Effects of resistance training on resting blood pressure in hypertensive population: a systematic review of randomized controlled trials

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DOI: https://doi.org/10.5114/phr.2023.126006

Received: 06.12.2022 **Reviewed:** 21.12.2022 **Accepted:** 22.12.2022

Abstract

Background: The number of people with arterial hypertension is rising every year. Regular resistance training (RT) plays a significant role in blood pressure (BP) management because it can improve hypertension-related factors. Previous reviews relating to the effectiveness of exercise for hypertension showed positive results in the normalization of BP. However, they had a wide range of populations and mixed exercise interventions.

Aims: The purpose of this paper was to systematically review the current literature examining the effects of RT on resting BP in people with hypertension compared to the control group (CG).

Material and methods: The systematic review was carried out following the PRISMA statement between November and December 2022. After searching PubMed, Cochrane Library, and PEDro databases, reviewing potential studies in detail, and checking whether they met the eligibility criteria, nine studies were used in the review. The PEDro scale was used to establish the quality of included studies. Mean difference and Effect Size dppc2 were chosen to estimate the magnitude of RT effects.

Results: Regarding systolic blood pressure (SBP), eight studies showed positive results in RT favor, and 1 showed positive results in CG favor. The average value for the mean difference was 10 mmHg.

Regarding diastolic blood pressure (DBP), seven Studies showed positive results in RT favor, 1 showed positive results in CG favor, and 1 showed no difference. The average value for the mean difference was 4.6 mmHg.

Conclusions: This work showed that RT has a good chance of improving resting BP values in the hypertensive population. However, more good quality studies supported by statistical analysis are needed to draw firm inferences. Due to the limitations of this review, no firm conclusions cannot be drawn.

Key words

blood pressure, resistance training, hypertensive population, hypertension.

Introduction

Hypertension, defined by the American College of Cardiology (ACC) and American Heart Association (AHA) as chronic elevation in systolic blood pressure (SBP) ≥130 or in diastolic blood pressure (DBP) ≥ 80 [1], is a significant modifiable risk factor for cardiovascular disease onset and mortality worldwide counting 10.4 million deaths in 2017 [2]. The number of people with high blood pressure (BP) is rising every year. Between 1990 and 2019, the number of hypertensives increased from 648 million to 1.27 billion. Hypertension is also an economic burden. The USA in 2004 and 2005 spent 55.9$ billion on high BP, and predictions for 2035 say that it will increase to 220.9$ billion [3].

Regular resistance training (RT) plays a big role in BP management because it can improve factors associated with hypertension, such as: a decrease in arterial stiffness [4], a decrease in inflammatory markers [5], improved metabolic health [6], increased vasodilatation [7], decreased sympathetic activation [8]. For example, it was demonstrated that a reduction in SBP by 10 mmHg resulted in a 20% risk of major cardiovascular events lowering in the high-risk population [9].

Previous reviews relating to the effectiveness of exercise for hypertension showed positive results: SBP/DBP values reduced by 3.5/2.5 mmHg after endurance training, 1.8/3.2 mmHg after dynamic resistance training, and 10.9/6.2 mmHg after isometric resistance [10]. Network meta-analysis from 2020 showed a reduction in SBP/DBP by 12.1/7.1 mmHg after combining dietary intervention with aerobic training, 6.8/4 mmHg after isometric training, 5.2/2.7 after RT, and 5.6/3.4 after combining aerobic training with RT [11]. However, they had a wide range of populations and interventions (aerobic training with resistance training and dietary interventions with exercise [11]). Therefore, it is worth narrowing the criteria to a specific group (only hypertensive people) and a specific intervention (RT) to tailor decisions better while making more accurate predictions knowing how a given population responds to the use of RT alone. Since the current review consists only of randomized controlled trials, the level of evidence is estimated at level 1 [12].

Aims

The following systematic review tried to determine whether resistance training (RT) has any effect on resting BP and if so, what is the magnitude of that effect.

Materials and methods

Review standards

This review was carried out following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement [13], the Cochrane Handbook for Systematic Reviews of Interventions [14]. PICO (Population, Intervention, Comparator and Outcomes) framework [15] was used to structure eligibility criteria and search strategy. The author declares that the research conducted is not related to the exploitation of humans or animals.

