Review Article

Effects of Resistance Training on Blood Pressure in the Elderly

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Abstract

The aging process drastically reduces muscle mass, strength and power, decreasing the capacity to perform the activities of daily living. The practice of resistance exercises can reverse this picture, helping to maintain the muscular mass and improving muscular strength and resistance. However, the aging process causes cardiovascular alterations, which can result in increased blood pressure levels at rest and it is important to analyze the effects of resistance exercises on the blood pressure of elderly individuals. The objective of this study is to evaluate the current scientific knowledge on the responses of the blood pressure to resistance exercises and their mechanisms in elderly individuals. In order to do that, we carried out a literature review related to the theme, in both Portuguese and English. Based on the studies found, the current *corpus*, although scarce and controversial, suggests that, chronically, resistance exercises can have a hypotensive effect on elderly individuals. However, this effect occurs mainly in normotensive elderly individuals submitted to low-intensity training. The mechanisms involved in the hypotensive response still need to be clarified. Although the resistance training is recommended for elderly individuals and there is some evidence that it can have a chronic hypotensive effect, there is still lack of scientific data and much debate on the subject, which demonstrates that this field is still open to investigation.

Introduction

The improvement in life conditions and advances in medicine brought on by the progress of society have resulted in the increase of life expectancy, mainly in developing countries[1], significantly increasing the number of individuals that reach their 6th decade[2]. The estimate of the World Health Organization (WHO)[3] for Brazil in 2005 was a population of 16 million elderly individuals.

The process of aging can be defined, among other concepts, as the combination of biological, psychological and social alterations that lead to the gradual decrease of the capacity of adaptation and performance[4], making the individual more vulnerable to pathological processes. In spite of the aforementioned progresses, the process of aging causes, after the 6th decade of life, a marked decrease in muscle mass, strength and power[5]. Such modifications significantly reduce the capacity to perform the activities of daily living, increasing the degree of impairment of elderly individuals[6]. As a consequence, an increase in the number of falls is observed during this phase of life, which commonly results in fractures[7,8]. In fact, more than 90% of the fractures in elderly individuals are caused by falls - responsible for 70% of accidental deaths among those aged 75 or older[9].

To prevent this picture, it is important to adopt interventions that maintain muscular strength, as, even among the elderly, the neuromuscular system still retains part of its plasticity and can adapt in response to physical stimulation[10]. Thus, resistance exercises have shown to be a good solution.

Several studies[11-13] have reported important muscular benefits of this type of training for the elderly population, such as the maintenance of muscle mass and a marked increase in muscle strength and power. For this reason, the resistance exercise has been considered a promising intervention to prevent or reverse, at least partially, the losses caused by the aging process. It has been strongly recommended for the elderly[14], resulting in the improvement of functional capacity, health status, quality of life and degree of independence of elderly individuals[15].

In addition to muscle alterations, the aging process also causes alterations in the cardiovascular function, which, with the increasing age[16], result in the progressive increase of the blood pressure. Such alterations can influence the cardiovascular responses to resistance training. It is interesting to observe that, even in young and middle-aged individuals, the effects of resistance training on the cardiovascular function are controversial[17,18]. As they are being recommended to elderly individuals and as the latter present alterations in the cardiovascular function, it becomes important to investigate the effects of this training on the blood pressure of these individuals.

The objective of this article was to conduct a narrative review on the subject, discussing the current scientific knowledge on the blood pressure responses and their possible regulatory, hemodynamic and neural mechanisms, after a period of resistance training in elderly individuals. The text will initially address the alterations in blood pressure and their mechanisms in relation to the aging process and, subsequently, the effects of resistance training on these parameters.

Searches were conducted in libraries from the Biological Science area - electronic journals and virtual databases such

Key words

Blood pressure; aging; exercise.

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Manuscript received October 29, 2008; revised manuscript received February 18, 2009; accepted June 17, 2009.

as *MEDLINE*, *PUBMED* and *SCIELO* - regarding the last 20 years to identify mainly randomized controlled trials that have evaluated the chronic effect of resistance exercises on the blood pressure of elderly individuals. The following key words were used in the search: blood pressure, aging, resistance exercise/strength, resistance training/strength and their respective counterparts in Portuguese.

Cardiovascular system and aging

The aging process is associated with several alterations that culminate with a significant increase in cardiovascular system diseases[19]. Among the most notable alterations that accompany the aging process is the increase in the blood pressure, which results from structural and functional modifications in the heart and vessels, in addition to alterations in the autonomic nervous system[20-23].

