REVIEW ARTICLE

Quantity of Aerobic Exercise Training for the Improvement of Heart Rate Variability in Older Adults

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Abstract

Cardiovascular autonomic markers such as cardiovagal baroreflex sensitivity (CBS) and heart rate variability (HRV) decline with the aging process. Aerobic training (AT) may be able to improve HRV, suggesting that AT can alter neuroregulatory control over the heart, improving autonomic markers and cardiac protection. Together, age and AT can influence HRV, but not revert the overall effects of aging on the decline of physical performance and HRV. The aim of this study was to review studies and describe the volume of AT necessary to produce modifications in HRV in elderly individuals. The review followed the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA). The articles selected were indexed in PubMed/MEDLINE, Lilacs and Scopus. The used keywords were "aging", "heart rate variability", "exercise" combined with the Boolean descriptors "AND" and "OR" with the synonyms "elderly", "cardiac autonomic modulation", "aerobic training" and "endurance training". The filters "languages", "humans", "age" and "clinical trial" were applied in the selection of the articles. Initially, 940 articles were found, PubMed (n = 729), Lilacs (n = 16) and Scopus (n = 195), filters and searches led to the 287 potential studies. The keyword combinations provided 24 articles that were in agreement with the inclusion criteria, and after full reading of the texts, 17 studies were excluded. From seven articles, four showed increases in HRV in response to AT. In an older population, 8 weeks of AT is enough to induce positive changes on HRV. However, longer exercise protocols and higher intensities also seem to have some influence.

Keywords

Exercise; Aging; Aged; Autonomic Nervous System; Heart Rate.

Introduction

Aging provokes changes in cardiovascular autonomic regulation, and a broad range of alterations in cardiovascular structure and function occurs as a part of the process.[1] Cardiovascular autonomic markers such as cardiovagal baroreflex sensitivity (CBS) and heart rate variability (HRV) decline with the aging process.[2,3] Experimental evidence indicates that CBS and HRV provide prognostic information regarding the risk of sudden cardiac death.[4,5] The spontaneous fluctuation of heart rate (HR) can be assessed by the spectral analysis of HR time series, known as HRV, which is a non-invasive and selective assessment of the sympathetic and parasympathetic contributions on cardiac autonomic regulation.[6,7] Through HRV, we can observe the natural consequence of aging and of physical fitness on cardiovascular function.[8]

In this sense, aerobic training (AT) is a broad mode of exercise practiced worldwide by the older population. For the elderly, AT induces a chronic bradycardia at rest accompanied by increased vagal-mediated HRV in healthy individuals.[8] In fact, AT may be able to exert an antiarrhythmic effect and other effects on RR interval because the higher frequency power (HF) of HRV, vagal modulation, suggests that aerobic exercise training can alter the neuroregulatory control over the heart.[8]

In addition to that, the effects of AT on RR interval are different between age groups. Older and middle

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age subjects showed different effects, which were common in magnitude for both on RR interval. They demonstrated a reduction in trainability of the heart and neural input with age.[8] A recent review of Sandercock et al.[8] demonstrated distinct results of several methods of HRV analysis, large differences in mean effect size and the lack of a control group. Other studies presented an improvement of HRV through many types of exercise, including aerobics, endurance, and force exercises, but responses were different when compared to the sedentary control group.[9]

Aging and AT can, together, influence HRV, although without reverting the overall effects of aging on the decline of physical performance and HRV. The aim of this study was to review studies and describe the volume of AT necessary to produce modifications in the HRV in elderly individuals.

Methods

Research strategy: The review followed the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA). The articles selected for this study were indexed in PubMed/MEDLINE, Lilacs and Scopus. The keywords used for the searched were "aging", "heart rate variability", "exercise" combined with the Boolean descriptors "AND" and "OR" with the synonyms "elderly", "cardiac autonomic modulation", "aerobic training" and "endurance training". The filters "languages", "humans", "age" and "clinical trial" were applied for the selection of the articles.

Inclusion criteria: We included articles in English, Portuguese and Spanish that did human clinical trials in middle-aged or elderly individuals undergoing AT protocol to compare their changes in HRV to that of a sedentary control group.

Exclusion criteria: We excluded preliminary studies, pilots, articles without AT protocol, without a sedentary control group, those that did not measure HRV in the time and frequency domains, that used drugs that could influence HRV, and those that included smokers and individuals with some types of diseases.

Study selection: These were the criteria analyzed in the selected articles: sex, age, and fitness, type of exercise, time, frequency and intensity of training. The methods and procedures for the measurement of HRV were: analyzed position, time and breathing in the test, technique used for spectral analysis and the variables in the time and frequency domains.