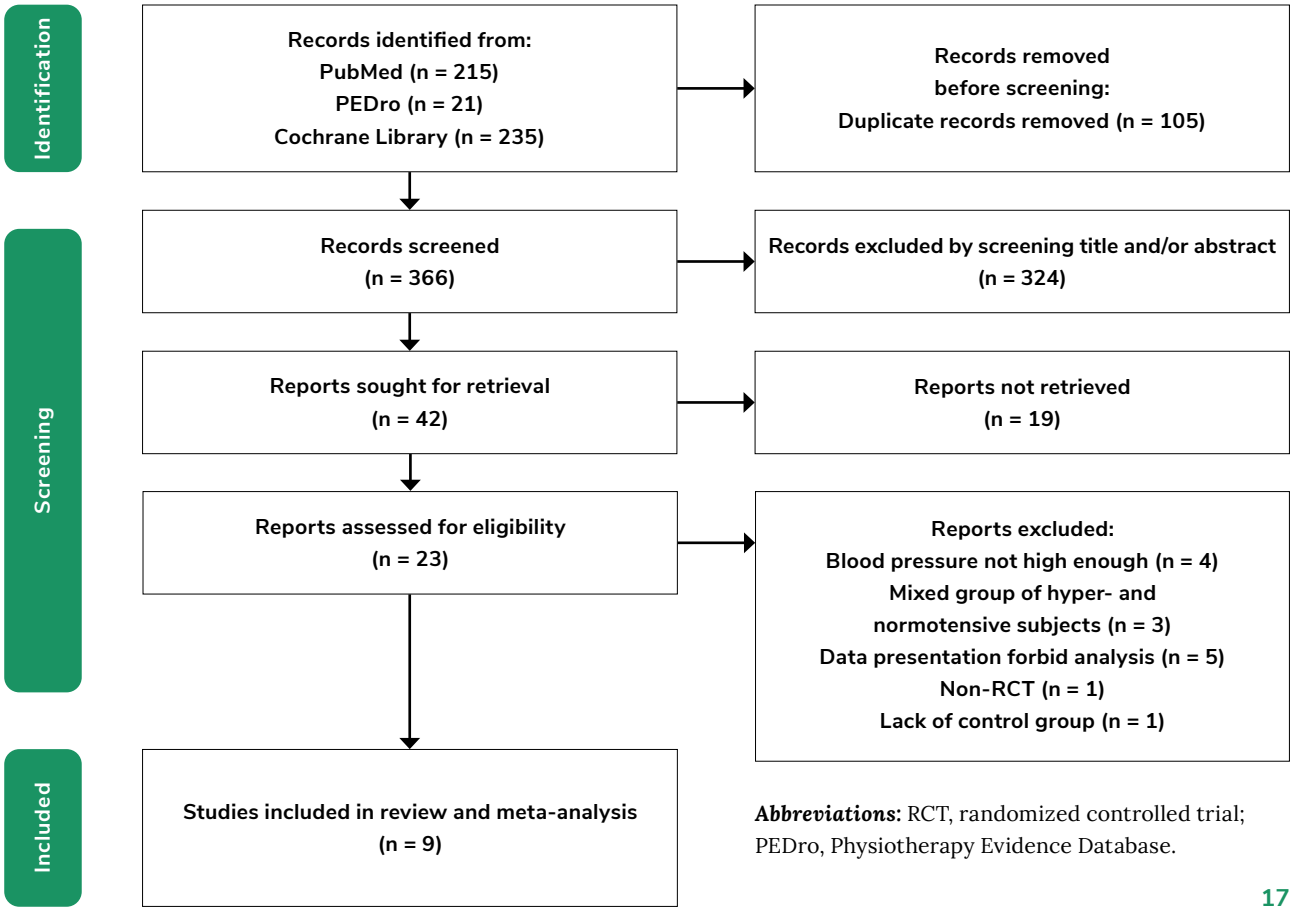
Search strategy

The search strategy was established in order to conduct a systematic literature review in 3 electronic databases: PubMed, Physiotherapy Evidence Database (PEDro), and Cochrane Library (**Table 1**). Databases were searched until December 2022. Identification and screening of executed studies was described in the flow chart in **Figure 1** [13].