With the passing of time, the aortic artery and the arterial tree undergo a decrease in their compliance and distensibility and become more rigid. These modifications lead to an increase in the systolic blood pressure, which results in an overload of the heart[20,21,24], causing collagen deposition and increased left ventricular wall thickness, thus also increasing cardiac rigidity[24,25]. However, even with such cardiac structural alterations, the systolic function remains unaltered, whereas the ventricular compliance decreases, impairing the diastolic function and causing an increase in ventricular relaxation time[20,24].

With aging, the peripheral circulation also undergoes alterations, both morphological as well as functional ones, such as the decrease in the capillary-fiber ratio in the muscle and a decreased capillary diameter[22]. Additionally, there is a decrease in the release of nitric oxide and a lower endothelium-dependent vasodilation response[24], resulting in lower vascular responsiveness to the neurohumoral stimuli of vasodilation. Therefore, the total peripheral vascular resistance increases, which can also lead to the increase in the diastolic and mean blood pressure[22,26].

The aging process also promotes the alteration in the modulation of the cardiac function by the autonomic nervous system. There is a decrease in the heart rate variability[23,27,28], with an increase in the low-frequency component and a decrease in the high-frequency one, which indicates an increase in the sympathetic modulation and a decrease in the parasympathetic modulation of the heart, explaining the increase in heart rate with aging.

All aforementioned alterations increase the elderly individual's chance of developing arterial hypertension[16], imposing an overload on the already aged cardiovascular system. In fact, the prevalence of arterial hypertension increases with age[29] and affects up to 60% of elderly individuals[16]. The increase in blood pressure in the elderly has a strong and direct association with vascular mortality[30] and it is one of the main risk factors for the development of diseases such as coronary failure, heart failure and cerebrovascular accident[16]. The prevention of blood pressure elevation in the elderly population is, therefore, of utmost importance.

In the setting of cardiovascular function, aerobic exercises are considered an important intervention for the prevention of diseases. That is due to the existence of innumerable studies that have demonstrated their chronic benefits on the cardiovascular structure and function, mainly in the decrease of blood pressure and prevention of arterial hypertension[31]. On the other hand, until recently, resistance exercises were contraindicated for individuals with cardiovascular diseases, as they promoted a high pressure overload on the heart during their performance[32]. Therefore, for many decades, few studies were carried out regarding the effect of this type of exercise on the cardiovascular system. With the increased interest and use of resistance exercises by the elderly population, their effects on the cardiovascular function stated to be investigated. Thus, more recently, some health institutions such as the American College of Sports Medicine (ASCM)[33] and the American Heart Association (AHA)[18], started to recommend resistance exercises as a complement to the aerobic training for individuals with cardiovascular problems, especially women and the elderly, due to their confirmed osteomuscular benefits[11] and the current indications of their possible benefits for some cardiovascular risk factors[18].

Effects of resistance exercises on blood pressure

Considering the effects of resistance training on blood pressure, an initial meta-analysis[34], published in 2000, included 11 studies and observed a decrease of -2 and -4% in the systolic and diastolic blood pressures, respectively. Similarly, a more recent investigation[35], published in 2005, included 9 randomized controlled studies and verified a decrease of -3.2 mmHg and -3.5 mmHg in the systolic and diastolic blood pressures, respectively, after resistance training. However, these meta-analyses included few studies and they involved populations and training protocols with different characteristics. The present review focused on studies that included only elderly individuals. The main results are shown in Table 1.

The decrease in the blood pressure at rest after resistance training was observed in 10 studies[15,36-44]. Four studies[45-48] observed no alterations. Such results suggest that the resistance training can also have a hypotensive effect on the elderly. However, the magnitude of the blood pressure alteration was different among the studies, which suggests that factors related to the characteristics of the studied population and/or training protocol used can have undergone some influence.

Considering the studied population, the aforementioned studies involved normotensive individuals, hypertensive individuals and/or diabetics. In the hypertensive population, of the 6 studies that included these individuals, 4 observed a decrease in blood pressure[36,40,43,44], whereas 2 others did not observe any alteration[45,46]. However, it is important to emphasize that, in 3 of the 4 studies that demonstrated a decrease in blood pressure, the sample also included normotensive individuals. Furthermore, in one of these studies, the aerobic training was performed concomitantly to the resistance training, so the hypotensive effect might be due to the aerobic stimulation[40]. In 2 other studies, the individuals also presented other concomitant metabolic diseases and the presence of these diseases might also have

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Table 1 - **Main outcomes of studies on the effect of resistance training on the blood pressure of the elderly**

