Mini-Review/Systematic Review

Acute and chronic effect of dynamic and isometric resistance exercise on blood pressure: a review with meta-analysis

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Abstract - Objective: This study investigated the association between the acute blood pressure (BP) response to a single session of dynamic or isometric resistance exercise and the chronic adaptations induced by training in these modalities. **Methods:** A systematic review with meta-analysis was conducted using the PubMed, Cochrane Central, SPORTDiscus, and LILACS databases. Eligible studies included adults undergoing dynamic or isometric resistance training, with BP assessments at baseline, during or immediately after a session (acute response), and post-intervention (chronic effect). Thirteen studies met the inclusion criteria. The primary outcome was BP measured during or after the interventions. Studies were required to report correlation data (r-value) between the acute response and chronic BP adaptations. **Results:** A significant correlation was observed between the acute systolic BP response during isometric resistance exercise and its chronic effect (r = −0.591), whereas no significant correlation was found for diastolic BP (r = 0.044). Similarly, a significant correlation was identified between the acute response following a single session of dynamic resistance training and the chronic effect for both systolic BP (r = 0.599) and diastolic BP (r = 0.571). **Conclusion:** The acute systolic BP response during isometric exercise and the post-exercise hypotensive effect following dynamic resistance training are associated with long-term BP reductions. These findings underscore the potential of acute BP responses as predictors of chronic adaptations, highlighting their relevance for exercise prescription and cardiovascular health management.

Keywords: physical exercise, blood pressure, cardiovascular diseases.

1. Introduction

Cardiovascular diseases are the leading cause of disability and premature mortality in adults worldwide[1] representing about 31% of all causes of death[2]. The chances of developing cardiovascular disease increase in the presence of risk factors, which include age, heredity, physical inactivity, being overweight, unhealthy diet, excess alcohol, stress, smoking, high cholesterol and diabetes. In addition, hypertension, whose main characteristic is the sustained elevation of blood pressure levels at values ≥ 140 mmHg for systolic blood pressure (SBP) and ≥ 90 mmHg for diastolic blood pressure (DBP), is considered the risk factor most strongly associated with cardiovascular diseases[3].

The treatment of hypertension consists of adopting measures to reduce the risk of future adverse cardiovascular events. The practice of exercises in hypertensive patients is recommended by several guidelines and organizations around the world, with specific guidelines for the type, intensity, frequency and time of practice[3-8]. When it comes specifically to blood pressure, meta-analysis studies point to positive chronic effects of both aerobic and resistance training. It is suggested, for example, that aerobic training is capable of promoting average reductions between 3.5 and 12.3 mmHg for SBP and between 2.2 and 6.1 mmHg for DBP[9-12]. As for dynamic resistance training, evidence points to average reductions between 1.8 and 8.2 mmHg for SBP and between 2.0 and 5.2 mmHg for DBP[10,11,13,14]. Regarding isometric resistance training, studies point to average reductions between 8.3 and 13.8 mmHg SBP and between 2.7 and 7.8 for DBP[15-20].

Although there is less evidence, the literature also points to positive acute effects of a single exercise session on blood pressure levels, both with the practice of aerobic exercise[21] and dynamic resistance exercise[21,22] The acute effects of isometric exercise, in turn, are still poorly investigated in the literature and, to date, the results of the studies are inconclusive.

Although the literature is limited in providing more evidence on the acute effect of a single exercise session on blood pressure response, it is possible that there is an association between short-term (acute effect) and long-term (chronic effect) responses[5]. Previously published studies support the hypothesis that a single exercise session can predict the outcomes resulting from a training period. Liu et al[23] found significant reductions in acute and chronic SBP and DBP, and identifying a positive association between acute blood pressure responses after a single session of aerobic exercises and the chronic adaptations resulting from this exercise modality in pre-hypertensive individuals[23]. Association between acute and chronic effect of aerobic training on blood pressure was also found in the study by Hecksteden et al. (2013)[24] with healthy adults, suggesting that those who have hypotension after a single bout of exercise are the most likely to have chronically reduced blood pressure[24] corroborating the findings from more recent studies[25,26]. The results observed in these studies represent an important tool for exercise prescription, since the blood pressure response to a single exercise session is able to predict the long-term effects that the individual may experience with training in this modality.

When it comes to exercise/resistance training, studies involving this theme are more incipient. Although some studies[27-30] have investigated whether acute blood pressure responses to a resistance exercise session can predict the chronic adaptations resulting from this type of training, it is still unclear whether this association also applies to this training modality, as more consolidated with aerobic training. Thus, the present study aims to investigate, through a systematic review with meta-analysis, whether the acute blood pressure response to a single session of dynamic or isometric resistance exercise is associated with chronic adaptations resulting from a training period.

2. Methods

2.1. Research characterization

The present study is characterized as a systematic review with meta-analysis of clinical trials. The study was previously registered on the PROSPERO platform (CRD42021239757).

2.2. Article search

The search for articles was performed in Pubmed, Cochrane Central, SPORTDiscus and Lilacs databases. Eligible publications were searched in February 2024, using the terms "adults or elderly", "isometric exercise or resistance exercise" and "blood pressure", in a combined way and applying the Boolean operators "OR" and "AND". In addition, searches were conducted using the MeSH terms with their respective synonyms.

2.3. Eligibility criteria

2.3.1. Type of study

Studies with a clinical trial design, published and indexed in databases in English, Portuguese or Spanish, were considered eligible. There was no restriction regarding the year of publication.

2.3.2. Population

Studies that included adults (≥18 years) of both sexes in their sample were considered eligible, regardless of blood pressure levels (normotensive, pre-hypertensive and hypertensive) and trainability status (sedentary, physically inactive, physically active, untrained and trained). Studies that included participants with specific conditions (e.g., pregnant participants) and/or some syndrome of genetic origin (e.g., participants with down syndrome) were excluded.

2.3.3. Intervention

Eligible studies should involve resistance, dynamic or isometric training interventions, performed in a structured and supervised manner. There were no restrictions on the frequency, duration or intensity of the exercises performed, however, the training program should last at least four weeks.

2.3.4. Outcome

Studies that provided SBP and/or DBP data, through mean values and dispersion measures, were considered eligible, so that the analysis of the acute response (measured before and during or after a session was evident) exercise) and the chronic effect (measured before and after a training program). In other words, the studies should present the measurements at three different moments: before the beginning of the intervention (baseline), at rest, which could refer to a measurement performed before the training period, or before the first exercise sessions; during and/or immediately after a resistance exercise session (acute response), at the beginning of the training program; after the end of the intervention (chronic effect), at rest, and may refer to a measurement performed after the training period or before the last exercise sessions. Additionally, studies should provide correlation data (r-value) between the acute response and the chronic effect.

