
REVIEW

ACUTE AND CHRONIC EFFECTS OF AEROBIC AND RESISTANCE EXERCISE ON AMBULATORY BLOOD PRESSURE

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Hypertension is a ubiquitous and serious disease. Regular exercise has been recommended as a strategy for the prevention and treatment of hypertension because of its effects in reducing clinical blood pressure; however, ambulatory blood pressure is a better predictor of target-organ damage than clinical blood pressure, and therefore studying the effects of exercise on ambulatory blood pressure is important as well. Moreover, different kinds of exercise might produce distinct effects that might differ between normotensive and hypertensive subjects.

The aim of this study was to review the current literature on the acute and chronic effects of aerobic and resistance exercise on ambulatory blood pressure in normotensive and hypertensive subjects. It has been conclusively shown that a single episode of aerobic exercise reduces ambulatory blood pressure in hypertensive patients. Similarly, regular aerobic training also decreases ambulatory blood pressure in hypertensive individuals. In contrast, data on the effects of resistance exercise is both scarce and controversial. Nevertheless, studies suggest that resistance exercise might acutely decrease ambulatory blood pressure after exercise, and that this effect seems to be greater after low-intensity exercise and in patients receiving anti-hypertensive drugs. On the other hand, only two studies investigating resistance training in hypertensive patients have been conducted, and neither has demonstrated any hypotensive effect. Thus, based on current knowledge, aerobic training should be recommended to decrease ambulatory blood pressure in hypertensive individuals, while resistance exercise could be prescribed as a complementary strategy.

KEYWORDS: Exercise; Blood pressure; Hypertension; Physiology and Health.

INTRODUCTION

Hypertension is a serious public health problem that affects 22 to 44% of the Brazilian population.¹ It is an independent risk factor for atherosclerosis, which is the most common cause of mortality worldwide.² It is also a major risk factor for stroke, which is the most prevalent cause of death in some regions of Brazil.³

Regular physical exercise has been recommended for the prevention and treatment of hypertension.^{1,2,4} It has been

shown that active subjects have a lower risk of becoming hypertensive than do sedentary subjects.^{4,5} Moreover, many researchers have shown that a single episode of exercise is able to reduce blood pressure during the recovery period.⁴ In addition, meta-analyses have concluded that aerobic training is effective in reducing clinical blood pressure in the general population as well as in hypertensive patients.^{4,5} Despite these well-known benefits, it is also important to take into account the type of population, exercise, and type of blood pressure measurement when analyzing the effects of exercise.

First, the effects of exercise on clinical blood pressure might be different in normotensive and hypertensive subjects, because cardiovascular hemodynamics are modified by hypertension. Second, the effects of aerobic and resistance exercise on clinical blood pressure might be different, because they have different mechanical characteristics. Aerobic training is characterized by the

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execution of cyclic exercises, carried out with large muscle groups contracting at mild to moderate intensities for a long period of time.⁶ On the other hand, resistance training (also called weight or strength training) is characterized by the execution of exercises in which muscles from a specific body segment are contracted against a force that opposes the movement.⁶ Third, although clinical blood pressure (i.e., the blood pressure measured in the laboratory or the physician's office) is the classical measurement used to diagnose and assess hypertension, ambulatory blood pressure (which represents blood pressure levels assessed throughout the day while subjects perform their daily activities) has been shown to be a better predictor of target-organ damage.⁷

Therefore, it is important to investigate the effect of physical exercise on ambulatory blood pressure. Based on these previous considerations, this study reviews the acute and chronic effects of aerobic and resistance exercise on ambulatory blood pressure in normotensive and hypertensive subjects. We carried out a literature review related to this theme in both Portuguese and English. Searches were conducted in bioscience libraries, electronic journals, and virtual databases, such as MEDLINE, PUBMED, and SCIELO, and included studies published between 1988 and 2009. The following keywords were used in the search: blood pressure, exercise, hypertension, ambulatory blood pressure and their respective counterparts in Portuguese (pressão arterial, exercício, hipertensão e pressão arterial ambulatorial) .. More than 1000 studies were identified by this initial search, but most were discarded after an analysis of the title and abstract. Only trials that evaluated

the acute and chronic effects of aerobic and resistance exercise on ambulatory blood pressure in normotensive and hypertensive subjects were selected for the review. The presence of hypertension was accepted as defined in each original paper, although the criteria varied between studies. Most of the studies (30) defined hypertension as clinical systolic/diastolic blood pressures $\geq 140/90$ mmHg, others (7) defined it as values $\geq 135/85$ mmHg, and different criteria were employed in another five studies. The criteria were not explicitly stated in two of the studies.