Author	Population	Training	Exercise	Clinical SBP	Clinical DBP	24h ABPM
Anton et al[48]	NT Middle-aged and elderly	13 weeks 3x week	9 exercises NDS, 12 rep 75%1RM	→	→	NA
Castaneda et al[36]	NT and HT elderly DM	16 weeks 3x week	5 exercises 3 s/ 8 rep 60-80%1RM	↓	→	NA
Cononie et al[45]	NT and HT elderly	6 months 3x week	8 exercises 1 s/ 8-12 rep NDI	→	→	NA
Delmonico et al[37]	NT elderly	23 weeks 3x week	6-8 exercises 1-2 s/ 15 RM	↓	↓	NA
Dunstan et al[46]	NT and HT elderly DM	6 months 3x week	9 exercises 3 s/ 8-10 rep 50-85%1RM	→	→	NA
Martel et al[38]	Borderline NT elderly	24 weeks 3x week	7 exercises 1-2 s/ 15 RM	↓	↓	NA
Sallinen et al[39]	Adults + NT elderly	21 weeks 2x week	6-8 exercises 1 s/ 5-15 rep 40-80% of 1RM	↓	↓	NA
Simons & Andel[15]	NT elderly	16 weeks 2x week	6 exercises 1 s/ 10 rep 75% of 1RM	↓	→	NA
Stewart et al[40]	NT and HT elderly	26 weeks 3x week	8 exercises 2 s/ 10-15 rep 50%1RM + 45 min aerobics 60-90% maximum HR	→	↓	NA
Taaffe et al[41]	NT elderly	20 weeks 2x week	7 exercises 1 s/ 8 RM 3 s/ 8 RM	→ →	↓ ↓	NA NA
Terra et al[43]	HT elderly	12 weeks 3x week	10 exercises 3 s/ 12-8 rep 60-80% de 1RM	↓	→	NA
Thomas et al[44]	NT and HT elderly DM, Obese	1 year 3x week	7 exercises 1 s/ 30 rep Low intensity	↓	→	NA
Tsutsumi et al[42]	NT elderly	12 weeks 3x week	12 exercises 2 s/ 12-16 rep 55-65% of 1RM 2 s/ 8-12 rep 75-85% of 1RM	↓ ↓	↓ →	NA NA
Wood et al[47]	NT elderly	12 weeks 3x week	8 exercises 1-2 s/ 8-15 rep 75% of 5RM	→	→	NA

SBP - systolic blood pressure; DBP - diastolic blood pressure; 24-h ABPM- 24-hour ambulatory blood pressure monitoring; HT - hypertensive; NT - normotensive; DM - diabetes mellitus; CAD - coronary artery disease; NA - not assessed; HR - heart rate; s - sets; rep - repetitions; NDS - no data on the number of series; NDI - no data on exercise intensity; 1RM - one repetition maximum; → maintenance; ↓ reduction.

influenced the results[36,44]. Finally, the patients from the only study that evaluated exclusively hypertensive elderly individuals[43] used different anti-hypertensive medications, which did not allow the assessment of the isolated effect of resistance training on the blood pressure. Among the studies assessing only normotensive individuals, only 2 did not observe a decrease in clinical blood pressure[47,48], whereas other 6 studies observed a decrease in this pressure[15,37-39,41,42]. Such results suggest that the resistance training is effective to decrease the blood pressure of normotensive elderly individuals, but that its effect in hypertensive individuals still needs further investigation. It is worth mentioning that no study showed that the resistance training can increase the blood pressure, in either normotensive or hypertensive individuals.

Regarding the effect of the intensity of the resistance training, Tsutsumi et al[42] demonstrated that, in normotensive elderly individuals, the lower-intensity training (55 to 65% of 1 RM) was able to reduce the systolic as well as the diastolic blood pressure, whereas the higher-intensity resistance training (75 to 85% of 1 RM) only decreased the systolic blood pressure. In fact, other studies carried out with high-intensity training (75% of 1 RM) also observed a decrease of the systolic blood pressure only[15], or even no hypotensive effect[48]. Additionally, in general, the studies that involved exercises with the intensity that is classically used to develop localized muscular resistance, i.e., low intensity training (50 to 65% of 1 RM - 15 RM), observed a decrease in the systolic as well as in the diastolic blood pressure[37,38]. On the other hand, Taaffee et al[41] verified that resistance exercises performed at high intensity (8 RM) were able to decrease the diastolic blood pressure, but had no effect on the systolic blood pressure. Thus, most of the data allow us to suppose that the resistance training performed at lower intensity is more advisable to promote a decrease in the blood pressure at rest; however, there is still controversy about that.

The 24-hour ambulatory blood pressure monitoring (24-h ABPM) has shown to be more effective in assessing the cardiovascular risk than the clinical blood pressure[49] and it is interesting to verify the effects of clinical conducts on this pressure. However, there have been no study with elderly individuals that evaluated this aspect, which demonstrates the need to perform investigations with this purpose.