2.4. Selection of studies and data extraction

2.4.1. Title and abstract reading

The second stage involved screening the initially identified studies by reviewing their titles and abstracts. Initially, duplicate studies were identified and subsequently removed. Two researchers independently conducted the study selection, following predefined eligibility criteria. Studies were excluded if they did not meet one or more eligibility criteria or if one or more exclusion criteria were present in the title or abstract. Duplicate articles were identified and removed using EndNote® software. After completing this stage, a comparison was made between the researchers to identify common articles and resolve any disagreements through consensus with a third researcher.

2.4.2. Reading the articles in full

After the end of the second stage, all articles in common and disagreements resolved by consensus were considered for full reading. As in the previous step, two researchers independently read the articles. This step consisted of a careful reading of the full article, taking into account the eligibility criteria previously established. Articles were excluded if one or more eligibility criteria were not met or in situations where one or more exclusion criteria were present. Excluded studies were categorized according to the exclusion criteria and included studies were uniquely categorized. After completing this stage, a comparison was made between the researchers in order to establish the articles included in common and the differences in the categorization of excluded studies. The disagreements found were resolved based on the consensus made by a third researcher.

2.4.3. Data extraction

The fourth step involved extracting data from the articles, and this was carried out by the same researchers involved in the previous steps. The process was conducted independently and in a standardized manner. The data extracted included information about the sample's characteristics, the intervention and outcome.

For the sample characteristics, data such as: age, training status, blood pressure level, comorbidities, smoking status, dietary co-intervention, percentage of women, body mass, body mass index, time of hypertension diagnosis and number of users of antihypertensive drugs. Regarding the intervention, data on the number of participants randomized and analyzed, intervention duration, type of exercise, number of exercises per session, sets, repetitions, exercise intensity, interval between sets, weekly frequency, session duration, weekly duration, drop-outs rates, adherence to training and occurrence of adverse events were extracted. For outcome characteristics, data on pre and post-exercise session blood pressure values (systolic and diastolic), pre and post-training period (chronic effect), correlation between acute and chronic responses, timing of post-exercise blood pressure measurements and the method used for blood pressure assessment were collected. If any data were missing, the authors were contacted for information and excluded from the analysis only occurred if outcome-related data were unavailable.

The collected information was tabulated in an Excel file in a standardized manner by the researchers. After this step, the data extracted by each researcher were compared, and any discrepancies were resolved through consensus with a third researcher.

2.5. Methodological quality analysis

In the fifth step, researchers independently assessed the methodological quality of the studies, following the Cochrane Handbook instrument[31] to assess the risk of bias. The following evaluation criteria were considered: random sequence generation, allocation concealment, blinding of participants and professionals, blinding of evaluators to the primary outcome, description of incomplete outcomes, selective outcome reporting and study design (controlled trial). Studies were categorized as follows: high risk of bias - when the evaluated criterion was not applied or performed; low risk of bias - when the assessed criterion was performed properly; unclear risk - when it was not possible to determine the criteria as high or low risk; not applicable - when the assessed criterion does not apply to the study due to the design. Data from this step was tabulated in an Excel file, and any disparities among researchers were resolved based on the consensus made by a third researcher.

2.6. Data analysis

Analyzes were performed in the Comprehensive Meta-analysis program, considering blood pressure measurement timing (during or after intervention). Combined effect estimates were based on reported correlation coefficients (r value) and participant numbers. Results are presented as correlation coefficient with a 95% confidence interval, z-value and p-value, visually represented in forest plots. A significance level of $p < 0.05$ was applied.

3. Results

3.1. Selection of studies

Figure 1 represents the stages of identification, screening, eligibility and inclusion of studies. In the first step, identification, 8,405 studies were found, of which 7,027 were found in the Pubmed database, 670 in the Cochrane database, 471 in the Lilacs database and 237 in the SPORTDiscus database. The second stage started after removing the duplicates found (n = 1210) and consisted of

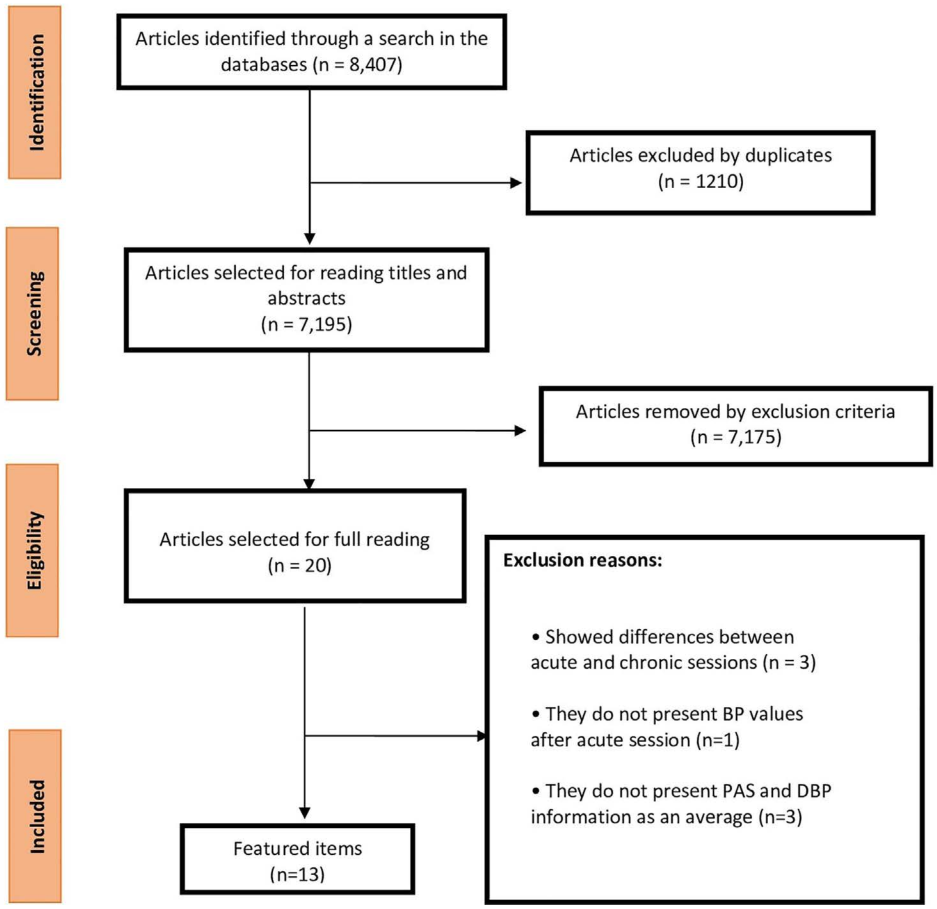


Figure 1 - Flowchart representing each phase of the study.

