 6.

The data was described in a qualitative manner, and tabulated according to the authors, year of publication, characteristics of the population, study objective, observed variables and conclusions.

## RESULTS

### Search and strategy of selection

149 articles were established in the first search, we then eliminated 141 articles after a second analysis, and another 4 were eliminated for not attaining the required criteria.

### Characteristics of the studies selected

Table 1, organized by authors and year of publication displays the characteristics of the population, objectives, analyzed variables, PEDro scale score and their conclusions.

## DISCUSSION

The study of Currie *et al*<sup>[8]</sup> (2014) observed enhancement in the oxygen consumption after three months of endurance training at moderate intensity with HIIT. Nevertheless, there was no more increase in peak oxygen consumption at the 6th month in patients with coronary arterial disease. They recognized that the low volume of HIIT associated to resistive exercises with an elapsed time of 20 minutes had less total workload per session than when combined with endurance training for 30 to 50 minutes. Nonetheless, there was an improvement in both group's cardiorespiratory performance<sup>[8]</sup>.

Astorino *et al*<sup>[9]</sup> (2000) and Marzolini *et al*<sup>[10]</sup> (2012) observed that

**Table 1** Description of the studies.

Authors and year of publish	Characteristics of the population	Objectives	Analyzed Variables	PEDro Scale Score	Conclusion
Currie KD <i>et al</i> , 2014	Men and women (N=19) with coronary disease event.	To combine resistive training with HIIT or with medium to high intensity endurance training and analyze its effects in the health of the patients.	HR; VO2 max; BP; Power;	7	Resistive training with endurance training was more effective than resistive training with HIIT. However, some individuals were already more physically active than others which may have influenced the results.
Guiraud T <i>et al</i> , 2013	Patients with chronic heart failure (N=18).	To verify the benefits of HIIT in patients with stable heart failure.	HR; SDNN; RMSSD; pNN50;	6	HIIT is a safe and healthy method to improve the health of patients with heart failure. Their HRV and ventricular blood pump strength was also raised.
Martinmaki K, Rusko H, 2007	Healthy men (N=13) and women (N=13).	To analyze the behavior of the sympathetic and parasympathetic systems in the first two minutes after exercise in two groups: One after high intensity exercise, and one after low intensity exercise.	HR; LF; HF; VO2 max; HRV;	6	LFP e HFP remained raised longer and in more intensively after high intensity exercise. HF raised abruptly in the first and second minutes, suggesting quick vagal reactivation. HRV is a reliable method to monitor sudden changes in the autonomic control of HR.
Lima, AH <i>et al</i> , 2011	Healthy men between 18 and 25 years old (N=15), and that did not practice any significant physical exercise in the last 6 months.	To verify the effects of the sympathetic and parasympathetic modulations after upper limbs exercises.	BP; HR; LF; HF; LF/HF; Maximum RR interval.	6	Resistance exercises in the upper limbs improved autonomic function of the patients.

HR: Heart rate; VO2 max: maximum oxygen consumption; HIIT: High intensity training; SDNN: Standard deviation of consecutive normal RR intervals; RMSSD: Root-mean square of differences between adjacent normal RR intervals; pNN50: Percentage of adjacent RR intervals with a difference of duration greater than 50ms; LF: Low frequency; HF: High frequency; BP: Blood pressure.

resistive training associated with medium endurance training and HIIT improved cardiorespiratory capacity. Conversely, the study of Currie *et al.*<sup>[8]</sup> (2014) did not achieve significance after three months of resistive training. This may have occurred because in the study of Currie *et al.*<sup>[8]</sup> (2014) after the first three months, the patients reached their body's maximum peak oxygen consumption ( $\text{VO}_2$ ), and they would not be able to further improve it. Taking into account the changes in the quality of life, the endurance training with resistive training was capable of raising the overall health and physiological welfare. The blood pressure and heart rate were not significantly transformed during the 6 months in either exercising groups. The lipid profile in the blood stream did not vary either, except for the high density lipoprotein, which was elevated in the groups after 6 months of training<sup>[8]</sup>.

Plasma lipid levels were not changed with training in both groups, except for the high-density lipoprotein. This is because of the monitoring of patients five months before the physical training. The procedure of endurance in medium intensity consisted of continuous cycling between 51-65% of the maximum exertion in each individual. The protocol of HIIT involved 10 intermittent minutes of 1 to 85% of maximum potency (PPO) (interval of 75-93%), separated by cessations of one minute to 10% of PPO. The advancements of the exercise consisted in the elevation of the intensity each month to obtain the new ideal PPO. For the final three months, the HIIT group trained at 121% (between 100-152% of PPO), while the endurance group at 78% (60-91%) of PPO.

The resistive protocol after 3 months consisted of exercises in 2 sets, with 10 to 12 repetitions in the upper and lower limbs. The weight was established by the scale of Borg, in a score from 11 to 15<sup>[10-12]</sup>. Physical training improved the cardiorespiratory capacity in those cardiac patients. It is important to consider the weight load, intensity and duration of the training.

Guiraud *et al.*<sup>[13]</sup> (2013) revealed that HIIT is beneficial and benign due to the increase in the parasympathetic modulation associated with a lower HR and premature ventricular contraction. Compared to the continued exercise of moderate intensity and the initial triage, there were improvements in HRV. This effect continued for 24 hours after a single exercise session, denoting the importance of this type of intervention to reduce the risk of cardiovascular incidents in patients with heart failure. The reduction of HR post exercise in HIIT is due to vagal modulation, as seen in the increase of HF. These responses may be related to the levels of angiotensin 2 and nitric oxide. The physical training delivers the action of angiotensin 2, which inhibits the vagal modulation<sup>[14]</sup>.

