Chronic Effect of Resistance Training on Blood Pressure in Older Adults with Prehypertension and Hypertension: A Systematic Review and Meta-analysis

Abstract

The chronic antihypertensive effect of resistance training (RT) has been widely recognized in mixed-aged populations. However, the specific effect of RT on blood pressure (BP) in older individuals (≥ 60 years) remains unknown. Therefore, this meta-analysis of randomized controlled trials explored the chronic effects of dynamic RT alone on BP in older people. The study followed the PRISMA statement, and the search was performed using MeSH terms "strength training", "blood pressure" and "aged" on MEDLINE (PubMed), SCOPUS, and Web of Science databases. From 1783 potential articles, 24 studies met all inclusion criteria resulting in 835 participants randomized into 26 RT interventions (n=430) and 24 control groups (n=405). Overall, BP reduction favoring RT was observed both in SBP (-6.88 [-10.02, -3.73] mmHg) and DBP (-3.37 [-4.71,-2.22] mmHg). Subgroup analysis revealed BP decreases in both participants with hypertension (SBP:-10.42 [- 15.67,-5.17]; DBP:-3.99 [-5.76,-2.22] mmHg), and prehypertension (SBP:- 4.87 [-7.76,-1.98]; DBP:-2.77 [-4.88,-0.66] mmHg). Improvement in BP was found in studies using traditional RT (free weights and machines) (SBP:-7.04 [-11.04,-3.05]; DBP:-2.60 [-3.72,-1.47] mmHg) and elastic band interventions (SBP:-2.79 [-3.72,-1.86]; DBP:-1.68 [-3.18,-0.18] mmHg). RT performed at moderate intensity (60-80% 1RM) reduced SBP (-6.98, [-11.93,-2.03]mmHg) and DBP (-3.64 [-5.11,-2.18] mmHg). In conclusion, RT can reduce BP in older people at prehypertensive and hypertensive stage, with traditional RT performed with moderate loads leading to an effect estimate of approximately -7 mmHg for SBP and -4 mmHg for DBP.

Keywords: Age, Haemodynamics, Strength training, Diastolic blood pressure, Systolic blood pressure.

1. Introduction

Systemic arterial hypertension is a common condition related to an increased risk of cardiovascular disease/mortality (Cornelissen et al., 2011; Danaei et al., 2009; Lim et al., 2012; Yang et al., 2012). The prevalence of elevated blood pressure (BP) increases with age (Go et al., 2014; Mills et al., 2016) and it has been reported that the number of adults aged 30-79 years living with hypertension doubled worldwide from 1990 to 2019 based on population estimates from low, middle and high-income countries(Zhou et al., 2021).

Regular aerobic exercise and dynamic resistance training (RT) are effective non-pharmacological strategies for high BP management and widely recommended for both young and older adults (Brook et al., 2015; Cornelissen et al., 2011; Cornelissen and Smart, 2013; Dasgupta et al., 2014; MacDonald et al., 2016; Pescatello et al., 2015). International guidelines recommend lifestyle modifications as the first line of treatment for hypertension, including aerobic exercise for at least 150 minutes per week, preferably supplemented with resistance exercise (Pescatello et al., 2015, 2004).

Aging is related to decreased muscle strength, power, and functional capacity, and RT programs are recommended to counteract age-related neuromuscular impairments (McKinnon et al., 2017; Pereira et al., 2012; Ramírez-Campillo et al., 2014). Besides its positive effects on the neuromuscular system, previous meta-analyses have shown that RT is effective in reducing systolic (SBP) and diastolic (DBP) BP (Ashton et al., 2020; Cornelissen and Smart, 2013; MacDonald et al., 2016). Accordingly, RT may be used as a therapeutic strategy to counteract age-related neuromuscular impairments while assisting in BP management (Cornelissen and Smart, 2013; MacDonald et al., 2016).

A variety of factors modulate the long-term (i.e. chronic) effects of training on BP. For example, the magnitude of the chronic antihypertensive effect of exercise (i.e.relatively persistent reduction in BP after weeks of months of training) is related to the degree of BP reduction after acute exercise sessions, and also may be influenced by training variables (e.g., intensity and/or volume) and participants' characteristics (e.g., previously BP status)(Cornelissen and Smart, 2013; Liu et al., 2012; Pescatello et al., 2015). According to previous exercise recommendations, Pescatello et al. (2015) found that weekly frequency of 2 to 3 times, intensity of 60 to 80% of 1RM (one repetition maximum), volume of 2 to 3 sets and 10 to 12 repetitions for 8 to 10 exercises per session can be the most favorable RT organization to obtain chronic BP benefits. Nevertheless, it's important to note that there is a consensus gap of organizations and committees regarding RT prescription, especially in specific populations (as older people). Importantly, previous meta-analyses have reported antihypertensive effects of RT in mixed populations, including young and older adults (Cornelissen et al., 2011; Cornelissen and Fagard, 2005; Cornelissen and Smart, 2013; de Sousa et al., 2017; Kelley, 1997; Kelley and Kelley, 2000; Rossi et al., 2013), which means that existing effect estimates on BP are not specific for older adults. Furthermore, the chronic impact of different RT variables (e.g., type and intensity) on BP in this population remains unknown. Identifying whether specific RT is related to improved BP outcomes in older adults may help plan and use RT as antihypertensive therapy for this population. Hence, this systematic review with meta-analysis of randomized clinical trials was conducted to explore the chronic effects of RT compared to non-exercise control in SBP and DBP in older adults ($\geq$ 60 years) .

