Exercise Training for Blood Pressure: A Systematic Review and Meta-analysis

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Background—We conducted meta-analyses examining the effects of endurance, dynamic resistance, combined endurance and resistance training, and isometric resistance training on resting blood pressure (BP) in adults. The aims were to quantify and compare BP changes for each training modality and identify patient subgroups exhibiting the largest BP changes.

Methods and Results—Randomized controlled trials lasting ≥4 weeks investigating the effects of exercise on BP in healthy adults (age ≥18 years) and published in a peer-reviewed journal up to February 2012 were included. Random effects models were used for analyses, with data reported as weighted means and 95% confidence interval. We included 93 trials, involving 105 endurance, 29 dynamic resistance, 14 combined, and 5 isometric resistance groups, totaling 5223 participants (3401 exercise and 1822 control). Systolic BP (SBP) was reduced after endurance (−3.5 mm Hg [confidence limits −4.6 to −2.3]), dynamic resistance (−1.8 mm Hg [−3.7 to −0.011]), and isometric resistance (−10.9 mm Hg [−14.5 to −7.4]) but not after combined training. Reductions in diastolic BP (DBP) were observed after endurance (−2.5 mm Hg [−3.2 to −1.7]), dynamic resistance (−3.2 mm Hg [−4.5 to −2.0]), isometric resistance (−6.2 mm Hg [−10.3 to −2.0]), and combined (−2.2 mm Hg [−3.9 to −0.48]) training. BP reductions after endurance training were greater ($P<0.0001$) in 26 study groups of hypertensive subjects (−8.3 [−10.7 to −6.0]/−5.2 [−6.8 to −3.4] mm Hg) than in 50 groups of prehypertensive subjects (−2.1 [−3.3 to −0.83]/−1.7 [−2.7 to −0.68]) and 29 groups of subjects with normal BP levels (−0.75 [−2.2 to +0.69]/−1.1 [−2.2 to −0.068]). BP reductions after dynamic resistance training were largest for prehypertensive participants (−4.0 [−7.4 to −0.5]/−3.8 [−5.7 to −1.9] mm Hg) compared with patients with hypertension or normal BP.

Conclusion—Endurance, dynamic resistance, and isometric resistance training lower SBP and DBP, whereas combined training lowers only DBP. Data from a small number of isometric resistance training studies suggest this form of training has the potential for the largest reductions in SBP. **(*J Am Heart Assoc.* 2013;2:e004473 doi: 10.1161/JAHA.112.004473)**

Key Words: adults • blood pressure • exercise • humans • training

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Current National Health and Nutrition Examination Survey data suggest that the prevalence of hypertension (HTN) varies with ethnicity and gender but lies between 25% and 43% in the US population, with an upward trend during the past 3 National Health and Nutrition Examination Surveys.[1] HTN, or the chronic elevation of resting arterial blood pressure (BP) >140 mm Hg systolic (SBP) and/or 90 mm Hg diastolic BP (DBP), remains one of the most significant modifiable risk factors for cardiovascular disease (eg, coronary artery disease, stroke, heart failure).[2] Although antihypertensive medications are efficacious and most have minimal side effects, the economic health care costs are increasing.[3] Both national and international treatment guidelines for the primary and secondary prevention of HTN recommend nonpharmacological lifestyle modifications as the first line of therapy, including increasing levels of physical activity.[4] There is Class I, Level B evidence that 150 minutes of weekly physical activity offers an alternative that may be used to complement antihypertensive medication.[5]

The American College of Sports Medicine position stand on exercise and HTN[6] recommends dynamic aerobic endurance training for at least 30 minutes daily, preferably supplemented with dynamic resistance exercise. The effects of exercise training may vary with different exercise modalities (eg, endurance training or resistance exercise) and dose parameters, specifically program length, session duration,

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Accompanying Figures S1–S8 and Tables S1–S2 are available at http://jaha.ahajournals.org/content/2/1/e004473.full

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frequency, and workload or intensity. As such, the optimal exercise training prescription remains unclear. Dynamic aerobic endurance exercise involves large muscle groups in dynamic repetitive activities that result in substantial increases in heart rate and energy expenditure. Resistance training is activity in which each effort is performed against a specific opposing force generated by resistance and is designed specifically to increase muscular strength, power, and/or endurance. According to the type of muscle contraction, resistance training can be divided into 2 major subgroups: "dynamic" versus "static or isometric" resistance training. Dynamic resistance training involves concentric and/or eccentric contractions of muscles while both the length and the tension of the muscles change. Isometric exertion involves sustained contraction against an immovable load or resistance with no or minimal change in length of the involved muscle group. Current thinking varies with respect to the preferred type of physical activity for BP; historically endurance training has been preferred. Isometric activity has previously been associated with exaggerated hypertensive responses, but recent work has suggested isometric handgrip activity may become a new tool in the nonpharmacological treatment of high BP.[7,8] Previous meta-analyses have examined the effects of endurance training,[9] dynamic resistance training,[10,11] and isometric resistance training[7,8] in isolation on BP, although a meta-analytic comparison of all different exercise modalities, strictly limited to randomized controlled trials and eliminating data from crossover studies, has not been conducted.