Results

Using this research strategy 940 articles were initially found: PubMed (n = 729), Lilacs (n = 16) and Scopus (n = 195). After we applied the filters, the research led to the identification of 287 potential studies to be included in the analysis. The combination of keywords yielded many irrelevant studies and only 24 of those met the inclusion criteria. Of the other papers, when analyzed to full text, 17 studies were excluded for not meeting the inclusion criteria, as show in Figure 1.

Table 1 describes the characteristics of the selected studies, volunteers and exercise protocols. There are five studies done with women, one with men and two with men and women. Age showed great variation, with individuals under and over 60 years of age. The studies used aerobic exercises like walking, jogging, cycling, rowing, step aerobics, treadmill, leg ergometer and dancing. Intensity had 50% to 85% variation of heart rate (HR) and maximum oxygen onsumption (VO2max). Duration of sessions observed a prevalence of periods of 40 minutes, and a frequency of three times per week. The period of exercise training was very different among the studies, varying between 8 to 36 weeks of training.

Table 2 shows the results of the review for changes in RR interval after exercise training. In the analysis of the duration, we compared five studies that measured SD of all R-R intervals (SDNN) and square root of the mean of the sum of the squares of differences between adjacent R-R intervals (rMSSD) before and after exercise training, and one study that analyzed RR interval standard deviation (SDRR), mean RR interval (RRi), coefficient of variation (CV), SD of SD (SDSD), NN50/20, RR intervals differing more than 50 ms (NN50), percentage value of NN50 intervals (PNN50), NN20 represents the RR intervals differing more than 20 ms (NN20), percentage value of NN20 intervals (PNN20). Regarding the analysis of the frequency domain, the studies compared high-frequency power (HF), low-frequency power (LF), LFnu, HFnu, total-frequency power (TP), sympathovagal balance (LF/HF) and VLF.