the analysis of 7,197 studies, performing a screening by reading titles and abstracts, thus identifying the potential studies to be included based on the established criteria. After performing the screening, it was identified that 7,175 studies did not meet the eligibility criteria, leaving 20 studies for the full reading stage. During this stage of reading in full, seven other studies were excluded, three for reasons related to the characteristics of the intervention and four studies excluded for reasons related to outcome information. At the end of all stages, 13 studies were included in the review[28,30,32-42].

3.2. Sample characterization

Table 1 presents information regarding the characteristics of the samples investigated in the studies included in this review. In total, 298 participants were analyzed, of which 105 were male (35.2%) and 193 were female (64.8%). The mean age of participants included in the studies was 43.9 years and the mean body mass index across all studies was 27.0 kg/m^2.

As for the blood pressure level, among the 298 participants analyzed, 142 were hypertensive (47.7% of the sample) and 93 were normotensive (31.2%). Among hypertensive patients, 118 (83.1%) used medication to control blood pressure. Also, two studies were carried out with pre-hypertensive, hypertensive and normotensive participants, however they did not clearly report the percentage of each group. Regarding the training status of study participants, 181 were classified as untrained (60.8%), 93 were classified as physically active (31.2%) and 24 were not characterized in any way (8.0%).

3.3. Physical training variables

Information related to the characteristics of the training applied in the different studies are reported in Table 2. Among the 13 studies included in the present review, five applied isometric resistance training and eight applied dynamic resistance training. In relation to studies with isometric training, the intervention period varied between four and 10 weeks. The number and duration of sets were similar between studies, with four sets of 120 s being performed. As for the weekly frequency adopted, all studies reported three weekly sessions. The weekly duration of training varied between 33 and 51 min.

Studies that performed dynamic resistance training showed variation in intervention time between six and 16

Table 1 - Characterization of the sample of studies included in the systematic review.

Study	Sample size (% women)	Average age (years)	BMI (kg/ m^2)	Blood pressure level	Trainability status	Comorbidities	Smoking participants	Co-nutritional intervention
Ash et al., 2017	5 (20%)	43.4 ± 5.3	33.0 ± 4.9	Prehypertensive/hypertensive	Untrained	No	No	No
Badrov et al., 2013	E: 12 (50%)	65.0 ± 7.0	27.0 ± 4.0	Hypertensive	Nr	No	NR	No
	C: 12 (41%)	63.0 ± 9.0	29.0 ± 6.0					
Chaudhary et al., 2010	E: 10 (100%)	NR	32.2 ± 2.6	Normotensive	Untrained	No	NR	No
	C: 10 (100%)	NR	31.8 ± 1.5					
Devereux et al., 2015	13 (0%)	21.0 ± 2.4	NR	Normotensive	Trained	No	No	No
Gerage et al., 2015	14 (100%)	65.5 ± 5.0	23.9 ± 2.9	Normotensive	Trained	No	No	No
Harris and Holly, 1987	E: 10 (0%)	32.7 ± 5.2	NR	Hypertensive	Untrained	No	No	No
	C: 16 (0%)	31.4 ± 6.2	NR					
Machado et al., 2019	12 (58.3%)	68.8 ± 7.8	28.2 ± 3.8	Hypertensive/normotensive	Untrained	DM II	No	No
Moreira et al., 2016	20 (100%)	66.8 ± 5.6	28.3 ± 5.8	Hypertensive	Untrained	No	NR	No
Mota et al., 2013	E: 32 (100%)	67.5 ± 7.0	27.8 ± 5.5	Hypertensive	Untrained	No	NR	No
	C: 32 (100%)	66.8 ± 5.4	29.4 ± 4.6					
Somani et al., 2018	G1: 13 (0%)	24.0 ± 4.0	25.0 ± 4.0	Normotensive/ pre-hypertensive	Trained	No	NR	No
	G2:13 (100%)	25.0 ± 5.0	23.0 ± 4.0					
	G3: 10 (0%)	21.0 ± 3.0	24.0 ± 2.0					
	G4:10 (100%)	23.0 ± 5.0	26.0 ± 5.0					
Tibana et al., 2015	13 (100%)	35.7 ± 7.4	28.3 ± 5.4	Normotensive	Untrained	No	No	No
Trevizani et al., 2018	H: 8 (0%)	59.0 ± 7.6	28.8 ± 4.0	Hypertensive	Untrained	No	No	No
	N: 13 (0%)	57.1 ± 6.0	25.8 ± 4.1	Normotensive				
Yamagata et al., 2020	E: 10 (100%)	21.0 ± 1.0	22.0 ± 1.0	Normotensive	Trained	No	No	No
	C: 10 (100%)	20.0 ± 1.0	20.0 ± 2.0					

Note: E - exercise group. C - control group. H - hypertensive group. N - Normotensive group. G1 - Handgrip training group with men. G2 - Handgrip training group with women G3 - Leg extension training group with men. G4 - leg extension training group with women.

Table 2 - Training variables.