The aims of this work were to (1) conduct a systematic review and meta-analysis of randomized controlled trials to compare the effects of endurance training, dynamic resistance training, isometric resistance training, or combined endurance and resistance training on the magnitude of change in SBP and DBP in subclinical populations; (2) examine whether magnitude of change in SBP and DBP was different with respect to sex, age, and BP classification; and (3) examine whether magnitudes of change in SBP and DBP were related to exercise program characteristics, that is, program duration, exercise session duration, exercise intensity, exercise mode, weekly exercise duration, or weekly session frequency.

Methods

Search Strategy

A database of randomized controlled trials on the effect of exercise training on BP was started in 1985[12] and updated in 1994,[13] 1999,[14] 2003,[9,10] and again for the current meta-analysis. Potential new studies were identified by a systematic review librarian. A systematic search was conducted of Medline (Ovid), Embase.com, and SportDiscus for the period November 1, 2003 until February 28, 2012. The search strategy included a mix of medical subject headings and free text terms for the key concepts aerobic/dynamic/endurance/resistance exercise, training, HTN, and SBP/DBP, and these were combined with a sensitive search strategy to identify randomized controlled trials. Reference lists of articles found were scrutinized for new references. The full search strategy for one of the databases (PubMed) is available on request of the corresponding author. No language limits were imposed.

Inclusion Criteria

The inclusion criteria for this meta-analysis were as follows: (1) randomized controlled parallel-design trials of exercise training for a minimum of 4 weeks; (2) participants were adults (age $\geq$18 years) without cardiovascular or other diseases; (3) the study reported before and after mean and SD (or standard error) of resting BP in exercise and control groups or mean change and SD (or standard error) in exercise and control groups; and (4) the study was published in a peer-reviewed journal up to February 2012. Any studies not meeting these criteria were excluded. All identified articles were assessed independently by 2 reviewers (N.A.S. and V.A.C.), and disagreements were resolved by discussion.

Data Extraction

Data relating to subject characteristics, exercise program characteristics, and the primary outcomes were systematically reviewed. Information was archived independently in a database by each author. Discrepancies were resolved by consensus. Study quality was evaluated according to the Physiotherapy Evidence Database (PEDro) scale.[15] However, we regarded participant and therapist blinding and allocation concealment as practical, so the maximum number of points possible was 8. Further, BP measurements using an automated, semiautomated, or random-zero device were considered as investigator blinded measurements.

Statistical Analysis

All meta-analyses were performed using Comprehensive Meta Analysis (CMA) V2 software (Biostat, NJ). The primary outcome measures were changes in resting SBP and DBP. Descriptive data of treatment groups and participants are reported as the mean$\pm$SD or median and range. Effect sizes for each study group were calculated by subtracting the preexercise value from the postexercise value (post–pre) for both the exercise (Δ1) and control groups (Δ2). The net treatment effect was then obtained as Δ1 minus Δ2.

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Variances were calculated from the pooled SDs of change scores in the intervention and control groups. If change score SDs were not available, these were calculated from pre-SD and post-SD values for which a correlation coefficient of 0.5 between the initial and final values was assumed.[16] Each effect size was then weighted by the inverse of its variance. Random-effects models that incorporate heterogeneity into the model were used to pool all primary and secondary outcomes from each study group.

Statistical heterogeneity among the studies was assessed using Cochran Q test, with a $P>0.05$ considered statistically significant and an inconsistency I^2 statistic in which a value >50% was considered indicative of high heterogeneity. Four main comparisons were made with each exercise group being compared with a no-intervention (sedentary) control group: that is, endurance training, dynamic resistance training, combined training, and isometric resistance training. In addition, a fifth comparison between endurance training and dynamic resistance training was made including trials that involved both an endurance training and dynamic resistance training arm. If trials compared multiple exercise interventions with a single control group within one comparison, we split the shared control group into ≥2 groups with smaller sample size.[17] We used a 5% level of significance and 95% CIs for all outcomes.