2. Material and Methods

Search strategy and studies selection procedure

The study was conducted following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement (Liberati et al., 2009). The search was carried out from January 2020 to May 2021, including all literature published until the date on MEDLINE (via PubMed), SCOPUS, and Web of Science electronic databases. The search was performed using the keywords "strength training" (MeSH terms) for intervention, "blood pressure" (MeSH terms) for study outcome, as well as "aged" (MeSH terms) for the population (Supplementary Material 1). The filters human interventions and the English language were used. The reference lists were examined to detect studies potentially eligible for inclusion, and the search strategy complete results are summarized in Figure 1.

Inclusion and exclusion criteria of studies

This manuscript included randomized controlled trials that measured SBP and DBP outcomes to RT programs alone vs. control/non-exercise in older adults. The inclusion criteria were the following: (1) participants included in studies should be 60 years or older (Coelho-Júnior et al., 2022); (2) randomized controlled trials with exercise intervention lasting at least six weeks; (3) use of supervised dynamic resistance training alone as intervention (i.e., traditional resistance exercise, power training, elastic bands or circuit-based; excluding studies interventions with aerobic or concurrent exercise); (4) presence of control group that did not perform regular physical exercise; (5) reported office blood SBP and DBP pre- and post-intervention for RT and control groups by the auscultatory or automatic method.

The exclusion criteria were: (1) studies that did not mention clear inclusion criteria and randomization of participants; (2) RT interventions combined with a diet program or specific drug therapy introduced as part of the study; (3) RT interventions with blood flow restriction; (4) participants with chronic conditions as cancer, Parkinson's disease, chronic kidney disease on hemodialysis, and chronic obstructive pulmonary disease; (5) studies employing only a single exercise as RT routine; (6) studies with exclusively acute assessment of BP; (7) unstable BP in the three months before the study; (8) studies including participants taking part on a regular physical exercise program three months before enrolment in the randomized controlled trial; (9) studies published in languages other than English; (10) no access to full-version of articles (11) crossover design and pilot studies.

Data extraction

Titles and abstracts of all articles identified by the search strategy were independently assessed by two researchers in duplicate (C.L.F.M. and J.H.) using Mendeley software (version 2.84.0). Abstracts that did not provide enough information regarding the inclusion and exclusion criteria were selected for full-text evaluation. In the second phase, the same reviewers independently evaluated these full-text articles and selected them following eligibility criteria. In case of lack of information regarding eligibility criteria, a contact was made with the authors to clarify each item. Disagreements between reviewers were resolved by consensus, and if conflict persisted, a third reviewer (E.N.W.) was consulted.

Data extraction was performed independently by the same reviewers in a standardized form. The primary results analyzed were SBP and DBP pre- and post-interventions. Also, information about study interventions, outcomes, and patients was recorded. Adverse events and feasibility were also extracted whenever informed.

Data presentation

The findings are presented in mean and 95% confidence interval (meta-analysis results) or mean and standard deviation. A meta-analysis with subgroup analysis based on BP classification (hypertensive and prehypertensive status), training mode (traditional RT [i.e., studies using free weights and machines], elastic band RT, and power training [i.e., the concentric phase completed as fast as possible followed by a controlled, slower eccentric muscle action]), number of training sessions, and RT intensity was performed. The mean group's SBP and DBP levels were classified as normotensive (<120/<80mmHg); prehypertensive (120-139/80-89mmHg); and hypertensive stage 1 (140 – 159 / 90 - 99mmHg) (Chobanian et al., 2003; Zhou et al., 2021). Total training session was calculated as weekly training frequency multiplied by training weeks, with subgrups split into studies with less than 33 sessions and those including 33 or more sessions. The RT intensity was classified as low (<60% of 1- repetition maximum [RM], or >15RM), moderate (60 - 80% 1RM, or 8 – 15 RM) or high (>80% 1RM, or <8RM) (Lopez et al., 2021).

Methodological quality

Methodological quality and assessment of the risk of bias included studies were performed independently by two investigators (C.L.F.M. and J.H.) using the PEDro scale. The score range from 0 to 10, and the scale consists of the following 11 items: specified eligibility criteria (not rated and taken into account in the PEDro score), randomly allocation, concealed allocation, similar baseline groups, blinding of subjects, blinding of therapists, blinding of assessors, measures in at least 85% of the participants, intention-to-treat analysis, between-group statistical comparisons and variability measures. As blinding of participants and therapists was considered not feasible for exercise interventions, these items were omitted (Olivo et al., 2008). One point was awarded when an item was present, resulting in a range from 0 to 8. Studies that reached 6 points or more were classified as high quality, 4 or 5 moderate quality, and < 4 points low methodological quality (Luo et al., 2020).

Statistical Analysis

Descriptive data is presented as mean ± standard deviation (SD) or range of values, whereas the mean difference for absolute values between the intervention (RT) and control groups with associated 95% confidence intervals was used for meta-analysis. Within-group change of scores was calculated (post - pre) and the net treatment effect was estimated as the mean difference of BP (both SBP and DBP) by subtracting the change of score of the control arm from that of the intervention arm of each trial. Effect estimates were calculated with random effect models using RevMan 5 (Cochrane, UK) considering mean differences of change of score and SD. Whenever SDs for changes from baseline were not available, these were calculated using pre and post-SDs using the coefficient of correlation (r) between pre and post-values. If r was not reported, the change of score SD was calculated assuming r = 0.50, as described elsewhere (Cornelissen and Smart, 2013; Higgins et al., 2019). To avoid double-counts of participants, in trials with multiple intervention arms the control arm was split into smaller sample size groups. Statistical heterogeneity was assessed with Cochran's Q statistic, with I^2 values above 50% considered as high heterogeneity. Subgroup analyses were performed considering participants' baseline BP (prehypertension vs hypertension), training mode (traditional, elastic band, or power RT), and RT intensity based on 1 repetition maximum (i.e. low intensity, moderate intensity, or high intensity). The level of significance was set at ≤ 0.05.