Study	Intervention time (weeks)	Modality	Number of sets	Number of repetitions	Intensity	Break between sets (seconds)	Weekly frequency	Weekly duration (minutes)
Ash et al., 2017	8	Isometric	4	120”	30% MCV	60	3	36
Badrov et al., 2013	10	Isometric	4	120”	30% MCV	60	3	NR
Chaudhary et al., 2010	6	Dynamic	4	10	50 | 75 | 100% 10 RM	NR	NR	NR
Devereux et al., 2015	4	Isometric	4	120”	22% MCV	180	3	NR
Gerage et al., 2015	12	Dynamic	2	10-15	Moderate fatigue	60 - 90”	3	150
Harris and Holly, 1987	9	Dynamic	3	15-20	40% 1 RM	15”	3	NR
Machado et al., 2019	12	Dynamic	3	8-10 | 6-8 | 4-6		180”	2	NR
Moreira et al., 2016	12	Dynamic	3	12 | 10 | 8	60 | 70 | 80 % 1RM	60”	3	NR
Mota et al., 2013	16	Dynamic	3	10 | 12 | 10 | 8	light | 60 | 70 | 80% 1 RM	30 | 60 | 60 | 90”	3	120
Somani et al., 2018	10	Isometric	4	120”	30% MCV	60”	3	33
	10	Isometric	4	120”	20% MCV	120”	3	42
Tibana et al., 2015	8	Dynamic	3	8-12	8 a 12 MCV	60”	3	120-135
Trevizani et al., 2018	4	Dynamic	2	20	50% 1 MCV	120”	3	180
Yamagata et al., 2020	8	Isometric	4	120”	25% MCV	180”	3	51

weeks. Regarding the number of series, the studies presented a variation of two to four series. The intensity of the series also presented variation between the studies, so that five studies used percentages of maximum repetitions, one study used the maximum number of repetitions and one study applied the exercises with moderate subjective intensity. Still in relation to intensity, three studies reported progression throughout training. With regard to weekly frequency, all studies reported three sessions per week and the weekly duration of the intervention ranged from 120 to 150 min.

3.4. Blood pressure response

3.4.1. Acute response of isometric and dynamic resistance exercise on SBP

Regarding the acute response of isometric resistance exercise in SBP, the greatest increase identified during the exercise was 69.0 mmHg, while the smallest increase was 2.7 mmHg, measured after the exercises. Regarding the acute response of dynamic resistance exercise, the greatest increase in blood pressure was 12.4 mmHg, while the greatest drop was 11.7 mmHg, both measurements performed after the exercises. Regarding the chronic effect of isometric resistance training on SBP, the greatest increase observed was 1.8 mmHg, while the greatest decrease was 8.0 mmHg. In relation to the chronic effect of dynamic resistance training on SBP, the greatest increase observed was 0.6 mmHg and the greatest decrease was 14.3 mmHg. As for the correlation values between the acute response and the chronic effect, for studies with isometric resistance training, the highest positive correlation for SBP was 0.78, while the highest negative correlation observed was -0.81. Regarding the correlation values between the acute response and the chronic effect for the studies with dynamic resistance training, the highest positive correlation for SBP was 0.81 and the lowest positive correlation presented was 0.09 (Table 3).

3.4.2. Acute response of isometric and dynamic resistance exercise on DBP

As for the acute response of isometric resistance exercise in DBP, the greatest increase observed was 27.0 mmHg, from the measurement during exercise, while the smallest increase was 3.2 mmHg. In relation to the acute response of dynamic resistance exercise in DBP, the highest value observed was 4.0 mmHg, while the greatest drop was 10.1 mmHg, both measures measured after the exercises. Regarding the chronic effect of isometric resistance training on DBP, the highest reported increase was 3.1 mmHg and the highest reported drop was 5.0 mmHg. Regarding the chronic effect on DBP, the greatest increase reported was 0.5 mmHg and the greatest decrease was 4.5 mmHg. Regarding the correlations between the acute response and the chronic effect of isometric training on DBP, the highest reported positive correlation was 0.80, while the highest reported negative correlation was -0.30. As for the effect of dynamic training on DBP, the highest positive correlation reported was 0.78 and the lowest positive correlation was 0.05 (Table 4).

Table 3 - Acute response and chronic effect of training on systolic blood pressure.

Study	Group	Acute SBP (mmHg)			Chronic SBP (mmHg)			*r*
		Pre	Post	Δ	Pre	Post	Δ	
Isometric training								
Ash et al, 2017		119.3 ± 11.7	122.0 ± 8.4	+2.7	121.5 ± 9.6	123.3 ± 3.9	+1.8	0.72
Badrov et al, 2013	E			+ 26.0	129.0 ± 16.0	121.0 ± 16.0	-8.0	-0.79
	C			+27.0	130.0 ± 17.0	131.0 ± 18.0	+1.0	0.13
Devereux et al, 2015		120.0 ± 12.0	189.0 ± 32.0	+69.0	120.0 ± 12.0	115.0 ± 12.0	-5.0	0.78
Somani et al, 2018	G1	117.0 ± 5.0		+22.0	117.0 ± 5.0	112.0 ± 5.0	-5.0	-0.66
	G2	103.0 ± 6.0		+14.0	103.0 ± 6.0	100.0 ± 6.0	-3.0	-0.67
	G3	126.0 ± 8.0		+35.0	126.0 ± 8.0	118.0 ± 8.0	-8.0	-0.81
	G4	122.0 ± 5.0		+25.0	122.0 ± 5.0	116.0 ± 5.0	-6.0	-0.79
Yamagata et al 2020	E			+15.0	107.0 ± 4.0	102.0 ± 5.0	-5.0	0.69
	C			+6.0	106.0 ± 8.0	104.0 ± 8.0	-2.0	
Dynamic training								
Chaudhary et al, 2010		129.7 ± 4.5	131.7 ± 4.6	+2.0	129.7 ± 4.5	126.7 ± 3.7	-3.0	
		125.8 ± 4.2	126.4 ± 4.4	+0.6	125.8 ± 4.6	125.8 ± 4.6	0	
Gerage et al, 2015		123.4 ± 7.7	123.0 ± 8.3	-0.4	125.6 ± 7.8	120.9 ± 6.5	-4.8	0.62
Harris and Holly, 1987	E	142.3 ± 7.9	154.7 ± 12.1	+12.4	141.7 ± 7.9	142.3 ± 7.5	+0.6	
	C				146.1 ± 8.2	145.8 ± 6.9	-0.3	
Machado et al, 2019		131.3 ± 12.9	124.3 ± 14.1	-7.0	125.0 ± 15.1	119.9 ± 9.8	-5.1	
Moreira et al, 2016				+1.0			-10.5	0.47
Mota et al, 2013	E	134.5 ± 14.6	132.2 ± 13.4	-2.3	134.5 ± 14.6	120.2 ± 11.8	-14.3	
	C	131.8 ± 16.9	127.8 ± 16.8	-4.0	131.8 ± 16.9	132.3 ± 17.6	+0.5	
Tibana et al, 2015		117.3 ± 11.7	108.5 ± 7.0	-8.8	117.3 ± 11.7	117.3 ± 9.3	0	0.81
		108.5 ± 11.9	105.7 ± 10.0	-2.8	108.5 ± 11.9	107.9 ± 10.0	-0.6	0.71
Trevizani et al, 2018	H	128.6 ± 9.7	116.9 ± 14.2	-11.7	128.6 ± 9.7	121.9 ± 8.4	-6.7	0.77
	N	122.8 ± 4.8	111.5 ± 14.2	-11.3	122.8 ± 4.8	113.5 ± 10.7	-9.3	0.09

Table 4 - Acute response and chronic effect of training on diastolic blood pressure.