Table 1. Detailed search strategy.

PubMed search strategy
#1 Search: "Hypertension" [mesh] OR "High blood pressure"[tiab] OR "High blood pressures"[tiab] OR "Pulmonary hypertension"[tiab] OR "Arterial hypertension"[tiab] OR "hypertensive"[tiab] 387,576 results #2 Search: "Resistance training" [mesh] OR "Strength Training"[tiab] OR "Weight lifting"[tiab] OR "Strengthening"[tiab] OR "Weight training"[tiab] 58,642 results #3 Search: "Blood pressure" [mesh] OR "Diastolic pressure"[tiab] OR "Systolic pressure"[tiab] OR "resting blood pressure"[tiab] 323,165 results #4 Search: #1 and #2 and #3 215 results
PEDro search strategy
Abstract & Title column: Hypertension "Resistance training" "Blood Pressure" Method column: clinical trial 21 results
Cochrane Library search strategy
Title Abstract Keyword: Hypertension AND "Resistance training" AND "Blood pressure" 235 results

Figure 1. Flow chart describing systematic search strategy.



Abbreviations: RCT, randomized controlled trial; PEDro, Physiotherapy Evidence Database.

Eligibility criteria

Studies were screened for selection and included if they were designed as randomized clinical trial with RT group and non-exercise control group (CG) containing only human, adult participants, taking at least four weeks, and RT was the only intervention.

Studies had to report average resting BP pre- and post-intervention for RT and CG with standard deviations for pre-intervention along with RT characteristics (total duration, frequency, duration per session, and intensity) and participants' characteristics (age, sex).

Only studies published in peer-reviewed journals written in English with full text available were eligible. Subjects had to be diagnosed as hypertensives (if the study mixed hypertensive and normotensive in one group, subjects with hypertension were extracted if possible, and when hypertensive subjects were divided into subgroups, they were combined to align with Cochrane Handbook [14]).

Considering that hypertension often occurs with other cardiovascular diseases (CVD) risk factors, only studies with diseases unrelated to CVD were excluded. If the study did not meet any inclusion criteria or contained unconventional training interventions like qigong, tai chi, or stretching, it was excluded.

Data extraction

The following data were extracted from eligible studies: first author, number, age, and sex of participants within each group, resistance training characteristics, criteria used to define hypertension, dropouts, and adverse effects.

Study quality assessment

The quality of studies was assessed with the PEDro scale [16]. The study could be rated as poor quality (PEDro score (0-3), fair (4-5), high (6-8), or excellent (8-10). It should be noted that these classifications have not been verified by researchers. All studies were included in data synthesis independently of their score.

Effect measures

The effectiveness of resistance training was quantified as standardized mean difference "Effect Size dppc2" (d) proposed by Morris [17] for pretest-posttest control group designs, where the trait or dependent variable assessed in the paper is a quantitative variable.

Negative d values pointed that RT reduced resting BP more than CG, and the magnitude of d was interpreted as <-0.20 = trivial, -0.20-(-0.59) = small, -0.60-(-1.19) = moderate, -1.20-(-1.99) = large, -2.00-(-3.99) = very large and ≥-4.00 = extremely large [18]. A Benchmark of 0,2 was used as the smallest meaningful difference [19]. In addition, an unstandardized mean effect in the form of a mean difference between RT and CG was calculated. The mean for each group was established as post-BP subtracted by pre-BP, and then RT mean subtracted by CG mean, so negative values testified to the positive effect of RT.

Data synthesis

Continuous variables are summarized as mean ± standard deviation (SD) (if the study reported standard error, it was transformed to SD aligned with Cochrane Handbook [14]).

Results

Study selection

Figure 1 outlines the searching and screening process. From 471 initially found studies after duplicate removal, 366 records were screened, from which 23 full texts were retrieved and, only 9 of them met all inclusion criteria.