3. Results

Literature search

A total of 1783 potential studies were identified in electronic databases, from which 24 met all inclusion criteria. Two studies (Coelho-Junior et al., 2018; Kanegusuku et al., 2011) had two intervention groups, which were analyzed separately. Overall, 835 participants were randomized into 26 RT interventions (n = 430) and 24 control groups (n = 405). Main study characteristics are shown in Table 1.

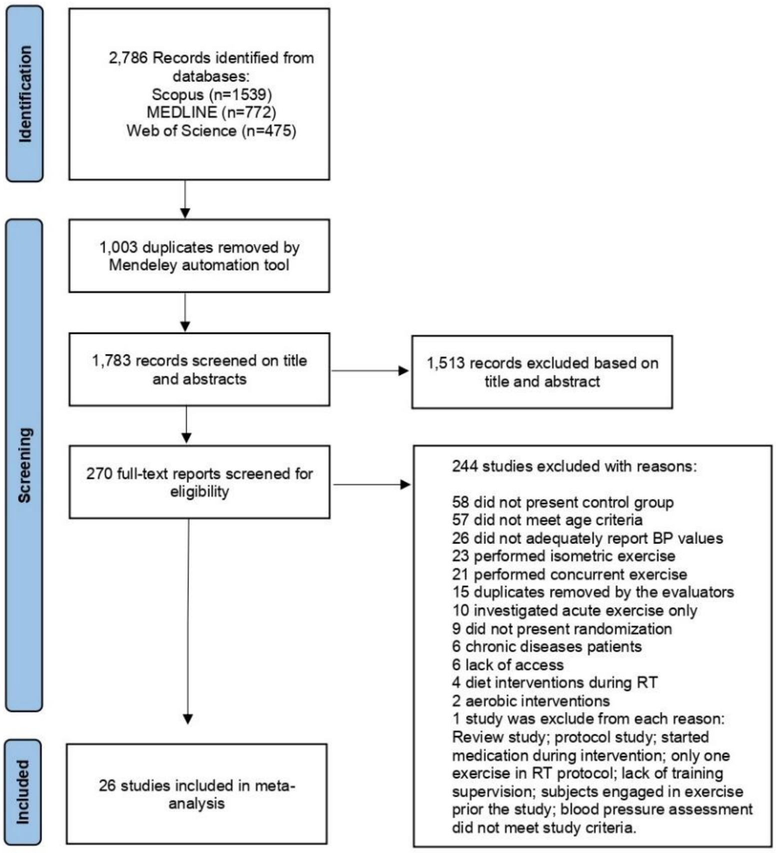

Figure 1. PRISMA flow diagram depicting study selection and screening process for the systematic review and meta-analysis.

Table 1. Overall characteristics of included studies.

Study	Country	Participants per G	Sex of Participants	Age ±SD	Baseline SBP/DBP (mmHg)	Training Type	Training Details	SBP/DBP Change (mmHg)
Beltran et al., 2014	Italy	PT: 13 CG: 10	M: 7 F: 6 M: 5 F: 5	72±1 72±1	122/78 131/75	Power Training	4 exercises 70% 1RM or 12RM 3-4 sets of 10-12 reps 2x/wk for 12 wks	-6/-2 -2/+9
Castaneda et al., 2002	United States	RT: 31 CG: 31	M: 10 F: 21 M: 12 F: 19	66±1 66±2	145/73 143/71	Traditional RT	5 exercises 60-80% 1RM 3 sets of 8 reps 3x/wk for 14 wks	-10/-3 +8/0
Coelho-Junior et al., 2018	Brazil	MIX: 12 RT: 10 CG: 14	M: 0 F: 12 M: 0 F: 10 M: 0 F: 14	67±5 68±4 68±6	149/86 145/91 138/80	RT, PT, & Elastic Band Traditional RT	9 exercises 3-6 RPE (CR-10) 3 sets of 8-10 reps 2x/wk for 22 wks	-14/-10 -20/-14 +7/+3
Cononie et al., 1991	United States	RT: 20 CG: 12	M: 11 F: 9 M: 4 F: 8	72±3 72±3	132/78 137/81	Traditional RT	10 exercises 12RM 1 set of 12 reps 3x/wk for 26 wks	0/0 +3/+2
Gerage et al., 2013	Brazil	RT: 15 CG: 14	M: 0 F: 15 M: 0 F: 14	66±5 66±4	125/81 123/80	Traditional RT	8 exercises 10-15RM 2 sets of 10-15 reps 3x/wk for 12 wks	-5/-1 +3/+2
Gonçalves et al., 2014	Brazil	RT: 7 CG: 10	M: 0 F: 7 M: 0 F: 10	66±2 66±1	126/81 137/88	Traditional RT	8 exercises 40% 1RM or "mild" to "moderate" RPE 2 sets of 15 reps 3 x/wk for 12 wks	-3/+1 -2/0
Gurjão et al., 2013	Brazil	RT: 10 CG: 7	M: 0 F: 10 M: 0 F: 7	62±5 65±5	131/86 121/75	Traditional RT	7 exercises 10-12RM 3 sets of 10-12 reps 3x/wk for 8 weeks	-13/-11 +5/-3