Study	Group	Acute DBP (mmHg) Pre	Chronic DBP (mmHg)			Study			Group
			Post			Pre	Post		
Isometric training									
Ash et al., 2017		0.72	75.8 ± 9.9	79.0 ± 5.2	+3.2	77.8 ± 8.5	80.9 ± 5.7	+3.1	0.80
Badrov et al., 2013	E	-0.79			+11.0	72.0 ± 9.0	67.0 ± 8.0	-5.0	-0.30
	C	0.13			+11.0	73.0 ± 12.0	74.0 ± 14.0	+1.0	-0.20
Devereux et al., 2015		0.78	-	-	-	-	-	-	
Somani et al., 2018	G1	-0.66	65.0 ± 7.0		+11.0	65.0 ± 7.0	65.0 ± 8.0	0	-0.26
	G2	-0.67	62.0 ± 8.0		+9.0	62.0 ± 8.0	61.0 ± 8.0	-1.0	-0.28
	G3	-0.81	73.0 ± 5.0		+27.0	73.0 ± 5.0	72.0 ± 6.0	-1.0	0.18
	G4	-0.79	73.0 ± 5.0		+21.0	73.0 ± 5.0	72.0 ± 6.0	-1.0	0.10
Yamagata et al., 2020	E	0.69			+12.0	64.0 ± 3.0	60.0 ± 6.0	-4.0	0.77
	C				+6.0	63.0 ± 6.0	61.0 ± 5.0	-2.0	

(*continued*)

Table 4 - continued

Study	Group	Acute DBP (mmHg) Pre	Chronic DBP (mmHg)			Study			Group
			Post			Pre	Post		
Dynamic training									
Chaudhary et al., 2010			83.7 ± 2.3	83.0 ± 2.2	-0.7	83.7 ± 2.3	83.5 ± 2.9	-0.2	
			84.8 ± 4.1	85.1 ± 4.0	+0.3	84.8 ± 4.1	84.8 ± 4.1	0	
Gerage et al., 2015		0.62	79.1 ± 6.3	83.1 ± 5.4	+4.0	80.6 ± 6.0	880.4 ± 5.4	-0.3	0.24
Harris and Holly., 1987	E		91.3 ± 6.4	81.2 ± 6.2	-10.1	95.8 ± 6.4	91.3 ± 8.0	-4.5	
	C		-	-	-	94.6 ± 3.8	92.6 ± 3.3	-2.0	
Machado et al., 2019			78.2 ± 3.2	73.7 ± 4.1	-4.5	68.3 ± 3.7	68.8 ± 5.1	+0.5	
Moreira et al., 2016		0.47			+1.0			-1.0	0.7
Mota et al., 2013	E		76.0 ± 9.2	73.9 ± 9.6	-2.1	76.0 ± 9.2	72.4 ± 9.3	-3.6	
	C		74.3 ± 7.4	73.3 ± 7.5	-1.0	74.3 ± 7.4	73.8 ± 7.8	-0.5	
Tibana et al., 2015		0.81	79.3 ± 8.2	71.5 ± 6.4	-7.8	79.3 ± 8.2	78.8 ± 7.2	-0.5	-0.5
		0.71	67.4 ± 9.1	66.1 ± 7.8	-1.3	67.4 ± 9.1	66.8 ± 7.8	-0.6	0.78
Trevizani et al., 2018	H	0.77	78.6 ± 10.8	73.5 ± 9.5	-5.1	78.6 ± 10.8	74.9 ± 9.2	-3.7	0.73
	N	0.09	76.8 ± 3.2	73.3 ± 10.2	-3.5	76.8 ± 3.2	74.4 ± 7.5	-2.4	0.01

3.5. Meta-analysis

3.5.1. Correlation between the acute response evaluated during isometric resistance exercise and the chronic effect of this modality on blood pressure

The combination of the effects of the correlation between the acute response and the chronic effect of isometric training on blood pressure showed an overall correlation of -0.591 (95% CI - 0.846, -0.115; p = 0.018; I2: 11%) for SBP and 0.044 (95% CI - 0.336, 0.412; p = 0.825; I2: 4%) for PAD (Figure 2).

3.5.2. Correlation between the acute response evaluated after dynamic resistance exercise and the chronic effect of this modality on blood pressure

An overall correlation of 0.599 (95% CI - 0.377, 0.756; p ≤ 0.0001; I2: 0%) was identified for SBP and 0.571 (95% CI 0.302, 0.755; p ≤ 0.0001; I2: 0%) for PAD (Figure 3).

3.6. Assessment of methodological quality

Overall, only four studies (30.7%) had a low risk of bias in at least three of the seven criteria evaluated, while the others had inconsistent data or a high risk of bias. Only one study (7.7%) performed the randomization process properly, while most studies did not clearly report this information. Regarding the concealment of participant allocation, most studies did not clearly report this information (53.8%) and no study reported that the process was carried out completely adequately.

The blinding criterion of participants and professionals involved in the interventions was not applicable in 100% of the studies. Regarding the blinding of evaluators to the main outcome of the study, most studies did not clearly report this information (61.5%) and no study reported performing the process completely adequately.

Most studies (53.8%) adequately reported incomplete study outcomes, representing a criterion with low risk of bias. Regarding the selective outcome report, 92.3% of the studies reported the process adequately. Regarding the bias related to the study design, seven studies (53.8%) reported the presence of a control group or control session and were classified as low risk of bias (Table 5).

4. Discussion

The present study aimed to investigate, through a systematic review with meta-analysis, whether the acute blood pressure response during or shortly after a dynamic and isometric resistance exercise session is associated with chronic adaptations resulting from a training period involving these modalities. The main findings of the study were: a) the SBP response, evaluated during isometric resistance exercise, is negatively correlated with the chronic effects identified after a period of training in this modality; b) the response of SBP and DBP, evaluated after dynamic resistance exercise, is positively correlated with the chronic effects, after a period of training in this modality.