Acute effects of aerobic exercise

An acute exercise session can promote the lowering of clinical blood pressure during the post-exercise period in both hypertensive and normotensive subjects. This phenomenon has been called post-exercise hypotension (PEH) and is characterized by a sustained decrease in blood pressure after a single episode of exercise.⁴ Blood pressure levels are lower after exercise in comparison to blood pressure measured before exercise or on a control day when no exercise is performed. In order to be clinically relevant, post-exercise hypotension must have a significant magnitude and be sustained for a long period of time under ambulatory conditions.

The effect of a single period of aerobic exercise on post-exercise ambulatory blood pressure has been widely studied;⁸⁻³² the major results of these studies are shown in Table 1. Post-exercise ambulatory hypotension in normotensive subjects has been observed in only four

Table 1 - Effects of aerobic exercise on post-exercise ambulatory blood pressure

Authors	Pop	Exercise	SBP/DBP (mmHg) 24 h	SBP/DBP (mmHg) daytime	SBP/DBP (mmHg) night time	Duration (hours)
Syme et al. (8)	HT	cycle 30 min	↓(3)/→	↓(3)/→	...	10
	hsp	(40% VO ₂ max)	↓(5)/→	↓(5)/→	...	10
	msh	(60% VO ₂ max)	→/→	→/→	...	...
	lsh	(40% VO ₂ max)	→/→	→/→	...	...
		(60% VO ₂ max)	→/↓(2)	→/↓(2)	...	10
		(60% VO ₂ max)	↓(6)/→	↓(6)/→	...	10
Lehmkuhl et al. (9)	HT	(treadmill, 50 min, 50% VO ₂ max)	→/→	→/→	→/→	...
Bermudes et al. (10)	NT	(cycle, 45 min / 60-80% FCmax)	→/↓(2)	...	...	Mean 24
Quinn et al. (11)	HT	treadmill, 30 min (50% VO ₂ max)	↓(4)/↓(5)	...	...	4
		(75% VO ₂ max)	↓(9)/↓(7)	...	...	13
	NT	(50% VO ₂ max)	→/→	...	...	...
		(75% VO ₂ max)	→/→	...	...	...
Forjaz et al. (12)	HT	(cycle, 45 min / 50% VO ₂ max)	→/→	→/→	→/→	...
	NT	(treadmill, 5x10min/ 50% VO ₂ max)	↓(2)/↓(1)	↓(2)/→	→/↓(2)	Mean
Wallace et al. (13)	HT	(treadmill, 5x10min/ 50% VO ₂ max)	↓(8)/↓(6)	↓(8)/↓(6)	→/→	11
	NT		→/→	→/→	→/→	...
Hara et al. (14)	HT	(treadmill, 45 min / 60-70% VO ₂ max)	→/→	→/→	...	...
	NT		→/→	→/→	...	...

Table 1 - Effects of aerobic exercise on post-exercise ambulatory blood pressure (cont.)