Heffernan et al., 2013	Not informed	RT: 11 CG: 10	M: 2 F: 9 M: 4 F: 6	60±2 63±3	140/83 136/86	Traditional RT	9 exercises 40-60% 1RM to 15RM 2 sets of 12-15 reps 3x/wk for 12 wks	-6/-6 +3/-4
Hsieh et al., 2018	Taiwan	RT: 15 CG: 15	M: 5 F: 10 M: 6 F: 9	71±4 72±5	127/67 132/70	Traditional RT	8 exercises 40-50% 1RM or 12-13 RPE (6-20 scale); 75% 1RM or 14-16 RPE 3 sets of 8-12 reps 3x/wk for 12 wks	-8/0 -1/-4
Kadoglou et al., 2012	Greece	RT: 23 CG: 24	M: 7 F: 16 M: 5 F: 19	62±5 65±4	121/71 144/83	Traditional RT	8 exercises 60-80% 1RM 2-3 sets of 6-8 reps 3x/wk per 12 wks	-10/-5 -5/-2
Kanegusku et al., 2011	Brazil	RT:13 PT: 15 CG: 11	M: 5 F: 8 M: 4 F: 11 M: 2 F: 9	63±1 65±1 63±1	121/78 125/75 127/77	Traditional RT Power training	RT: 7 exercises 70-90% 1RM 2-4 sets of 4-10 reps 2x/wk for 16 wks PT: 7 exercises 30-50% 1RM 3-4 sets of 4-7 reps 2x/wk for 16 wks	-5/-3 -8/-2 -9/-4
Lee et al., 2019	United States	RT:10 CG: 8	M: 3 F: 7 M: 3 F: 5	67±7 67±5	126/81 121/77	Traditional RT	5 exercises 70% 1RM or 10RM 2 sets of 10 reps 2x/wk for 12 wks	0/0 +1/+1

Oliveira-Dantas et al., 2016	Brazil	RT: 13 CG: 12	M: 0 F: 13 M: 0 F: 12	65±5 68±6	143/68 140/67	Traditional RT	9 exercises 5-7 OMNI-RES scale 1-3 sets of 9-15 reps 2-3x/wk for 10 wks	-6/-3 +5/+5
Park et al., 2016	North Korea	EB: 15 CG: 15	M: 15 F: 0 M: 15 F: 0	73±3 71±4	129/75 128/74	Elastic Band Training	14 exercises Green elastic band 3-5 sets of 10-15 reps 3x/wk for 24 wks	-1/0 0/0
Roberson et al., 2018	United States	PT: 9 CG: 7	M: 2 F: 7 M: 1 F: 6	72±3 70±3	139/81 124/71	Power Training	11 exercises 40-70% 1RM 3 sets of 12 reps 3x/wk for 12 wks	-20/-10 0/+3
Ruangthai et al., 2019	Thailand	RT: 13 CG: 12	M: 0 F: 13 M: 5 F: 7	68±7 67±6	147/81 141/83	Traditional RT	14 exercises 50-80% 1RM 3 sets of 10-15 reps 3x/wk for 12 wks	-5/-6 +2/0
Simons & Andel et al., 2006	United States	RT: 21 CG: 21	M: 6 F: 15 M: 3 F: 18	85±5 84±3	133/70 128/68	Traditional RT	6 exercises 75% 1RM or 10RM 1 set of 10 reps 2x/wk for 16 wks	-9/-2 +1/+2
Son et al., 2020	South Korea	EB: 10 CG: 10	M: 0 F: 10 M: 0 F: 10	68±1 68±1	139/82 139/81	Elastic Band Training	9 exercises 11-16 RPE (6-20 scale) 2-4 sets of 10-20 reps 3x/wk for 12 wks	-3/-1 0/0
Thomas et al., 2005	China	EB: 65 CG: 78	M: 35 F: 30 M: 44 F: 34	69±3 69±3	142/72 140/71	Elastic Band Training	7 exercises intensity not informed 1 set of 30 reps 3x/wk for 52 wks	-5/0 0/+1

Timmons et al., 2018	Ireland	RT: 21 CG: 21	M: 10 F: 11 M: 8 F: 13	70±5 69±3	148/86 140/82	Traditional RT	6 exercises 60% 1RM or 15RM 4 sets of 15 reps 3x/wk for 12 wks	-3/-5 -4/-2
Tomeleri et al., 2017	Brazil	RT: 15 CG: 15	M: 0 F: 15 M: 0 F: 15	69±7 67±5	142/80 136/75	Traditional RT	8 exercises 10-15RM 1 set of 10-15 reps 2x/wk for 12 wks	-9/-8 -2/-1
Tomeleri et al., 2018	Brazil	RT: 22 CG: 23	M: 0 F: 22 M: 0 F: 23	72±6 69±5	121/70 124/70	Traditional RT	8 exercises 10-15RM 3 sets of 10-15 reps 3x/wk for 12 wks	-6/-2 +1/0
Wanderley et al., 2013	Portugal	RT: 11 CG: 19	M: 4 F: 7 M: 4 F: 15	67±5 68±6	131/71 141/76	Traditional RT	9 exercises 80% 1RM 2 sets of 12-15 reps 3x/wk for 34 wks	-8/-4 -5/-2
Wood et al., 2001	United States	RT: 10 CG: 6	M: 5 F: 5 M: 3 F: 3	70±6 68±5	129/75 134/78	Traditional RT	8 exercises 8-12RM 2 sets of 8-12 reps 3x/wk for 12 wks	-5/-3 -4/+2

Data are presented as mean, or the absolute number of participants per group.n: number; SD: standard deviation; SBP: systolic blood pressure; DBP: diastolic blood pressure; RT: resistance training group; CG: control group; PT: power training group; EB: elastic band training group; MIX: Mixed training group (RT, PT and EB); M: male; F: Female; RM: maximal repetitions; 1RM: one repetition maximum; reps: repetitions; RPE: rate of perceived effort; wk: week.