Using stratified meta-analyses, we tested 8 a priori hypotheses that there may be differences in the effect on BP with regard to type of exercise (endurance training, dynamic resistance training, combined training, isometric resistance training) and for endurance training and dynamic resistance training across particular subgroups, sex (men versus women), age (<50 versus ≥50 years), weekly frequency, training intensity, session duration (minutes), program duration (weeks), BP classification using the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure,[4] and total weekly exercise time. *Z* tests were used to compare summary variables.

In addition, simple random-effects meta-regression analysis (methods of moment approach) was performed to investigate the association between changes in BP and changes in weight.

Finally, to qualitatively assess publication bias, funnel plots of the effect size versus the standard error AUTHOR: Does standard error refer to SEM or SEE?for each study group were generated. Funnel plot asymmetry was evaluated by use of Begg and Egger tests, and a significant publication bias was considered if the *P* value was <0.10.[18] The trim and fill computation was used to estimate the effect of publication biases on the interpretation of the results.[18] Cumulative meta-analyses, ranked by year, were used to examine results over time for each of the different training modalities.

Results

Literature Search

One hundred three articles published between 1976 and 2003 were already available in our database as they were used for previous reviews. The electronic search yielded an additional 522 citations, which were screened by reviewing the title or abstract of each. Of these 625 publications, 93 trials were included in the meta-analysis (Figure 1). Some of these trials involved several groups of individuals or applied different training regimens, so that a total of 153 study groups (ie, 105 endurance training, 29 dynamic resistance training, 5 isometric resistance training, and 14 combined training groups) were available for meta-analysis. A general description of each trial is shown in Table S1. The studies enrolled 5223 patients: 3401 were exercise training participants and 1822 were sedentary controls. Based on the average baseline BP, 47 study groups included individuals with normal BP (29 endurance training, 12 dynamic resistance training, 2 isometric resistance training, and 4 combined), 73 study groups involved prehypertensive participants (50 endurance training, 13 dynamic resistance training, 2 isometric resistance training, and 8 combined training), and 33 training interventions were performed in hypertensive patients (26 endurance training, 4 dynamic resistance training, 1 isometric resistance training, and 2 combined training).

Collectively, exercise intervention length ranged from 4 to 52 weeks. For those studies that reported data, the between-study frequency ranged from 1 to 7 times per week, and intensity ranged from 35% to 95% peak oxygen consumption for endurance training, between 30% and 100% of 1-repetition maximum for dynamic resistance training, and between 10% and 40% for isometric resistance training.

Study quality is summarized in Table S2. The median PeDro score was 6 of 8. Ninety (97%) trials clearly stated eligibility criteria, all studies were randomized, and 90 (97%) studies matched intervention groups at baseline for BP, although groups were also well matched for age and sex. Blinding of outcome assessment was performed in 58 (62%) studies, but no more than 8 trials specifically reported that the observers were blinded to treatment allocation. Only 44 (47%) of studies clearly reported that >85% of participants had complied with the intervention, only 7 (8%) studies completed an intent-to-treat analysis, 90 (97%) studies completed between-group analyses, and all studies provided point estimates for effect size.

Quantitative Data Synthesis

Figures 2 and 3 show the overall results for SBP and DBP. Statistically significant reductions were found for SBP after endurance training (−3.5 mm Hg [−4.6 to −2.3], $P<0.0001$),