Pescatello et al. (15)	HT	cycle 30 min				
	High calcium	(40% VO ₂ max) (60% VO ₂ max)	→/→	→/→	...	...
		(40% VO ₂ max) (60% VO ₂ max)	→/→	→/→	...	...
	Low calcium		↓(6)/→	↓(6)/→	...	10
			↓(6)/→	↓(6)/→	...	10
Pescatello et al. (16)	HT	(cycle/treadmill, 39min /	→/→	↓(5)/→	→/→	Mean
	NT	63% VO ₂ max)	→/→	↓(1)/→	→/→	Mean
Pescatello et al. (17)	HT	(cycle, 30 min /				
	white	60% VO ₂ max)	↓(8)/↓(5)	↓(8)/↓(5)	...	Mean
	black		→/→	→/→	...	...
	NT					
	white		→/→	→/→	...	...
	black		→/↓(3)	→/↓(3)	...	Mean
Pescatello et al. (18)	HT	(cycle, 30 min /	↓(6)/↓(9)	↓(6)/↓(9)	...	13
	NT	60% VO ₂ max)	→/→	→/→	...	...
Pescatello et al. (19)	HT	(cycle, 30 min /	↓(9)/↓(7)	↓(9)/↓(7)	...	7
	NT	60% VO ₂ max)	→/→	→/→	...	...
Somers et al. (20)	HT	Maximal	→/→	→/→	...	...
	NT	Intensity	→/→	→/→	...	...
Brownley et al. (21)	BD	(cycle, 20 min. /	↓(5)/↓(4)	↓(5)/↓(4)	→/→	5
	NT	60-70% FCmax)	→/→	→/→	→/→	...
Rueckert et al. (22)	HT	(treadmill, 45 min / 50% VO ₂ max)	→/→	→/→	...	...
Wallace et al. (23)	HT	(treadmill, 5x10min / 50% VO ₂ max)	→/→	→/→	→/→	...
	NT		→/→	→/→	→/→	...
Fagard et al. (24)	CAD	(cycle, 75 min / 60-80% VO ₂ max)	→/→	→/→	→/→	...
Taylor et al. (25)	HT	(treadmill, 3x15min / 70% VO ₂ max)	↓(7)/↓(4)	↓(9)/↓(4)	↓(6)/↓(4)	16
Fisher, MM (26)	NT	(cycle, 35 min /				
	H	60% VO ₂ max)	→/→	→/→	...	...
	M		→/→	→/→	...	...
Brandão et al. (27)	HT	(cycle, 45 min /	↓/↓	↓/↓	↓/↓	Mean 22
	NT	50% VO ₂ max)	→/→	→/→	→/→	...
Park et al. (28)	HT	(treadmill, 30 min, 50% VO ₂ max)				
	Dip am		↓(6)/...	↓(6)/...		12
	n-Dip am		↓(7)/...	↓(6)/...		12
	Dip pm		→/...		→/...	
	n-Dip pm		↓(7)/...		↓(12)/...	
Blanchard et al. (29)	HT	(40% VO ₂ max)	...	↓(2)/↓(2)	...	14
		(60% VO ₂ max)	...	↓(2)/→	...	...
Pescatello et al. (30)	HT	cycle, 30 min				
		(40% VO ₂ max)	↓(2)/→	↓(2)/→	...	9
		(60% VO ₂ max)	↓(3)/→	↓(3)/→	...	9
Park et al. (31)	HT	treadmill, 50%VO ₂ max	↓(6)/↓(3)	↓(6)/↓(3)	...	7
		(40 min) (4x10 min)	↓(5)/↓(3)	↓(5)/↓(3)	...	11
Forjaz et al. (32)	NT	cycle, 45 min				
		(30% VO ₂ max)	→/→	→/→	→/→	...
		(50% VO ₂ max)	→/→	→/→	→/→	...
		(75% VO ₂ max)	→/→	→/→	→/→	...

In all studies, comparisons were made between exercise and control sessions. Pop: population; HT: hypertensive; NT: normotensive; BD: borderline; HSP: high systolic peak; MPS: mean systolic peak; LPS: low systolic peak; Dip: dipper; n-Dip: non-dipper; M: male; F: female; Cycle: cycle ergometer; VO₂max: maximal oxygen uptake; ...: missing data; SBP: systolic blood pressure; DBP: diastolic blood pressure; →: maintained; ↓: reduced.

studies,^{10,12,16,17} while other studies of normotensive subjects^{11,13,14,18-21,23,26,32} did not identify any change in post-exercise blood pressure values. In contrast, most studies in hypertensive subjects demonstrated significant post-exercise ambulatory blood pressure decreases.^{8,11,13,15-19,25,27-31} Moreover, hypotension was usually observed during waking

periods,^{13,15-19,25,27-31} which are associated with greater stress and higher blood pressure levels. Thus, it is possible to state that a single episode of aerobic exercise reduces ambulatory blood pressure during the recovery period when this decrease is most needed; in other words, when blood pressure levels are already increased.

Although the phenomenon of post-exercise ambulatory hypotension is well established in hypertensive individuals, its magnitude (-2 to -12 mmHg) and duration (4 to 16 hours) vary considerably, which suggests that factors like subject or exercise characteristics might influence the phenomenon. Recent studies have suggested that genetic variation could affect post-exercise blood pressure responses in hypertensive subjects. Blanchard et al.²⁹ found that hypertensive individuals with a homozygous deletion of the angiotensin converting enzyme gene (ACE DD) showed ambulatory post-exercise hypotension, while patients with the other polymorphic variants (ACE II/ID) did not. Furthermore, these authors²⁹ also found that hypertensive patients with three or more polymorphisms associated with the renin-angiotensin-aldosterone system showed greater decreases in post-exercise ambulatory blood pressure.