Methodological quality

The methodological quality and reporting of the included trials are presented in Table S1. The mean score for the PEDro scale was 5.8 (ranging from 4 to 8). Of the 24 trials, 14 reached 6 or more points and were considered high quality and low risk of bias (Castaneda et al., 2002; Coelho-Junior et al., 2018; Heffernan et al., 2013; Hsieh et al., 2018; Kadoglou et al., 2012; Kanegusuku et al., 2011; Lee et al., 2019; Oliveira Dantas et al., 2016; Park, 2016; Simons and Andel, 2006; Thomas et al., 2005; Timmons et al., 2018; Tomeleri et al., 2018). Ten studies reached four or five points and were considered as moderate methodological quality (Beltran Valls et al., 2014; Cononie et al., 1991; Gerage et al., 2013; Gonçalves et al., 2014; Gurjão et al., 2013; Roberson et al., 2018; Ruangthai and Phoemsapthawee, 2019; Tomeleri et al., 2017; Wanderley et al., 2013; Wood et al., 2001). No study was classified as low methodological quality. All studies satisfied the criteria concerning specified eligibility criteria (not rated), random allocation, similar baseline values, between-group statistical comparisons, and variability measures. The items least informed were blinding of assessors, allocation concealment, and intention-to-treat analysis.

Studies characteristics

Details of participants in the studies included are presented in Table 2. Six emails were sent regarding eligibility criteria, and only two were answered by the authors. Among the studies that reported the previous training status of the individuals, all were classified as untrained. The RT interventions had an average of 16 ± 11 participants (ranging from 7 to 65), with training adherence greater than 85%. Most of the interventions (14 of 26)(Beltran Valls et al., 2014; Castaneda et al., 2002; Heffernan et al., 2013; Hsieh et al., 2018; Kadoglou et al., 2012; Kanegusuku et al., 2011; Lee et al., 2019; Nunes et al., 2014; Roberson et al., 2018; Ruangthai and Phoemsapthawee, 2019; Simons and Andel, 2006; Timmons et al., 2018; Wanderley et al., 2013) prescribed the RT program based on % of 1RM (ranging from 30 to 90% 1RM). Six interventions(Cononie et al., 1991; Gerage et al., 2013; Gurjão et al., 2013; Tomeleri et al., 2018, 2017; Wood et al., 2001) used RM (ranging from 8 to 15 RM), and six(Coelho-Júnior et al., 2018; Gonçalves et al., 2014; Hsieh et al., 2018; Oliveira Dantas et al., 2016; Son et al., 2020) employed intensity based on rate of perceived effort. Two studies using elastic bands(Park, 2016; Thomas et al., 2005) did not report RT intensity. Interventions lasted on average 16.5 ± 9.3 weeks (ranging from 8 to 52 weeks), with a frequency of 2.3 ± 0.5 sessions/week (ranging from 2 to 3 sessions/week). The mean number of repetitions per set was 11.8 ± 4.5 (ranging from 4 to 30), with 2.5 ± 0.9 sets volume (ranging from 1 to 5 sets) per exercise. An average of 8.2 ± 2.3 exercises were performed for each RT session (ranging from 4 to 12 per training session).

Table 2. Characteristics of participants in the included studies.

Sample characteristics	RT Interventions (n)	RT participants	GC Interventions (n)	CG participants
Men, n (%)	16	131 (30.4)	16	124 (30.6)
Women, n (%)	25	299 (68.9)	23	281 (69.4)
Diabetes Mellitus, n (%)	7	77 (17.9)	7	71 (17.5)
Antyhipertensive medications, n (%)	14	99 (23.0)	13	97 (24.0)
BP classification, n (%)				
Prehypertension	17	239 (55.6)	16	212 (52.3)
Hypertension Stage 1	9	191 (44.4)	8	193 (47,7)
Hypertension stage 2	0	-	0	-

Data are presented as mean ± SD, or the number of participants and proportion of the RT and control groups, n (%). n: number; RT: resistance training group; CG: control group.

Meta-analysis results

RT effect on Resting BP

The BP changes are presented in Figures 2 and 3. A reduction in SBP (-6.88 mmHg, 95% CI: -10.02, -3.73) was observed in favor of RT (Figure 2). Similarly, a reduction in DBP (-3.37 mmHg, 95% CI: -4.71, -2.22) was found favoring the RT intervention (Figure 3).