In the case of acute responses, in most studies, an increase in blood pressure was observed during the execution of the exercises and a reduction after the exercises. It is noteworthy that only two studies with isometric training

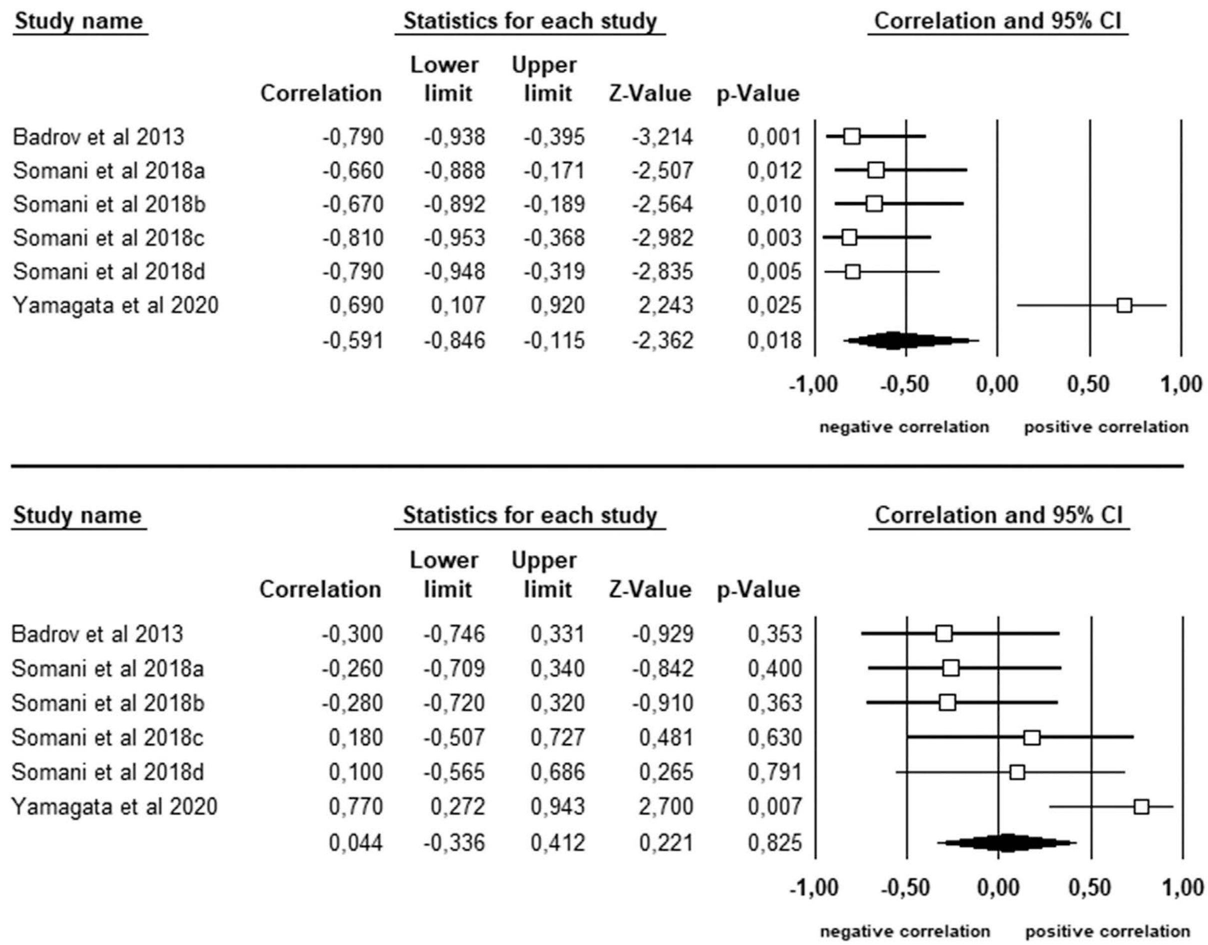


Figure 2 - General effect of correlation between the acute response assessed during isometric resistance exercise and the chronic effect of this training modality on systolic blood pressure (A) and diastolic blood pressure (B). Individual results (white square) and overall result (black diamond).

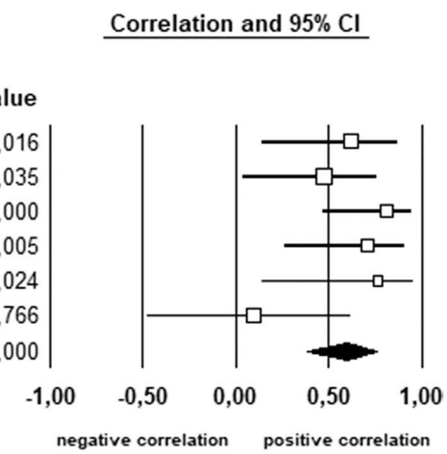
performed blood pressure measurements after the exercise session, which made an analysis on this aspect impossible. In addition, no study with dynamic resistance training performed blood pressure measurements during the execution of the exercises, making it impossible to compare the values in relation to the training method and the moment of measurement.

Among the studies with isometric resistance training, the greatest increases in SBP during exercise performance were observed in the studies by Devereux et al. (2015)[35] and Somani et al. (2017)[28], who used the knee extension exercise, which differs from other studies, which used the handgrip exercise. This difference is possibly associated with the size of the muscle mass involved in the exercises, considering that the influence of such a factor on the hemodynamic responses identified during exercise is already evidenced in the literature[43-45]. Other factors such as intensity and interval between sets were applied in different ways between studies. While Devereux et al. (2015)[35] performed the protocol bilaterally and applied a higher interval between sets than the other studies, Somani et al. (2017)[28] used a lower intensity and an intermediate interval in relation to the other studies, showing that there was possibly no interference of these factors on the acute pressure response. Regarding DBP, the greatest increase was observed in the study by Somani et al. (2017)[28], considering that in the study by Devereux et al. (2015)[35] DBP data were not reported.

For studies with dynamic resistance training, only one study showed a considerable increase in blood pressure[37] while the others showed small increases or reductions in this outcome after performing the exercises. The fact that the study by Harris and Holly (1987)[37] showed the highest level of post-exercise SBP may be associated with the monitoring time after the session (up to 45 s). Interestingly, the same study showed the largest drop in DBP among the studies. The greatest reduction in SBP occurred in the study by Trevizani et al. (2018)[42], with a greater magnitude of this reduction being observed in hypertensive individuals.