Specific characteristics of the exercise itself might also be important in determining post-exercise hypotension; however, the effect of exercise intensity remains controversial. For example, Pescatello et al.¹⁸ did not find any difference in the reduction of ambulatory blood pressure after exercise with different intensities within the aerobic range (40 to 75% of maximum oxygen consumption, i.e., VO₂max). On the other hand, Quinn et al.¹¹ observed greater hypotensive effects after heavy exercise in comparison to light exercise. In contrast, some authors²⁹ observed greater post-exercise hypotension after low-intensity exercise. Exercise duration may also be a relevant variable; however, this has not been investigated with respect to ambulatory blood pressure. The presence of pauses during the exercise

about should also influence blood pressure response. Park et al.³¹ observed that post-exercise ambulatory hypotension lasted longer when the same exercise was divided into multiple short periods than when exercise was continuous.

The interaction between subject and exercise characteristics is another potentially interesting factor. Pescatello et al.¹⁵ verified that hypertensive subjects who had low calcium intakes and the ACE DD polymorphism showed greater hypotension after low-intensity aerobic exercise, whereas subjects with low calcium intakes but without the polymorphism, or with high calcium intakes and the polymorphism, responded better to moderate intensity exercise.

In summary, a single episode of aerobic exercise decreases ambulatory blood pressure during the post-exercise period in hypertensive subjects. This effect is significant in magnitude and lasts for several hours, and is thus of clinical significance for these patients; however, many factors may influence the magnitude and duration of post-exercise ambulatory hypotension. These effects require further study.

Chronic effects of aerobic training

The effect of aerobic training in reducing clinical blood pressure in hypertensive subjects is well proven and accepted;⁴ however, the effect of this kind of training on ambulatory blood pressure has not been fully determined. Several studies^{5,33-58} that have investigated this issue in normotensive, hypertensive, and hyperactive subjects are shown in Table 2.

Table 2 - Effects of aerobic training on ambulatory blood pressure

Authors	Pop	Aerobic Training (characteristics)	SBP/DBP (mmHg) 24h	SBP/DBP (mmHg) daytime	SBP/DBP (mmHg) nighttime
Blumenthal et al. (33)	HT	cycle/walking/(3-4x/wk, 70-85% FCmax, 6 mo)	↓(...)/↓(...)	→/→	→/→
Blumenthal et al. (34)	HT	walking/(3x/wk, 35 min, 70% VO ₂ max, 4 mo)	→/→	...	...
Bursztyn et al. (35)	HT	cycle/(3x/wk, 45 min, 60-70% FCmax, 14 wk)	→/→	→/→	→/→
Cooper et al. (36)	HT	walking/(5x/wk, 30 min, 150-200 Kcal, 6 wk)	→/→	→/→	→/→
Cox et al. (37)	NT	flex+cycle/(3x/wk, 30 min, 18% FCmax, 16 wk)	→/→	→/→	→/→
		cycle/(3x/wk, 30 min, 76% FCmax, 16 wk)	→/→	→/→	→/→
		diet+flex+cycle/(3x/wk, 30 min, 18% FCmax, 16 wk)	↓(...)/ →	↓(...)/ →	↓(...)/ →
		diet+cycle/(3x/wk, 30 min, 76% FCmax, 16 wk)	↓(...)/ →	↓(...)/ →	↓(...)/ →
Fortmann et al. (38)	NT	calisthenics, walking, and jogging (3x/wk, 60 min, 70-85% FCmax, 1 yr)	↓(...)/↓(...)	...	...
Gilders et al. (39)	HT	cycle/(3x/wk, 10-30 min, 35-70% VO ₂ max)	→/→	...	...
	NT				

Table 2 - Effects of aerobic training on ambulatory blood pressure (cont.)