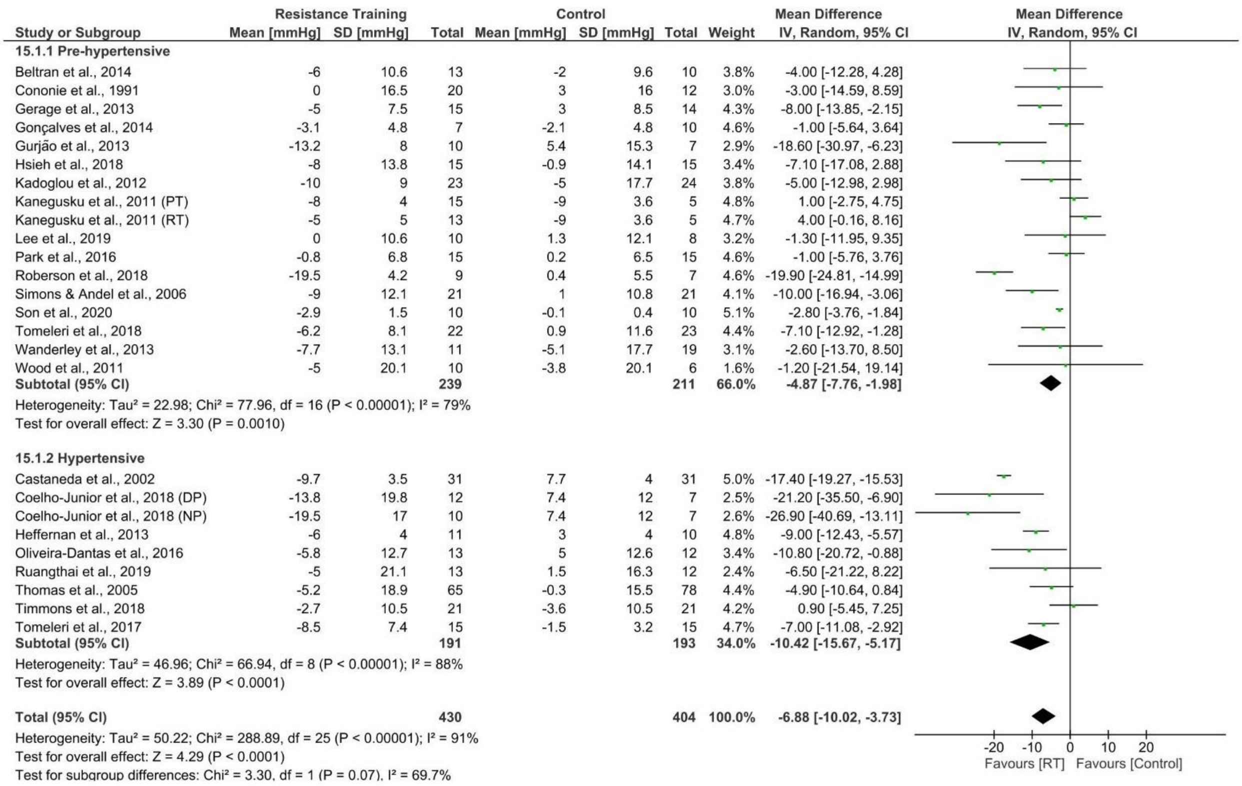

Figure 2. Systolic blood pressure (SBP) changes in response to resistance training in older adults with prehypertension and hypertension.

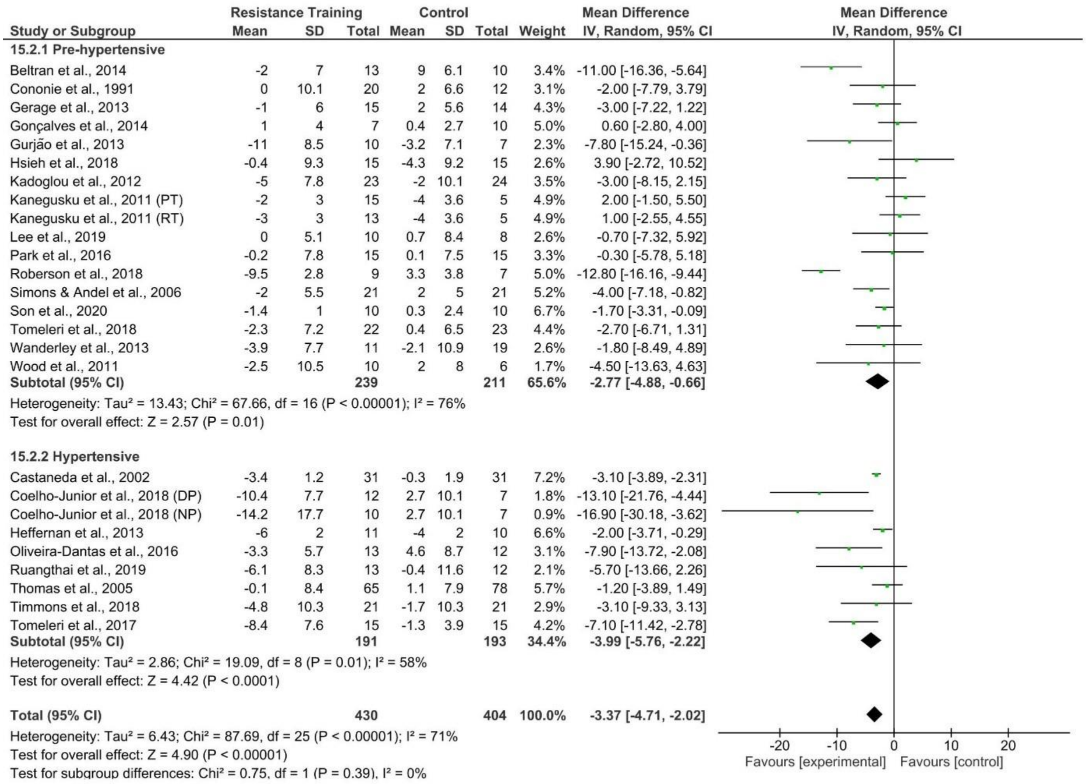

Figure 3. Diastolic blood pressure (DBP) changes in response to resistance training in older adults with prehypertension and hypertension.

RT effects based on resting BP status

Subgroup analysis revealed SBP reductions in participants with hypertension and those at the prehypertensive stage. Figure 2 shows that individuals with hypertension achieved SBP reductions of -10.42 mmHg (95% CI: -15.67, -5.17), and those with prehypertension decreased SBP by -4.87 mmHg (95% CI: -7.76, -1.98) compared to the control arm. Similarly, effect estimates showed as reduction in DBP in older individuals with hypertension (-3.99 mmHg, 95% CI: -5.76, -2.22), with those with prehypertension benefiting from a drop of -2.77 mmHg (95% CI: -4.88, -0.66) in DBP. No difference was evident between participants with hypertension and prehypertensioin in SBP (p = 0.07) and DBP (p = 0.39). High heterogeneity (>50%) was observed in all analyses.