In the review study by Casonatto et al. (2016)[22], it was observed that a single session of dynamic resistance

Study name	Correlation	Lower limit	Upper limit	Z-Value	p-Value
Gerage et al 2015	0,621	0,135	0,866	2,410	0,016
Moreira et al 2016	0,470	0,035	0,755	2,103	0,035
Tibana et al 2015a	0,810	0,468	0,941	3,564	0,000
Tibana et al 2015b	0,710	0,261	0,906	2,806	0,005
Trevizani et al 2018a	0,766	0,133	0,955	2,260	0,024
Trevizani et al 2018b	0,094	-0,482	0,613	0,298	0,766
	0,599	0,377	0,756	4,596	0,000



Study name	Correlation	Lower limit	Upper limit	Z-Value	p-Value
Gerage et al 2015	0,244	-0,329	0,686	0,826	0,409
Moreira et al 2016	0,700	0,373	0,872	3,576	0,000
Tibana et al 2015a	0,690	0,224	0,899	2,681	0,007
Tibana et al 2015b	0,780	0,402	0,931	3,306	0,001
Trevizani et al 2018a	0,727	0,046	0,947	2,062	0,039
Trevizani et al 2018b	0,013	-0,542	0,560	0,041	0,967
	0,571	0,302	0,755	3,774	0,000

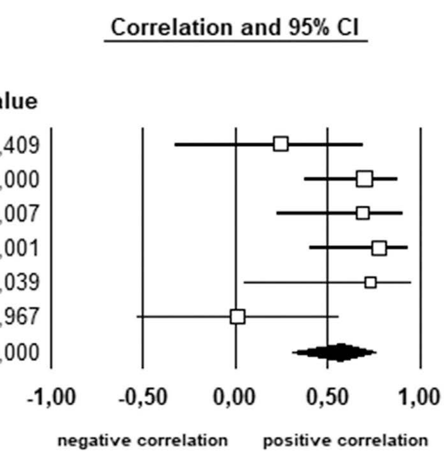


Figure 3 - General effect of correlation between the acute response assessed after dynamic resistance exercise and the chronic effect of this training modality on systolic blood pressure (A) and diastolic blood pressure (B). Individual results (white square) and overall result (black diamond).

exercise is able to reduce blood pressure levels, suggesting that this post-exercise hypotension is more pronounced in low-volume and moderate-intensity sessions, and in sedentary and hypertensive patients. The findings of the present study corroborate the results presented in the review study by Casonatto et al. (2016)[22], since the studies by Trevizani et al. (2018)[42] and Harris and Holly (1987)[37] who, respectively, showed the greatest reductions for SBP and DBP acutely, were performed with hypertensive and sedentary participants. Still, in relation to the characteristics of the studies, Harris and Holly (1987)[37] and Trevizani et al. (2018)[42] applied series of low intensity, which may explain the acute responses of higher magnitudes among studies with dynamic resistance exercise.

Regarding the chronic effect, most of the studies included in this review with resistance training, both isometric and dynamic, identified reductions in SBP and DBP after a period of training. In the case of studies with isometric training, only two studies showed increases (without statistical significance) in blood pressure levels after the training period and the others showed chronic reductions. The greatest reductions observed occurred in the study by Somani et al. (2017)[28] more specifically in the training group with isometric knee extension in men and women, and in the study by Badrov et al. (2013)[33] with handgrip training in hypertensive adults. The chronic reductions observed in these studies are in agreement with the findings of meta-analyses that investigated the effects of isometric training on blood pressure[15-20].

The fact that the greatest chronic reductions occurred in the studies by Somani et al. (2017)[28] and Badrov et al. (2013)[33] may be related to the duration of interventions, since both studies were conducted for a period of 10 weeks, the longest period among studies with this type of training. Such results corroborate with an analysis carried out by Inder et al. (2016)[16] which resulted in more expressive chronic reductions in studies with a training period longer than eight weeks (Inder, 2016)[16]. With regard to other training characteristics, there was a similarity between the studies in relation to the volume, intensity and frequency used, further reinforcing the possible relationship of effects with the total duration of training.

Table 5 - Assessment of the methodological quality of the studies.

Study	**Generation of the sequence random**	**Concealment of allocation**	**Blinding of participants and professionals**	**Blinding of evaluators of ending**	**Outcomes incomplete**	**Report of outcome selective**	**Others sources of bias (design)**
Isometric training							
Ash et al., 2017	low risk	high risk	not applicable	unclear	low risk	low risk	high risk
Badrov et al., 2013	unclear	unclear	not applicable	unclear	unclear	low risk	low risk
Devereux et al., 2015	unclear	unclear	not applicable	unclear	unclear	high risk	low risk
Somani et al., 2018	high risk	not applicable	not applicable	not applicable	low risk	low risk	high risk
Yamagata et al., 2020	unclear	unclear	not applicable	unclear	low risk	low risk	low risk
Dynamic training							
Chaudhary et al., 2010	unclear	unclear	not applicable	unclear	unclear	low risk	low risk
Gerage et al., 2015	unclear	unclear	not applicable	unclear	low risk	low risk	low risk
Harris and Holly, 1987	unclear	unclear	not applicable	unclear	low risk	low risk	low risk
Machado et al., 2019	not applicable	not applicable	not applicable	not applicable	low risk	low risk	high risk
Moreira et al., 2016	not applicable	not applicable	not applicable	not applicable	high risk	low risk	high risk
Mota et al., 2013	unclear	unclear	not applicable	unclear	unclear	low risk	low risk
Tibana et al., 2015	not applicable	not applicable	not applicable	not applicable	low risk	low risk	high risk
Trevizani et al., 2018	not applicable	not applicable	not applicable	not applicable	unclear	low risk	high risk

Among the studies with dynamic resistance training, only two showed an increase (less than 1 mmHg, without statistical significance) in SBP and one in DBP (also less than 1 mmHg, without statistical significance). The greatest chronic reduction observed in SBP occurred in the study by Mota et al. (2013)[40] who performed training with hypertensive and sedentary adults, while the greatest reduction in DBP occurred in the study by Harris and Holly (1987)[37]. The results observed are superior to the findings of meta-analysis studies that investigated the effects of dynamic resistance training on blood pressure[10,11,13,14,46].

The fact that the study by Mota et al. (2013)[40] have identified the greatest drop in SBP may be associated with the intervention time, given that this study took place during 16 weeks, the longest duration among studies with dynamic resistance training. The effect of intervention duration on blood pressure is also evidenced in other studies, which observed greater reductions in long-term interventions when compared to short-term interventions[10,14,46]. In the review by Ashton et al. (2020)[47] significant reductions in SBP and DBP were observed in medium (7-23 weeks) and long-term (≥ 24 weeks), but not short-term (≤ 6 weeks) studies, which further highlights the influence of this variable in blood pressure adaptations to training.