Jessup et al. (40)	NT	treadmill/(3x/wk 25-45min, 50-85% FCres, 16 wk)	↓(8)/↓(4)	→/→	→/→
Ketelhut et al. (41)	HT	run/(2x/wk, 60 min, 70% FCres, 18 wk)	→/↓(11)	→/→	→/→
Lima et al. (42)	HR	aerobic (...)	→/→	→/→	→/→
Marceau et al. (43)	HT	cycle/(3x/wk, 30-45 min, 10 wk) 50% VO ₂ max, 70% VO ₂ max,	→/→ →/→	↓(6)/↓(5) →/→	→/→ →/↓(5)
Miller et al. (44)	HT	walking/(3x/wk, 30-45 min, 50-70% FCmax, 9 wk)	↓(10)/↓(5)	↓(12)/↓(7)	↓(7)/→
Miyai et al. (45)	HR	cycle/(3x/wk, 45 min, 50-60%FCmax, 12 wk)	→/→	↓(3)/↓(3)	→/→
Moreira et al. (46)	HT	cycle/(3x/wk, 30-45, 10 wk) 69% FCmax 84% FCmax	↓(3)/↓(3) ↓(3)/↓(3)	→/→ →/→	→/→ →/→
Nami et al. (47)	Dip n-Dip	cycle/(3x/wk, 60 min, 40-60% Cargamax, 3 mo)	→/→ →/→	↓(5)/↓(5) →/→	→/→ →/→
Ohkubo et al. (48)	NT	cycle/(3x/wk, 10-25 min, 20-60% FCmax, 25 wk)	→/→	↓(8)/↓(4)	→/→
Pinto et al. (49)	HT	walking/(3x/wk, 1000m, quick respiration, 6 wk)	↓(7)/ ↓(6)	↓(10)/ ↓(8)	→/→
Jessup et al. (40)	NT	treadmill/(3x/wk 25-45min, 50-85% FCres, 16 wk)	↓(8)/↓(4)	→/→	→/→
Ketelhut et al. (41)	HT	run/(2x/wk, 60 min, 70% FCres, 18 wk)	→/↓(11)	→/→	→/→
Lima et al. (42)	HR	aerobic (...)	→/→	→/→	→/→
Marceau et al. (43)	HT	cycle/(3x/wk, 30-45 min, 10 wk) 50% VO ₂ max, 70% VO ₂ max,	→/→ →/→	↓(6)/↓(5) →/→	→/→ →/↓(5)
Radaelli et al. (50)	HT	cycle/(5x/wk, 20 min, 60%VO ₂ max, 3 wk)	→/→	→/→	→/→
Seals & Reiling (51)	HT	walking/(3x/wk, 30-50 min, 40-57% FCres) 6 mo 12 mo	→/→ ↓(6)/→	→/→ ↓(7)/→	→/→ →/→
Seals et al. (52)	HT BD	walking/(3-4x/wk, 45 min, 60-70% FCres, 12 wk)	→/→ →/→	→/→ →/→	→/→ →/→
Somers et al. (53)	HT	run/(3-4x/wk, 20 min, 6 months) trained trained + detrained	... ...	↓(4)/↓(7) ↓(8)/↓(5)	... ...
Tsai et al. (54)	WC	treadmill/(3x/wk, 30 min, 60-70% FCmax, 12 wk)	↓(8)/ ↓(5)	→/→	→/→
Van Hoof et al. (55)	NT	cycle, jogging (3x/wk, 60 min, 48 sessions)	...	→/↓(5)	...
Wijnen et al. (56)	HT	cycle/(3x/wk, 45 min, 75% VO ₂ max, 6 mo)	→/→	→/→	→/→
Zanettini et al. (57)	HT	cycle/(3x/wk, 30 min, 70-80%FCres, 12 wk)	↓(6)/ →	↓(8)/↓(6)	→/→
Zemva & Rogel (58)	NT M F	dance/(16h/wk, 9 yr)	→/→ ↓(11)/→	→/→ ↓(11)/→	→/→ ↓(12)/→

All studies except 35, 46, 49, and 56 included control groups. Pop: population; HT: hypertensive; NT: normotensive; BD: borderline; WC: white coat; HR: hyperreactive; M: male; F: female; ...: missing data; SBP: systolic blood pressure; DBP: diastolic blood pressure; →: maintain; ↓: reduce; Dip: dipper; n-Dip: non-dipper.

Ambulatory blood pressure response to aerobic training has not been thoroughly investigated in normotensive individuals. Under seven experimental conditions,^{5,37,38,40,48,55,58} aerobic training decreased ambulatory blood pressure, while it did not have any effect under two other conditions.^{37,58}

Among the studies that have reported decreased ambulatory blood pressure, four showed reductions in waking blood pressure^{37,48,55,58} and two demonstrated reductions in sleeping blood pressure.^{37,58} The remaining studies did not report waking and sleeping blood pressures.