Effect of RT Type, Number of Training sessions, and Internsity on BP

The magnitude of SBP and DBP changes based on RT mode and intensity are present in Table 3. The mean estimate effect of studies using traditional RT was a reduction of -7.04 mmHg (95% CI: -11.04, -3.05) for SBP, while elastic band interventions resulted in a drop of -2.79 mmHg (95% CI: -3.72, -1.86), presenting a significant difference between subgroups (p=0.04). Regarding DBP, traditional RT interventions resulted in a mean reduction of -2.60 mmHg (95% CI: -3.72, -1.47), and elastic band interventions reduced DBP by -1.68 mmHg (95% CI: -3.18, -0.18), with no difference between subgroups. Interventions using power training did not lead to statistically significant reduction in BP (SBP: -7.67 [95% CI: -22.05, 6.72] mmHg; DBP: -7.21, [95% CI: -17.28, 2.87] mmHg).

Regarding RT intensities, only interventions employing at moderate intensity resulted in significant SBP (-6.98, 95% CI: -11.93, -2.03 mmHg) and DBP (-3.64, 95% CI: -5.11, -2.18 mmHg) reductions. The low-intensity interventions did not reach a statistical decrease in SBP or DBP. A significant difference between intensity subgroups was found for both SBP and DBP (p = 0.03, and 0.001, respectively). No study included in the analysis was classified as high intensity.

No subgroup differences were observed between studies totalling less than 33 training sessions compared to those with more than 33 sessions throughout the experimental period for SBP (p= 0.35) and DBP (p = 0.60) (Table 3).

One intervention arm (Coelho-Junior et al., 2018) [daily periodization group] was not included in the RT type analysis due to a mix of training methods within the training program. Similarly, others studies(Heffernan et al., 2013; Hsieh et al., 2018; Oliveira Dantas et al., 2016; Roberson et al., 2018; Ruangthai and Phoemsapthawee, 2019; Son et al., 2020) were not included in the intensity analysis because the session exercises were performed at intensities ranging from low to moderate throughout the intervention program.

Table 3. Mean difference of systolic and diastolic blood pressure changes based on RT protocols.

RT characteristics	Groups (n)	SBP (mmHg)	p	DBP (mmHg)	p
Training Mode		Subgroup differences	0.10	Subgroup differences	0.40
		RT vs. EB	0.04*	RT vs. EB	0.34
		RT vs. PT	0.93	RT vs. PT	0.37
		EB vs. PT	0.51	EB vs. PT	0.29
Traditional RT	19	-7.04 (-11.04, -3.05)	<0.001*	-2.60 (-3.72, -1.47)	<0.001*
Elastic band	3	-2.79 (-3.72, -1.86)	<0.001*	-1.68 (-3.18, -0.18)	0.03*
Power Training	3	-7.67 (-22.05, 6.72)	0.30	-7.21 (17.28, 2.87)	0.16
Intensity		Subgroup differences	0.03*	Subgroup differences	0.001*
Low (<60% 1RM)	4	-0.88 (-3.16, 1.41)	0.45	0.12 (-1.60, 1.83)	0.89
Moderate (60-80% 1RM)	15	-6.98 (-11.93, -2.03)	0.006*	-3.64 (-5.11, -2.18)	<0.001*
Total training sessions		Subgroup differences	0.35	Subgroup differences	0.60
Less than 33 sessions	8	-4.78 (-9.48, -0.08)	<0.001*	-4.12 (-7.47, -0.77)	<0.001*
More than 33 sessions	18	-7.74 (-11.76, -3.72)	<0.001*	-3.13 (-4.65, -1.61)	<0.001*

Data shown in mean, 95%CI. SBP: systolic blood pressure; DBP: diastolic blood pressure; n: number; RT: resistance training; EB: Elastic Band; PT: Power Training; 1RM: maximum repetition.*p<0.05

4. Discussion

The main findings of the present study were that a) RT alone decreases SBP and DBP in older adults with prehypertension and hypertension; and b) traditional RT and c) RT programs with moderate intensity are effective strategies for BP management in older individuals. To our knowledge, this is the first meta-analysis investigating the effects of traditional RT on BP exclusively in older people and, based on effect estimates, a mean reduction of approximately -7 mmHg for SBP and -3 mmHg for DBP might be expected in this population.

Recently, a meta-analysis by Ashton et al., (2020)(Ashton et al., 2020) reported a larger magnitude of SBP reductions in ≥41 years old adults compared to younger adults after RT interventions. The present study expands the current understanding of the field by providing an effect estimate of different types of RT and intensities on the BP exclusively in older people (≥ 60 years). Prior meta-analyses using mixed-age groups reported a positive effect of RT alone on BP, with reductions ranging from -1.8 to -8.2 mmHg for SBP and -2.1 to -4.9 mmHg in DBP (Ashton et al., 2020; Cornelissen and Smart, 2013; de Sousa et al., 2017; MacDonald et al., 2016). Decreases of ~5 to 3 mmHg have been reported in subgroup analysis including older adults with exercise(Abrahin et al., 2021; Herrod et al., 2018), however, the effect estimate of RT on BP in older adults had not been explored in detail before. The mean SBP reduction found in this study (~-7 mmHg) presents considerable relevance since differences of approximately 5 mmHg were associated with a lower risk for stroke (-14%) and coronary heart disease (-9%)(Stamler, 1991; 2002). Similarly, small DBP differences of ~2 mmHg are also associated with reduced risk for stroke (-15%) and coronary heart disease (-6%)(Cook et al., 1995).