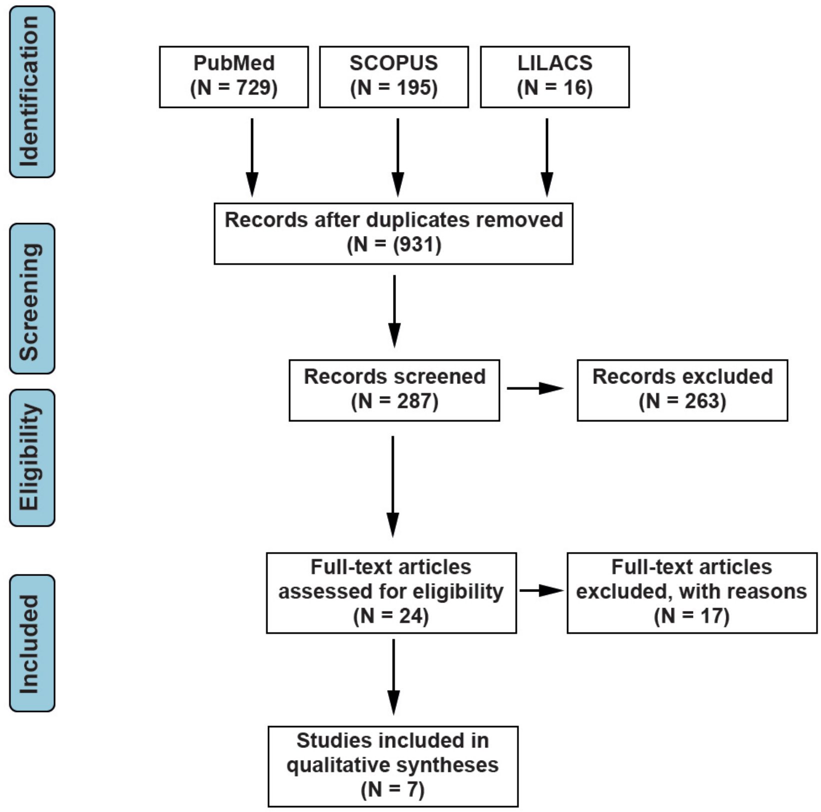

Figure 1 – *Shows de flow diagram of the researched literature.*

Table 1 – Variables in volunteers' and protocol of exercise training

Study	Age	Sex	Exercise	Intensity	Duration	Frequency	Period
Audette et.al. (2006)	≥ 65	female	walking	50-70% of HR	15 min of warm-up, 40 min of walking and 5 min of cool down	3x week	12 weeks
Jurca et.al. (2004)	56 ± 6	female	treadmill and a recumbent leg ergometer	50% of VO2max	165 min per week	3-4x week	8 weeks
Schuit et.al. (1999)	66.2 ± 4.2	female and male	walking, jogging, cycling, and rowing	60-70% of HR	45 to 60 min	5x week	24 weeks
Karavirta et.al. (2013)	40 a 65	female	bicycle ergometer	--	90 min	2x week	21 weeks
Monahan et.al. (2000)	57 a 79	male	walking	65-80% of HRR	40-50 min	5-7x week	12 weeks
Shen and Wen (2013)	58.48 ± 0.53	female	step-aerobics	75-85% HR	35-40 min	3x week	10 weeks
Wanderley et.al. (2013)	≥ 60	male and female	walking, step aerobics and dancing	70-80% of HR Reserve	10 min warm-up, 30 min aerobic, 10 min of cool down	7x week	32 weeks

HR: heart rate; HRR: heart rate reserve.

Table 2 – Effect of variables in RR interval after training

Study	Sample	Domain		Results	
		Time	Frequency	Time	Frequency
Audette et.al. (2006)	CG n = 8 EG n = 8	--	LF/LFnu, HF/HFnu, TP, LF/HF	--	↔LF/LFnu, ↔HF/HFnu, ↔TP, ↔LF/HF
Jurca et.al. (2004)	CG = 39 EG = 49	SDNN, rMSSD	LF/LFnu, HF/HFnu, TP	↑SDNN ↑rMSSD	↑LF ↑HF ↑TP
Schuit et.al. (1999)	CG = 16 EG = 16	SDNN, rMSSD	LF, HF, VLF	↑SDNN ↔rMSSD	↑LF ↔HF ↑VLF
Karavirta et.al. (2013)	CG n = 17 EG n = 26	SDNN, rMSSD	LF/LFnu, HF/HFnu, TP	Rest before and after 21 weeks. No statistically significant changes were observed	Rest before and after 21 weeks. No statistically significant changes not observed
Monahan et.al. (2000)	CG = 15 EG = 16 Endurance G = 15	SDRR, RRi	HF	↑SDRR ↑ RRi	↑HF
Shen and Wen (2013)	CG n = 30 EG = 32	RRmean, SDNN, CV, NN50, Pnn50, NN20, Pnn20, rMSSD, SDSD	LF, HF, TP, VLF, LF/HF	↓RRmean, ↓SDNN, ↓CV, ↓NN50,↓Pnn50, ↓NN20,↓Pnn20, ↓rMSSD, ↓SDSD	↓LF, ↑HF, ↓TP, ↓VLF, ↓LF/HF
Wanderley et.al. (2013)	CG = 10 EG = 20	SDRR	HF	↔SDRR	↔HF

CG: control group; EG: exercise group; EnduranceG: endurance group; ↔ : no significant; ↓: significant decrease; ↑: significant increase; LF: low frequency; VLF: very low frequency component; HF: High frequency component; LF/HF: sympathovagal balance; SDNN: standard deviation of normal to normal intervals; SD: standard deviation; TP: total power; CV: coefficient of variation; NN50 and NN20: number of consecutive RR intervals; Pnn50 and Pnn20: percentage value of NN50 intervals; rMSSD: root mean squared standard deviation; SD of SD (SDSD).

Discussion

The aim of this study was to review studies and describe the volume of aerobic exercise training necessary to produce modifications in the HRV in elderly individuals. Firstly, this systematic review described, with the included studies, that AT improves cardiac autonomic modulation in healthy elders. In this sense, the quantity of exercise to improve HRV was discussed. AT increases HRV after 8 weeks,[10] but after 10 weeks,[11] 12 weeks,[12] and 24 weeks[13] increases were also observed.

Jurca et al.[10] investigated the influence of aerobic exercise during 8 weeks, 3-4 days per weeks at 50% of VO2max. The exercise training group (n = 46, age= 56 ± 6) showed a significant increase in all vagal-HRV indeces. On the other hand, Shen and Wen showed a high effect of AT on HRV, but the exercise training protocol was longer (10 weeks) and more intense (75-85% VO2max).