The effect of aerobic training has been extensively studied in hypertensive patients. Many longitudinal studies^{5,33,41,43,44,46,49,51,53,57} have reported reductions in ambulatory blood pressure levels after aerobic training. In fact, a meta-analysis⁵ about aerobic training effects in blood pressure has verified that aerobic training is associated with reductions of 3.3 (95% CI, -5.8 to -0.9) and 3.5 (95% CI, -5.2 to -1.9) mmHg in waking systolic and diastolic blood pressures, respectively. Although these reductions appear modest, it has been shown that blood pressure decreases of as little as 2 mmHg are associated with a 6% decrease in stroke mortality and a 4% decrease in coronary artery disease.²

It is important to note that aerobic training sometimes failed to reduce ambulatory blood pressure in hypertensive subjects.^{5,34-36,50-52,56} Moreover, even when the reduction was present, its magnitude varied greatly among studies, suggesting that additional factors influence this response.

Nami et al.⁴⁷ verified that dipper but not non-dipper hypertensives showed reductions in ambulatory blood pressure after aerobic training. Moreover, white coat hypertensives⁵⁴ and hyperreactive subjects⁴⁵ also exhibited reduced blood pressures after aerobic exercise.

Training characteristics also seem to influence blood pressure responses to training. Seals and Reiling⁵¹ did not observe a significant reduction in ambulatory blood pressure after six months of aerobic training, but did observe lower ambulatory blood pressure levels after 12 months of training. Meanwhile, Marceau et al.⁴³ verified that training at 50 and 70% of VO₂peak decreased ambulatory blood pressure. Interestingly, low-intensity training reduced daytime blood pressure, whereas high-intensity training decreased nighttime values.

The mechanisms responsible for blood pressure reduction after aerobic training are not clear. Hypertension has a multifactorial etiology and, therefore, several mechanisms may be involved in the hypotensive effects of aerobic training. Nevertheless, a meta-analysis⁵ has

concluded that aerobic training reduces blood pressure due to a reduction in peripheral vascular resistance.

In summary, aerobic training can reduce ambulatory blood pressure in hypertensive subjects; however, the specific training parameters that are necessary to maximize this effect are not yet known. Moreover, individual responses to aerobic training are quite variable. Future research could address these important issues.

Acute effects of resistance exercise

All studies that have investigated clinical blood pressure after resistance exercise verified a significant post-exercise hypotensive effect; however, data regarding ambulatory blood pressure are both scarce and controversial, and are presented in Table 3.

Only five studies have investigated the acute response of ambulatory blood pressure to resistance exercise. In three of these studies, ambulatory blood pressure levels decreased significantly.^{10,59,60} Notably, three of these studies were conducted with normotensive subjects,^{10,61,62} whereas the other two were conducted with hypertensive subjects.^{59,60} Although post-exercise hypotension was observed in both studies including hypertensives, Hardy and Tucker⁵⁹ observed that the hypotensive effect persisted for only one hour. In contrast, Melo et al.⁶⁰ verified a significant decrease in blood pressure for 10 hours. Interestingly, subjects in the second study were receiving captopril, which suggests a possible interaction between exercise and hypotensive drugs. Moreover, this study showed a significant correlation between baseline blood pressure and its reduction after exercise, with greater hypotensive effects observed in volunteers with higher baseline levels.

In addition to the differences in subjects, the exercise activities themselves are also very different across studies, so it is difficult to establish the best exercise protocol for reducing post-exercise blood pressure; however, low-intensity exercise was employed in the two studies^{10,60}

Table 3 - Effects of resistance exercise on ambulatory blood pressure

Authors	Pop	Exercise	SBP/DBP (mmHg) 24 h	SBP/DBP (mmHg) daytime	SBP/DBP (mmHg) nighttime	Duration (hours)
Bermudes et al. (10)	NT	(10ex, 3s, 23rep, 40% 1RM)	→/→	→/→	→/↓ (3)	3
Hardy & Tucker (59)	HT	(7ex, 3s, 8-12rep, fatigue)	→/→	↓(12)/↓(7)	→/→	1
Melo et al. (60)	HT	(6ex, 3s, 20rep, 40% 1RM)	→/→	↓(7)/↓(5)	→/→	10
Roltsch et al. (61)	NT	(12ex, 2s, 8 rep arms and 12 rep legs, fatigue)	→/→	→/→	→/→	...
Queiroz et al. (62)	NT	(6ex, 3s, fatigue, 50% 1RM)	→/→	→/→	→/→	...