Study characteristics

Table 2 provides an overall depiction of each study. Nine included studies assessed the effect of RT on resting BP in a population with hypertension. Data were gathered from 321 subjects, from which 180 were females; all studies reported 61 adverse effects, and only three were reported as related to the intervention. The age of the subjects was in the range between 30 and 68.

Three types of RT were identified: whole body workout with external load, isometric handgrip training, and circuit weight training which was not considered the former type of RT due to the completely different structure of the session.

Study quality assessment

One study was assessed as poor quality, six studies as fair quality, two studies as high quality, and there was no study qualified as excellent quality (**Table 4**).

Table 2. Study characteristics.

First author	Subjects' characteristics [n]	RT characteristics*	Criteria to define hypertension	Adverse events and dropouts
Ruangthai [20]	n total = 24 (20 females) CG: n=12 Mean Age: 66.7 RT: n=13 Mean Age: 68	1. Type: Whole body workout with external load 2. Total duration: 12 weeks 3. Duration per session: 60 min 4. Frequency: 3 times per week 5. Intensity: 50%-80% 1 Repetition maximum (RM)	SBP ≥ 130 mmHg or DBP ≥ 80 mmHg	1 dropout in RT group, 8 dropouts in CG group The authors didn't state a reason
Dantas [21]	n total = 25 (25 females) CG: n=12 Mean Age: 67.7 RT: n=13 Mean Age: 64.7	1. Type: Whole body workout with external load 2. Total duration: 10 weeks 3. Duration per session: 4. Frequency:2-3 times per week 5. Intensity: 5–7 OMNI-RES scale	Subjects had to use drug treatment	Not occurred
Palmeira [22]	n total = 63 (44 females) CG: n=32 Mean Age: 52.7 RT: n=31 Mean Age: 54.3	1. Type: Isometric handgrip training 2. Total duration: 12 weeks 3. Duration per session: 4. Frequency: 3 times per week 5. Intensity: 30% maximum voluntary isometric contraction (MVIC)	Subjects had to use drug treatment	CG: n=17 RTG: n=16 1 woman from RTG dropped out due to joint pain. Rest dropouts were not connected to the intervention
Gonçalves [23]	n total = 17 (17 females) CG: n=10 Mean Age: 66.1 RT: n=7 Mean Age: 65.6	1. Type: Whole body workout with external load 2. Total duration: 12 weeks 3. Duration per session: 4. Frequency: 3 times per week 5. Intensity: loads started at 40% 1RM and were adjusted individually every week	The BP measurements were made according to the recommendations of the "V Brazilian Guidelines on Hypertension"	2 women were excluded from the study due to medical complications, and 1 due to fall

Punia [24]	n total = 40 (20 females) CG: n=20 RT: n=20 Age ranged between 30 and 45	1. Type: Isometric handgrip training 2. Total duration: 8 weeks 3. Duration per session: 26 minutes 4. Frequency: 3 times per week 5. Intensity: 30% MVIC	Subjects had to be classified as stage 1 or 2 of hypertension. Stage 1 values: SBP 130-139 mmHg and DBP 85-89 mmHg Stage 2 values: SBP 140-159 mmHg and DBP 90-99 mmHg	5 participants dropped out. The authors did not state a reason
Abrahin [25]	n total = 41 (31 females) CG: n=21 Mean Age: 67.2 RT: n=20 Mean Age: 65.8	1. Type: Whole body workout with external load 2. Total duration: 12 weeks 3. Duration per session: 30-40 minutes 4. Frequency: 3 times per week 5. Intensity: 7-8 OMNI-RES scale	Subjects had to be presented with stage 1 or stage 2 hypertension diagnosed by a physician	10 participants dropped out. The authors did not state a reason
Corrêa [26]	n total = 60 (23 females) CG: n=30 Mean Age: 57.6 RT: n=30 Mean Age: 58	1. Type: Whole body workout with external load 2. Total duration: 6 months 3. Duration per session: 4. Frequency: 3 times per week 5. Intensity: 50-70% 1RM	Ambulatory blood pressure monitoring was performed on all subjects, and then results were interpreted in accordance with "III Brazilian Consensus for the use of Ambulatory Blood Pressure Monitoring"	Not occurred
Harris [27]	n total = 26 (no females) CG: n=16 Mean Age: 31,4 RT: n=10 Mean Age: 32,7	1. Type: Circuit weight training 2. Total duration: 9 weeks 3. Duration per session: 4. Frequency: 3 times per week 5. Intensity: started at 40% 1RM and was increased individually	Hypertension was defined as five random resting blood pressure measurements at various times following 5 minutes of seated rest with SBP values between 140-160 mmHg and DBP values between 90-95 mmHg	Not stated, all subjects were included in the final statistical analysis
Hooshmand--Moghadam [28]	n total = 24 (no females) CG: n=12 Mean Age: 62,5 RT: n=12 Mean Age: 63,2	1. Type: Whole body workout with external load 2. Total duration: 12 weeks 3. Duration per session: 4. Frequency: 3 times per week 5. Intensity: started at 40% 1RM for upper limbs and 60% 1RM for lower limbs and were adjusted individually	SBP ≥ 140 mmHg or DBP ≥ 90 mmHg	Not stated, all subjects were included in the final statistical analysis