In the current study, moderate intensity (i.e. 60 to 80% 1RM) interventions elicited improvements in both SBP and DBP, which was not observed with low intensity RT (e.g. <60% 1RM). It is important to note that the current inference is not made based on a direct analysis of intensity effect as our findings are derived from a pooled analysis of different trials. Previous interventions compared the effects of moderate intensity RT (~60% 1RM or 15RM) to moderately-high RT (~80% or 10RM) performed three times a week in older adults. Both studies and training groups significantly improved SBP. In an earlier study (Tsutsumi et al., 1997), the moderate intensity RT group decreased SBP by 13.4 mmHg (-10.8%) and DBP by 2.1 mmHg (-3%); while the moderately-high intensity reduced SBP by 6.1 mmHg (-5.5%), with no significant changes in DBP. In a more recent trial (Ribeiro et al., 2020), both groups reduced SBP (moderate intensity RT ≈ -3.6 mmHg [-3.0%]; moderately-high intensity RT ≈ -5.9 mmHg [−4.6%], with no change in DBP. No study directly comparing low intensity RT (<60% of 1RM, or >15RM) with high intensities was found. Nevertheless, the current results in older adults support previous exercise recommendations (Pescatello et al., 2015; Polito et al., 2021) suggesting RT intensity to range from 60 to 80% 1RM to obtain BP benefits in adults.

Additionally, we observed that traditional RT can bring about positive adjustments in SBP and DBP, with the use of elastic bands also showing a positive (although less evident) effect on resting BP. The results regarding chronic effect of power training were not conclusive. Although some previous studies (Machado et al., 2020; Miyamoto et al., 2017) showed lower BP increases during a power training session compared to the traditional session in older adults, recently, a meta-analysis study by Coelho-Junior (2022) did not observe significant effects of an acute session of power training on BP. In this context, the authors(Hélio J Coelho-Júnior et al., 2022) presented that power training chronically reduced SBP, but not DBP, in older adults. At this point in time, it is not possible to recommend the use of this intervention specifically for long-term BP management in older adults with prehypertension and hypertension.

Despite that, it is important to highlight that effects estimated for the elastic band and power training are derived from a small number of studies (i.e. 3 trials for each type of training), with large variance in the results. Therefore, further RCTs are still necessary for a more categorical conclusion regarding the potential use of non-traditional types of RT for BP management in older individuals. Also, it is noteworthy that most elastic band interventions and power training groups included in this meta-analysis did not reach the minimum intensity (≥60% 1RM, or ≤15 RM) that seems to be more favorable to promote BP improvements.

Addressing the impact of body mass index and metabolic health on BP outcomes could benefit clinical practice. However, few studies recruited exclusively older individuals with type 2 diabetes mellitus (Castaneda et al., 2002; Hsieh et al., 2018; Kadoglou et al., 2012), while the others studies were performed with mixed populations, including healthy individuals and people living with type 2 diabetes mellitus (Roberson et al., 2018; Thomas et al., 2005; Tomeleri et al., 2017; Wanderley et al., 2013). Moreover, few studies were performed with participants' mean body mass index > 30 kg/m² (Castaneda et al., 2002; Kadoglou et al., 2012; Roberson et al., 2018), making it difficult to tease out the effect of obesity and metabolic conditions in our study. Also, most articles did not inform about hormone replacement therapy, with only 4 studies reporting exclusion of volunteers under hormone replacement therapy (Coelho-Júnior et al., 2018; Gerage et al., 2013; Tomeleri et al., 2018, 2017); and one study (Wanderley et al., 2013) reporting inclusion of 1 woman (out of the 30 participants in the RT and control groups) undergoing hormone replacement therapy. None of these studies addressed results based on the presence or absence of these conditions and, therefore, no subgroup-analyses were carried out considering these variables in the current manuscript.

Limitations

Our study is not without limitations. For example, we included only published studies written in English language, and potential publication bias has to be considered in the studies available in the electronic databases (Figure S1). In addition, the present study did not isolate the impact of intensity and other RT variables (e.g. volume, frequency) in the observed effects due to the small number of studies, and high heterogeneity was found in the results possibly due to different RT protocols applied. Also, the subgroup analyses presented here must be considered carefully due to the small number of studies for non-traditional RT (e.g. power and elastic band training). The interaction between antihypertensive medication type and RT should also be considered. Still, data reported in existing studies do not allow for a comprehensive analysis of potential pharmacological interaction with RT effects. Finally, although the randomized clinical trials included presented satisfactory levels of quality and bias risk in general, most studies did not adequately report the allocation concealment, blinding of outcome assessment, and intention-to-treat analysis, impairing the reliability of the results and hindering the assessment of the effect of the withdraws in the interventions. We suggest future studies follow specific guidelines(Schulz et al., 2010) to improve the reporting quality of trials and also encourage original research investigating the benefits of different RT variables in older people.

5. Conclusion

RT alone reduces SBP and DBP in older adults with prehypertension and hypertension. There is considerable evidence that moderate intensity (i.e., ranging from 60 to 80% 1RM) and traditional RT improves BP in prehypertensive and hypertensive older adults. However, low intensity RT might not be enough to bring about a chronic reduction in BP. The use of elastic bands also seems to be an alternative strategy, but the results are limited to a small number of trials. The benefit of power training, however, is inconclusive and this training method deserves further investigation given its value for older adults (e.g. improvements in muscle power and strength and fall prevention).

Conflict of Interest

The authors declare no conflict of interest.

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