Other factors related to training could also explain, in part, the results identified in this review. The studies by Mota et al. (2013)[40] and Moreira et al. (2016)[39] who showed the greatest reductions for SBP, used higher intensities than the other studies, progressing from a low intensity and reaching a high intensity at the end of the intervention. Harris and Holly (1987)[37] and Trevizani et al. (2018)[42] who identified the greatest reductions for DBP, used the highest volume of repetitions per set in their respective studies. In addition, a common factor among the studies that showed the greatest chronic reductions in SBP and DBP is related to the characteristics of the participants, who were hypertensive. This factor is evidenced in the study by Polito et al. (2021)[48] who observed reductions in SBP and DBP in antihypertensive drug users and did not observe the same behavior in non-users.

With regard to the analysis of the relationship between acute blood pressure responses, identified during or shortly after the exercise, and the chronic effect of isometric and dynamic resistance training, in the present study, a significant inverse correlation was observed for SBP between studies with isometric resistance training and a significant positive correlation for SBP and DBP between studies with dynamic resistance training. These findings indicate that those individuals who present greater increases in blood pressure during isometric exercise and greater post-dynamic resistance exercise hypotension tend to be those who will present the greatest decreases in blood pressure in a chronic way with these training modalities.

Despite having found a significant correlation, Yamagata et al. (2020)[30] was unique among studies with isometric training that showed a positive correlation, i.e. correlation between increased blood pressure during exercise and an attenuated chronic response. Although such results do not have a concrete explanation, Yamagata et al. (2020)[30] report a variability in the hypotensive effect among the participants, which may represent an influence on the results. In another study, Millar et al. (2009)[49] investigated the relationship between cardiovascular reactivity and the chronic effect of handgrip training. The authors observed a significant inverse correlation and a positive, but not significant, correlation between blood pressure responses to a mathematical test and to the cold pressor test, respectively, and the chronic effect of training, suggesting the influence of different physiological mechanisms in these processes.

In reference to this, Lawrence et al. (2015)[50] presented evidence of different factors and mechanisms that could influence pressure adaptations resulting from physical training, highlighting the importance of considering that not all participants respond in the same way, both acutely and chronically, and that there may be determinants linked to the characteristics of the group, such as gender, age, pre-existing diseases and medication use. Despite reports of inter-individual variability and possible relationships with mechanisms and factors, it was not possible to observe, in the studies presented here, differences related to the participants or to the training model used that could explain the divergences in terms of responses. Although a study has presented a divergent result, the meta-analysis points to an inverse and significant general correlation between the behavior of SBP during the execution of the exercise and the chronic adaptations resulting from isometric resistance training. Thus, this result indicates the potential role of predicting the blood pressure response during a single session of isometric exercise to the chronic effect of this modality.

As for dynamic resistance training, a trend was observed in the results presented. Although not all of them showed significant results, the studies showed a positive correlation between the occurrence of post-exercise hypotension and the chronic effect, reflecting the general correlation of the studies for both systolic and diastolic blood pressure. Among the studies included in the meta-analysis, only Tibana et al. (2014)[41] and Moreira et al. (2016)[39] aimed to analyze the correlation between acute response and chronic effect of dynamic resistance training. Both studies highlighted the influence of the inter-individual variability of the participants on the pressure response and agree that the explanations for the occurrence of these associations are still unclear. However, it is suggested that the acute and chronic responses are caused by the same mechanisms, since the sum of acute effects can lead to chronic adaptations[39].

Although the literature reports that the occurrence of post-exercise hypotension is more consistent in hypertensive than in normotensive individuals[51] the highest correlation between acute response and chronic effect of dynamic resistance training was achieved in the study by Tibana et al. (2014)[41] which was performed with normotensive women. However, these results do not differ from other studies. As evidenced in the discussion of studies with isometric training, it is possible that different factors and physiological mechanisms act on blood pressure responses. However, the studies included in the meta-analysis have different characteristics in terms of participants and training protocols, with studies performed with hypertensive and normotensive adults, trained and untrained, and training protocols were performed with varying volumes and intensities.

Although the literature is scarce regarding the analysis of the relationship between the acute and chronic effects of resistance exercise on blood pressure, it is important to highlight that the findings of this review, especially related to the behavior of blood pressure after dynamic resistance exercise, are in line with the findings of this review. previous studies involving aerobic exercise/training[23,24] suggesting that those who have hypotension after a single session of aerobic exercise and dynamic resistance exercise are the most likely to have a reduction blood pressure in chronic terms in these modalities.

To the best of our knowledge, this is the first meta-analysis study with correlation data between the acute response and the chronic effect of resistance training on blood pressure. The analysis model, with correlation data, differs from other meta-analysis studies in the area, which usually present analyzes with a mean difference. As advantages of this model, in addition to being different from the others, it also allows the inclusion of studies with different experimental designs. Regarding the analysis of the methodological quality of the studies included in the review, there is no specific tool that considers the different study designs, which limits the assessment of this aspect in a more robust way and compromises the real interpretation of the data. Even so, it was possible to observe a low heterogeneity between the studies in several aspects evaluated. Another important limitation related to the characteristics of the studies is the lack of data regarding the correlation of the acute response and the chronic effect, compromising the number of studies included in the meta-analysis, being lower than the number of selected studies. In addition, as it is a current topic, there is still not a diversity of studies that allow subgroup analyzes that help in the interpretation of the influence of the characteristics of the participants or the exercise/training session on the general effects.

It is suggested, therefore, that those who respond with greater increases in SBP during the performance of isometric resistance exercise and/or with greater drops in SBP and DBP after dynamic resistance exercise are those who tend to present the best chronic adaptations to training in these conditions outcomes. Such findings reinforce the usefulness and importance of analyzing blood pressure responsiveness to a single exercise session, representing a tool for predicting the chronic effects of training.

5. Conclusions

Based on the results of the present review, it is concluded that the acute response of blood pressure to a single session of isometric or dynamic resistance exercise is associated with the chronic adaptations of these training modalities on this variable. The SBP reactivity identified during a single isometric exercise session is related to the drop in SBP after a period of training in this modality. The hypotensive effect identified after a single session of dynamic resistance exercise is related to the chronic reduction in blood pressure resulting from training in this modality.

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