Abbreviations: RT, resistance training; CG, control group; SBP, systolic blood pressure; DBP, diastolic blood pressure; 1RM, one-repetition maximum (rep max); MVIC, maximum voluntary isometric contraction; OMNI-RES, OMNI Perceived Exertion Scale for Resistance Exercise.

Table 3. Detailed RT characteristics.

First author	Description of exercise intervention
Ruangthai [20]	Exercises included in the program: squat, legs raise, knee extension, unilateral knee flexion exercise, leg adduction/abduction exercise, leg kick back, shoulder press, bench press, bicep curl, triceps dip, lateral flexion exercise, sit-up exercise, back extension. The session started with 10 min warm-up and stretching exercises. During weeks 1-6, subjects performed 15 repetitions and three sets of each exercise with intensity between 50% and 70% of their 1RM. During weeks 7-12, subjects performed ten repetitions and three sets of each exercise with intensity between 60% and 80% of their 1RM. The session was followed with a 10 min cool-down.
Dantas [21]	Exercises included in the program: Seated Leg Press; Seated Rowing Machine; Trunk Flexion; Knee Flexion Machine, Bench Press, Trunk Extension Machine, Push Press, Standing Plantar Flexion, and Front Pulldown. Frequency: weeks 1-5 - 2 times per week, weeks 6-10 – 3 times per week. Sets and repetitions: first two weeks – 1 set and 9-11 repetitions for each exercise, weeks 3-7 – 2 sets and 9-13 repetitions for each exercise, weeks 8-10 - 3 sets and 13-15 repetitions for each exercise. Rest between sets lasted 120 seconds in weeks 1-4, 90 seconds in weeks 5-8, and 60 seconds in weeks 9-10. The intensity was the same for all periods: 5-7 OMNI-RES.
Palmeira [22]	Each session consisted of 4 sets of 2 minutes of isometric contractions with hand alternation. MVIC was established at the start of each session via a handgrip dynamometer.
Gonçalves [23]	Exercises included in the program: bench press, leg extension, pulldown, leg curl, biceps curl, seated calf raise, pushdown and abdominal crunch. Two sets of 15 repetitions for each exercise except abdominal crunches (30 repetitions (and seated calf raises - 20 repetitions). Rest between sets lasted 1-2 minutes. The load was adjusted weekly by the same examiner so that the rate of perceived effort was between "mild" and "moderate". At the end of the session, the subjects stretched working muscles for 5 minutes.
Punia [24]	MVIC was established by performing three isometric contractions lasting 5 seconds with 1-minute rest between them; the middle value was recorded. The session started with a 10 minutes warm-up followed by four isometric contractions lasting 2 minutes at 30% MVIC with an alternate hand separated by 4 minutes rest period.
Abrahin [25]	Exercises included in the program: bench press, deadlift, unilateral rowing, standing calf raise, leg curl, and abdominal reverse crunch. All sessions consisted of 6-10 repetitions in 2 sets for each exercise. Rest between sets lasted between 90 and 120 seconds. Training loads were adjusted according to American College of Sports Medicine recommendations and increased by 2-10% when participants were able to carry out ten repetitions in every set of a given exercise during two consecutive training sessions presenting a full motion range.
Corrêa [26]	Exercises included in the program: bench press, leg press at 45º, seated row, leg extension, shoulder press, leg curl, barbell biceps curl, and triceps pulley. The program was divided into three mesocycles for each taking two months. In the first mesocycle, subjects performed three sets and 12 repetitions at 50% 1RM. In the second mesocycle, subjects performed three sets and ten repetitions at 60% 1RM. In the third mesocycle, subjects performed three sets and eight repetitions at 70% 1RM.