In all studies, comparisons were made between exercise and control sessions. Pop: population; HT: hypertensive; NT: normotensive; ex: exercises; s: set; rep: repetitions; 1RM: repetition maximum; ...: missing data; SBP: systolic blood pressure; DBP: diastolic blood pressure; →: maintained; ↓: reduced.

Table 4 - Effects of resistance training on ambulatory blood pressure

Authors	Pop	Resistance Training (Characteristics)	SBP/DBP (mmHg) 24h	SBP/DBP (mmHg) daytime	SBP/DBP (mmHg) nighttime
Blumenthal et al. (34)	HT	16 weeks (2-3x/week, 30 min circuit)	→	...	...
Van Hoof et al. (64)	HT NT	48 sessions (3x/week, 3x 4-12 rep, 70-90% 1RM)	→	→	...

Both studies included control groups. Pop: population; HT: hypertensive; NT: normotensive; rep: repetitions; 1RM: repetition maximum; → maintained; ...: missing data.

that observed prolonged post-exercise hypotension. When high-intensity exercise was investigated, only one study⁵⁹ exhibited a decrease in blood pressure, and this reduction lasted for only a short time (one hour). Taken together, these results suggest that low-intensity exercise might have stronger hypotensive effects than high-intensity exercise.

To our knowledge, only one study⁶³ has investigated the mechanisms responsible for post-resistance exercise hypotension. This study verified a reduction in cardiac output due to a decrease in stroke volume, probably due to a pre-load reduction; however, this study was conducted in normotensive individuals, and different mechanisms might be observed in hypertensive subjects.

In summary, resistance exercise also promotes post-exercise hypotension, but its magnitude, duration, and mechanism of action need to be more thoroughly investigated. In general, low-intensity resistance exercise seems to have stronger hypotensive effects and subjects with higher blood pressures seem to experience greater blood pressure reductions after resistance exercise, similar to what is observed for aerobic exercise.

Chronic effects of resistance exercise

In practice, resistance training is employed to increase muscle strength, power, and endurance.⁶ These benefits are extremely desirable for the maintenance of good health, especially in post-menopausal women and older subjects, who often struggle with these functions. Nevertheless, it is important to ask whether these positive effects of resistance training are related to the influence of resistance training on blood pressure in hypertensive and normotensive subjects.

Many years ago, it was believed that resistance training could increase blood pressure; however, the most recent meta-analysis of this issue⁵ has clearly demonstrated that this statement is incorrect. In the general population, resistance training reduces systolic/diastolic clinical blood pressures by 3.2 and 3.5 mmHg, respectively; however, only three studies have investigated this issue in hypertensive subjects, and only one of these studies has shown a significant

decrease in diastolic blood pressure; however, this decrease was not significant after correction for the effect observed in the control group. In addition, only two studies^{34,64} have investigated the effects of resistance exercise on ambulatory blood pressure (**Table 4**). These studies did not verify any relevant change in ambulatory blood pressure after resistance training in either normotensive or hypertensive subjects.

The failure to observe hypotensive effects of resistance training may be linked to the absence of sympathetic nervous activity reduction after this kind of training⁶⁴; however, future studies are needed to fully understand the effects of resistance training on blood pressure.

In summary, there is no strong evidence that resistance training is effective in reducing ambulatory blood pressure in hypertensive subjects; however, the lack of data addressing this issue make any conclusion premature.

Final comments

Based on the previous discussion, it is clear that acute aerobic exercise is able to reduce ambulatory blood pressure levels when these levels are already elevated, whereas chronic aerobic exercise can reduce ambulatory blood pressures in normotensive and especially hypertensive subjects. Thus, aerobic training is a very useful tool for the prevention and treatment of hypertension.

In contrast, the acute and chronic effects of resistance exercise on ambulatory blood pressure levels are uncertain due to the limited amount of available data addressing this issue. It is important to emphasize that frequent participation in resistance training does not trigger hypertension. Nevertheless, the absence of proven hypotensive effects suggests that exclusive resistance training should not be recommended for hypertensive patients.

In summary, aerobic exercise should be recommended for ambulatory blood pressure reduction in hypertensive subjects, while resistance training is an important complement to aerobic training because of its osteomuscular benefits.

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