Trained individuals have lower levels of renin plasmatic action, as a consequence of angiotensin 2 and, high values of parasympathetic modulation compared to sedentary individuals<sup>[15]</sup>. Nitric oxide has an important role in the vagal control, maximizing its action in the cardio-myocytes, while also inhibiting sympathetic activity<sup>[16,17]</sup>. The elevation in very low frequency (VLF) refers to thermoregulation and the fluctuation of the activity of the renin-angiotensin system and the function of peripheral chemoreceptors. The reduction of levels of angiotensin 2 raises VLF and improved vagal modulation<sup>[18]</sup>.

There was inconsistency between the endurance exercise of medium intensity and HIIT. Although the first presented a decrease of HF, HIIT had the contradictory effect, suggesting that the benefits on HRV are related to the intensity model of HIIT. The exercises were performed on a bicycle, each session consisted of a "warming up" for 2 minutes with 50% of PPO, followed by two sets of interval at 100% of PPO. Each interval was composed of repetitive strikes of 30 seconds at 100% PPO, bounded by 30 seconds of passive rest in the seated position<sup>[19]</sup>. Four minutes of rest between the two sets

was permissible, as well as one minute of rest with 25% of PPO 30 seconds after the last session of exercises<sup>[20]</sup>. It is essential to identify the most favorable length and intensity to promote the optimal HRV value, especially in heart disease patients<sup>[13]</sup>.

Martinmäki *et al.*<sup>[21]</sup> (2008) established an abrupt rise in HF in the first minute of rest post-exercise of low intensity with a reduction of HR. They advocated that this is because of a rapid vagal reactivation immediately after exercise<sup>[21]</sup>. Previously, studies illustrated that during the first minute of rest, the vagal system is the main reason of reduced HR, and this assertion is supported by other investigations of vagal activity established by methods of HRV analysis<sup>[22,23]</sup>. Martinmäki *et al.*<sup>[21]</sup> (2008) observed a simultaneous rise in LF and HF immediately at the commencement of rest<sup>[21]</sup>. LF and HF were higher during the first minute after LI (Low intensity exercise), but after HIIT, LF retained this elevation up to the third minute, and HF up to the second minute. They elucidated that this is since the vagal reactivation, and changes in the baroreflex sensibility which is lessened during exercises of high intensity and partially restored when initiating rest. Although HRV steadied, HR still lowered until after the second minute of rest post LI, and for several minutes' post HI. This may be explicated by the slow sympathetic reactivation. In summary, they established a greater influence on the intensity of the exercise in the LF and HF. They increased rapidly in the first minute post LI, and elevated for several minutes' post HI, however, LF and HF were greater in the LI than in HI during the rest period. Consequently, it is suggested that there is a rapid vagal reactivation and HR restoration in low intensity exercise and, this recovery is impaired when there is excessive metabolic stress.

Lima *et al.* confirmed that resistive exercise for the trunk and upper limbs raised the autonomic sympathetic modulation and lowered the parasympathetic cardiac modulation. The cardiac modulation was greater the more vigorous the exercise. After 1 hour at 70% of maximum workload, there was an increase in the sympathetic modulation and decrease in the parasympathetic component of HRV. These results advocate that regardless of the exercises (larger muscular groups, lower limbs, upper limbs or trunk); exercise sessions influence the cardiac autonomic modulation and was maintained for an extended period after the session<sup>[24]</sup>.

In addition, the authors reported that there was orthostatic stress in the control group caused by extensive periods in the seated position, reducing venous return and raising the activity in the peripheral sympathetic nervous. Furthermore, the session of resistive exercise leads to a larger decrease of venous return since there was no post-exercise hypotension. In the study of Rezk *et al.*<sup>[25]</sup> (2006), there were similar modifications in the cardiac autonomic modulation. Conversely, this controversy was possibly caused by the difference in the number of repetitions between the intensities in Rezk *et al.*<sup>[25]</sup> study (2006), which was not observed by Lima *et al.*<sup>[24,25]</sup>. Considering that individuals of the group of 70% of maximum exertion were close to fatigue which was not the case in the group of 50%. We may suggest that exhaustive resistive exercises result in a higher and longer sympathetic cardiac activation. This effect is possibly related to the higher vascular workload in vigorous exercises of high intensity, which promotes increase in the mechanoreceptors and activation of the metaboreflex due to the reduction of the blood flow.

Likewise, as a consequence it results in the deactivation of the cardiopulmonary receptors and increases HR. The resistive exercise for the trunk and upper limbs above 70% of maximum exertion represents an increase in cardiovascular risks, which is not observed at 50%, henceforth, the recommendation of exercises at 50% is the best choice to avoid risks in heart diseases patients. Still, this hypothesis still needs to be confirmed by future studies<sup>[24]</sup>.

## CONCLUSION

In this review, we offered important studies that aimed to clarify the effects of high intensity exercise on HRV. The practice of exercises affects the cardiac autonomic modulation according to the level of intensity and volume prescribed.

## CONFLICT OF INTERESTS

There are no conflicts of interest with regard to the present study.

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