Harris [27]	Exercises included in the program: biceps curl, triceps extension, bench press, abdominal curl, lat pull, seated row, quadriceps extension, quadriceps press, hamstring step-up, and calf raise. Each session consisted of 3 sets and 20-25 repetitions for each exercise. The load was increased as the subject could perform 25 repetitions without undue fatigue. The exercise and rest ratio was 3:1 (45 seconds of exercise and 15 seconds of rest).
Hooshmand-Moghadam [28]	Exercises included in the program: chest press, latissimus dorsi pulldown, back row, biceps curl, leg press, leg extension, leg curl, abdominal crunch, and lower back extension. Each exercise included two sets and 12-15 repetitions with 2 minutes rest. The intensity increased by 5% every three weeks or when 15 repetitions were easily performed.

Abbreviations: 1RM, one-repetition maximum (rep max); MVIC, maximum voluntary isometric contraction.

Results of synthesis

Nine included studies assessed the effect and magnitude of RT compared to CG on resting BP in a population with hypertension. Regarding SBP, eight studies reported a positive change in RT favor and one study in CG favor. The average value for the mean difference was ten mmHg, and d ranged between 0.9 - (-12.8). Regarding DBP, seven studies reported a positive change in RT favor, one in CG favor, and one showed no difference. The average value for the mean difference was 4.6 mmHg, and d ranged between 0.6 - (-11.8). See **Table 5** and **Table 6**.

Discussion

Answering the question posed in this review, it is tempting to state that RT is a viable option for hypertensive patients. On average SBP/DBP reduction after RT was 10/4.6 mmHg, after separating RT into dynamic resistance training and isometric training, the average values are as follows 8.9/5.1 mmHg and 8.5/4.2 mmHg. Those results suggest that we could obtain similar results after implementing both dynamic and isometric RT, but we have to consider that in the synthesis of 9 studies, only 2 used isometric training.

The results of this review are very similar to those of other reviews showing a reduction in SBP/DBP by 1.8/3.2 mmHg and 10.9/6.2 mmHg after RT and isometric training, respectively [10], 6.8/4.0 mmHg after isometric training and 5.2/2.7 after RT [11]. However, they differ in the interventions analyzed; the population studied, and the overall breadth of the topic, from which small discrepancies may arise.

Previous studies showed that reducing SBP by 5 mmHg lowers the risk of all-cause mortality by 7%. In numbers, this amounts to 27.000 fewer deaths per year in the population aged 45-64[29]. Those results are similar to those already known from different studies. In addition, they showed that SBP was reduced by 6 mmHg and DBP by mmHg in the intervention group compared to control [30].

In the included studies, the number of people injured in the RT was really small, which is in line with a review that checked exercise safety in patients with hypertension [31].

Nevertheless, we must remember the limitations of this review.

The quality and number of studies could have been better. Only two studies were rated as high quality. As no age restrictions were imposed in the inclusion criteria, the age range in the review was between 30 and 68 years, making interpretations much more difficult. There were also no specifically imposed definitions of hypertension (criteria used by individual studies were adopted) which could have broadened the pressure values among the study population.

Table 4. Risk of bias assessment.