Regarding the weekly volume, we did not find studies comparing different weekly volume protocols. The studies reviewed show similar weekly volumes with 5 days per week and 40-50 minutes per session[12] and with 5 days per week and 45-60 minutes per session,[13] but the intensity and protocol duration were different in those studies. The first study[12] was performed with higher intensity intervals (65-80% of HRR) and duration (12 weeks) than the second study (60 - 70% of HR) and a duration of 10 weeks.[13] Studies with 10 weeks of AT showed a higher increase in HRV, but it is too difficult to compare them to other studies because the intensity and exercise type are different. Shen and Wen[11] showed significant decreases in SDNN (22.4 %), CV (21.4 %), NN50 (72.6 %), LF (55.8 %), HF (39.9 %), LFnu (11.2 %), and LF/HF (34.5 %) and a significant increase in HFnu (40.0 %), CAV (44.4 %) compared to smaller changes shown in the study by Jurca et. al.[10] rMSSD (25%), SDNN (18%), lnPHF (11%), lnPLF (9%), and lnPT (6%), to Schuit et al.[13] during the day SDNN (6%), pNN50 (16%), LF (15%), VLF 10% and to Monahan et al.[12] RRi (26%), RRSD (103%), InHF (16%).

All studies were consistent when showing that positive changes in HRV occurred within a short period of exercise and with a relatively modest amount of exercise but with greater intensity. With regards to the results of greater changes in HRV as shown by the review, there are several protocols of exercise intensity in the current studies. Monahan[12] used 65-80% of HR rest, Shen and Wen[11] used a little more intensity, 75-85% of HRmax. In fact, the intensity of exercise is an important determining factor for HRV adaptations, more so than the number of training weeks.

On the other hand, no changes in HRV were observed with 12, 32, 21 weeks respectively.[14-16] Audette et al.[14] did not perform between-group comparisons because baseline values were not consistent. Karavirta et al.[15] found no differences recorded during supine rest; however, during steady state exercise, they found training-induced changes in HR dynamics, submaximal HR significantly decreased, and changes in SDNN, HFP. Wanderley[16] demonstrated, in the aerobic group, lower levels of SBP and DBP after intervention. The fact that no changes were observed in HRV were not due to training.

The specific type of exercise is also very important in a study by Audette et al.[14] who used walking, but it was necessary to have more days of training in the week and higher intensity to obtain changes in HRV, whereas with step- aerobics changes are observed with fewer days in the week. The type of exercise influences the intensity of effort that the individual will use.

In relation to gender effects, there was a predominance of post-menopausal women in the articles, because this group shows a decrease in HRV.[17] Audette et al.[14], Jurca et al.[10], Earnest et al.[17] Karavirta et al.[15] and Shen and Wen[11] probably used women due to the difference in gender and the menopausal period, and in other studies, the volunteers were both male and female.[16,18] There is an interest in the postmenopausal period, and thus some studies included volunteers who were under 60 years old. In the studies by Jurca et al, Conrad et al, Karavirta et al. the female participants ranged between 45-75 and 40-65 years of age. The authors also demonstrated that gender can influence neural and hemodynamic responses in several situations,[19] and other studies support the theory that aerobic exercise training can alter neuroregulatory control over the heart in both genders.[19] AT can increase CBS in sedentary middle-age and older men in a 3 month period using the type (primarily walking), frequency, and intensity the exercise that middle-age and older men are able to perform.[3]

Other types of exercise were measured on the response to isometric exercise in autonomic modulation of the HR, but in older men, HR responses or the HRV (in the time domain) were not altered during sub-maximal isometric exercise.[20] Another study demonstrated, with increasing loads during a non-continuous resistance exercise protocol, a gradual withdrawal of the vagal tone followed by increased sympathetic activation. This shows the convergence of results of the effect to the other types of exercise. However, AT is the most robust exercise type to provoke cardiovascular adaptation. Thus, before we discuss other types of exercise, this systematic review can provide key points of quantity and quality of aerobic exercise in the improvement of HRV. This type of exercise is a powerful instrument proposed as a possible antiarrhythmic intervention. The increase in HRV is followed by the cardiovascular risk protection proposed by exercise.

Conclusion

Most studies included in this review show a change in HRV with AT. There are different results, but that can attributed to characteristics such as intensity and duration of training, since we observed that studies that used exercises with higher intensity obtained a more consistent improvement in HRV. In elders, we can observe changes in HRV with only 8 months of training, but there are differences in some works that probably lack standardization in exercise protocols.

Author contributions

Conception and design of the research: Ferreira LF, Rodrigues GD, Soares PPS. Acquisition of data: Ferreira LF, Rodrigues GD, Soares PPS. Analysis and interpretation of the data: Ferreira LF, Rodrigues GD, Soares PPS. Writing of the manuscript: Ferreira LF, Rodrigues GD, Soares PPS. Critical revision of the manuscript for intellectual content: Ferreira LF, Rodrigues GD, Soares PPS.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Study Association

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