In addition to the possible chronic hypotensive effect of the resistance training, it is important to observe the effect of each training session on the blood pressure (acute effect). Only one study assessed this effect in elderly and hypertensive individuals[50]. It was observed that a single session of resistance exercises promoted a significant decrease in the blood pressure after its conclusion. The maximum decrease was of around 8 mmHg and the hypotension was observed for up to 60 minutes post-training. However, the individuals included the study participated in a supervised physical exercise program, but did not have experience with strength training; thus, it is important to verify whether this acute hypotensive effect occurs in individuals regularly practicing resistance training.

Considering all these data, the current *corpus* suggests that the regular resistance training can have a hypotensive effect on the clinical blood pressure of the elderly. These effects seem to be mainly observed in normotensive individuals and with lower-intensity exercises. As there is still controversy and there are few studies about the subject, this field is quite open to scientific investigation.

Possible mechanisms responsible for the blood pressure response to resistance exercise

The mechanisms responsible for the blood pressure response after the resistance training are yet to be clarified, in both young and middle-aged individuals, as well as in the elderly. However, some mechanisms related to blood pressure regulation have been studied subsequently to the resistance training.

Regarding the effects of resistance training on the heart structure, the studies have not demonstrated modifications in ventricular mass, wall thickness or chamber size[51,52]. It is possible that the resistance training does not have significant structural effects on the heart in the elderly, but its effect on heart function is still controversial. Some studies demonstrate the maintenance of the systolic function[52] and the cardiac output[45,48] after a period of resistance training. However, Cononie et al[45] observed that the maintenance of the cardiac output occurred due to the fact that the decrease in the systolic volume was compensated by the increase in the heart rate, which suggests that the resistance training has a negative effect on cardiac function.

The same studies[45,48] that observed the maintenance of the cardiac output after the resistance training also verified the maintenance of the peripheral vascular resistance, which explains the maintenance of the blood pressure levels. Although the total vascular resistance is not modified by the training, Anton et al[48] observed an increase in the vascular flow and conductance in the lower limbs, suggesting that the resistance training can have important peripheral effects.

An important mechanism associated to the blood pressure control is the integrity of the vascular system structure and function. Studies involving young and middle-aged individuals have reported an increase in arterial stiffness after resistance training[53,54]. This increase was demonstrated in central elastic arteries as well as in muscular peripheral arteries, even when there was a decrease in the post-training mean blood pressure[53]. However, these are not unanimous findings, as some authors[55-57] have not demonstrated alterations in the arterial stiffness after resistance training in young adults. The possible increase in the arterial stiffness has important clinical implications, as it is associated with an increase in mortality[58]. This fact is especially important in elderly individuals, as they already present increased rigidity due to the aging process[59]. Only one study, that by Maeda et al[60], evaluated the effect of resistance training on the arterial stiffness of the elderly - there were no significant alterations.

Regarding the autonomic nervous system, some studies concluded that this type of training does not alter the sympathetic nervous activity. This fact was observed when the activity was measured by the spectral analysis of the heart rate variability[61,62], as well as when it was evaluated by the plasma levels of norepinephrine[45,56] or measured by the microneurography technique[63]. However, other studies[48,64] observed an increase in the plasma levels of norepinephrine, suggesting a possible increase in the sympathetic nervous activity after resistance training in elderly individuals.

Considering all these data, it is clear that the effect of the resistance training on the regulatory mechanisms of the blood pressure is still very controversial and must be further investigated in the future.

Final considerations

The current *corpus* suggests that the resistance training can decrease the blood pressure at rest of elderly individuals. The data, however, are still scarce and the effects of the training have been mainly demonstrated in normotensive elderly individuals with lower-intensity exercises. The mechanisms responsible for the blood pressure response after a period of resistance training have been scarcely investigated and remain unknown in the elderly. Although the resistance training is being recommended to elderly individuals and here are some indications that it can have a chronic hypotensive effect, there is still lack of scientific data and much controversy on the subject, which demonstrates that this is a field open to further investigation.

Acknowledgements

The authors wish to thank the financial support received from *Fundação de Amparo à Pesquisa do Estado de São Paulo* (The Research Support Foundation of the State of São Paulo - FAPESP).

Potential Conflict of Interest

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

Sources of Funding

This study was partially funded by FAPESP.

Study Association

This article is part of the thesis of master submitted by Andréia Cristiane Carrenho Queiroz, from *Escola de Educação Física e Esporte da Universidade de São Paulo*.

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