PEDro scale item	Ruangthai [20]	Dantas [21]	Palmeira [22]	Gonçalves [23]	Punia [24]	Abrahin [25]	Corrêa [26]	Harris [27]	Hooshmand--Moghadam [28]
Eligibility criteria	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Random allocation	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Concealed allocation	No	Yes	Yes	No	Yes	No	No	No	No
Baseline similarity	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Blinding of subjects	No	No	No	No	No	No	No	No	No
Blinding of therapists	No	No	No	No	No	No	No	No	No
Blinding of assessors	No	Yes	No	No	Yes	No	No	No	No
Measures of outcome from more than 85% of subjects	Yes	Yes	No	No	Yes	No	No	Yes	Yes
Intention-to-treat analysis	No	No	Yes	No	No	No	No	No	No
Between groups statistical analysis	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Point measures and measures of variability	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Total	5	7	5	2	7	4	4	5	5

Table 5. SBP synthesis.

Study	RT			CG			Effect Size dppc2	Mean difference mmHg
	Pre / post SBP	Pre SD	n	Pre / post SBP	Pre SD	n		
Ruangthai [20]	146,8/144,8	23.6	13	140.6/147.3	18.2	12	-0.397	-8.7
Dantas [21]	142.9/137.1	13.1	13	139.9/144.9	10.3	12	-0.882	-10.8
Palmeira [22]	129/121	15.5	31	126/126	16	32	-0.51	-8
Gonçalves [23]	126/122.9	13.7	7	137/134.9	13.2	10	-0.07	-1.1
Punia [24]	144.2/138.4	7.6	20	142.4/145.6	7.5	20	-1.163	-9
Abrahin [25]	133.2/122.4	14.1	20	138.7/135.6	11.5	21	-0.588	-7.7
Corrêa [26]	143/129.5	10.1	30	142.7/141.7	10.7	30	-1.186	-12.5
Harris [27]	141.7/142.3	25	10	146.1/145.8	32.8	16	0.032	0.9
Hooshmand-Moghadam [28]	151.1/138.3	4.4	12	153.5/153.5	4.4	12	-2.8	-12.8

Abbreviations: RT, resistance training; CG, control group; SBP, systolic blood pressure; DBP, diastolic blood pressure; SD, standard deviation; n, number of participants.

Table 6. DBP synthesis.

Study	RT			CG			Effect Size dppc2	Mean difference mmHg
	Pre / post DBP	Pre SD	n	Pre / post DBP	Pre SD	n		
Ruangthai [20]	80.5/76.6	7.8	13	82.5/81.5	10.1	12	-0.313	-2.9
Dantas [21]	68.2/64.9	6.2	13	67.4/72	9.5	12	-0.961	-7.9
Palmeira [22]	83/79	16.7	31	81/77	17	32	0	0
Gonçalves [23]	80.9/81.9	8.7	7	88.3/88.7	8.5	10	0.068	0.6
Punia [24]	92.7/87.5	4.9	20	89.5/92.7	4.5	20	-1.712	-8.4
Abrahin [25]	80.9/77.8	10.4	20	80.1/78.4	8.5	21	-0.144	-1.4
Corrêa [26]	93.8/82.2	10.3	30	92.4/92.6	9.8	30	-1.159	-11.8
Harris [27]	95.8/91.3	20	10	94.6/92.6	15.2	16	-0.141	-2.5
Hooshmand-Moghadam [28]	96.1/87.7	1.5	12	95.7/94.6	1.5	12	-4.7	-7.3

Abbreviations: RT, resistance training; CG, control group; SBP, systolic blood pressure; DBP, diastolic blood pressure; SD, standard deviation; n, number of participants.

The current review also does not distinguish between patients who have taken medications to lower BP and those who have not. Although most of the studies lasted 12 weeks using RT 3 times a week, the rest of the characteristics varied considerably, taking into account the choice of exercises (free weights, machines), the intensity used (from 30% to 80% 1RM), different progression rules, training volume or training duration. Outcome measures ranged between 0.9 - (-12.8) for SBP and between 0.6 - (-11.8) for DBP.

Such a wide range of responses to RT makes it extremely hard to predict how a patient will react. The lack of statistical analysis makes this review not a reliable educational source and should rather be considered informative.

Conclusions

There is a high probability that resistance training may be effective as the only intervention to combat hypertension, but for the sake of the quality of this review, one should refrain from drawing firm conclusions.

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