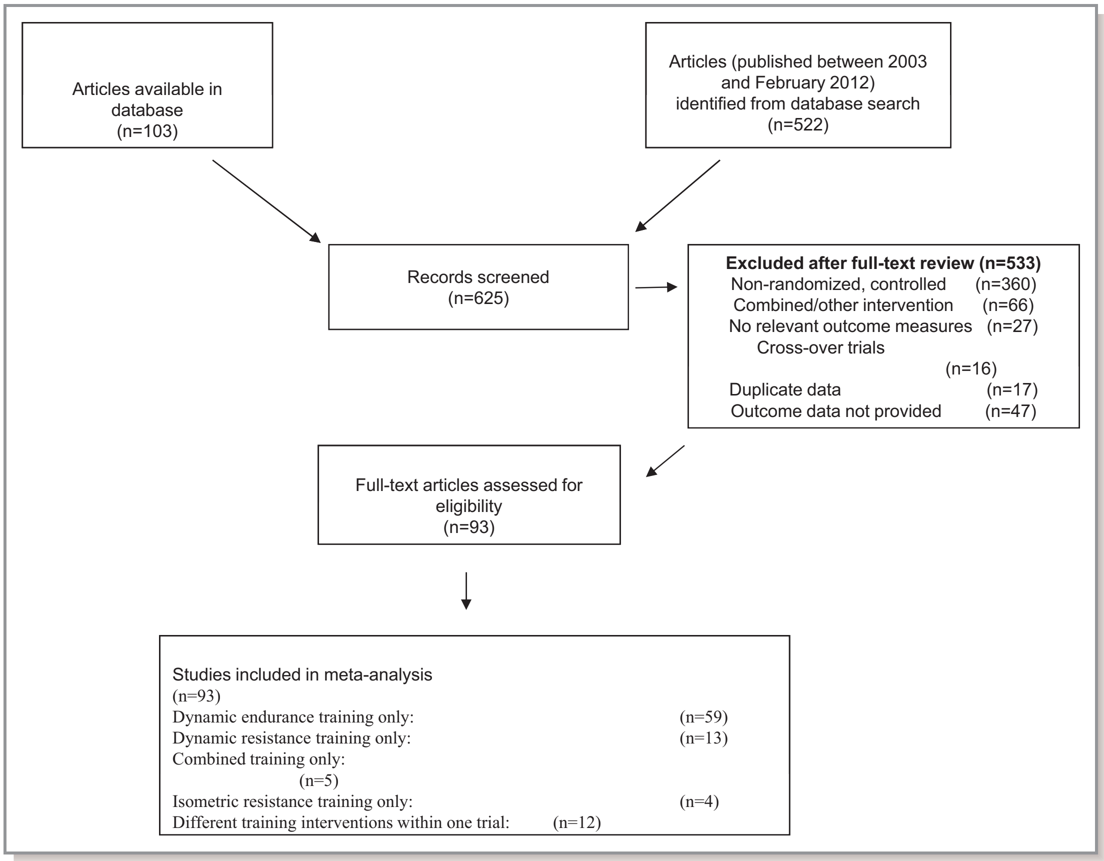

Figure 1. PRISMA flow diagram. PRISMA indicates preferred reporting items for systematic reviews and meta-analyses.

dynamic resistance training (−1.8 mm Hg [−3.7 to −0.011], P=0.049), and isometric resistance training (−10.9 mm Hg [−14.5 to −7.4], P<0.0001) but not after combined training (−1.4 mm Hg [−4.2 to +1.5], P=0.34). DDBP was significantly reduced after endurance training (−2.5 mm Hg [−3.2 to −1.7], P<0.0001), dynamic resistance training (−3.2 mm Hg [−4.5 to −2.0], P<0.0001), isometric resistance training (−6.2 mm Hg [−10.3 to −2.0], P=0.003), and combined training (−2.2 mm Hg [−3.9 to −0.48], P=0.012). Overall, there were no significant differences between the effects of endurance training, dynamic resistance training, and combined training on SBP and DBP (P>0.05 for all). Similar, the 10 trials that included both an endurance training and a dynamic resistance training arm showed no significant differences between exercise modalities for SBP (P=0.76) and DBP (P=0.94) effects. By contrast, reductions in SBP and DBP were larger after isometric resistance training compared with endurance training, dynamic resistance training, or combined training, although they were significant only for SBP (P<0.001 for all).

Cumulative meta-analyses showed that results have remained significant for the effect of endurance training on SBP and DBP since 1985 and 1990, respectively. For dynamic resistance training, cumulative meta-analysis showed that results remained significant since 2007 for SBP and since 1997 for DBP. Finally, with regard to isometric resistance training, the results have remained highly significant since the first publication in 1992 for both SBP and DBP.

The effect of endurance training on SBP (P<0.0001) and DBP (P<0.0001) was greatest in 26 study groups with hypertensive participants (−8.3 [−10.7 to −6.0]/−5.2 [−6.9 to −3.4] mm Hg) compared with groups with participants with prehypertension (−4.3 [−7.7 to −0.90]/−1.7 [−2.7 to −0.68] mm Hg) or normal BP (−0.75 [−2.2 to +0.69]/−1.1 [−2.2 to −0.068] mm Hg). The effect of dynamic resistance training on SBP and DBP tended to be greater in prehypertensive individuals although not significant (P>0.10).

Subgroup Analyses

Results of subgroup analyses for endurance training are summarized in Table 1. Subgroup analyses of endurance training suggested that male participants achieved greater than twice the reduction in SBP (P<0.01) and DBP (P=0.011) as female participants. Program duration of <24 weeks appears to lower SBP (P<0.0001) and DBP (P<0.01) to a greater extent than programs of >24 weeks' duration. Lower training intensity is associated with the smallest effect size on

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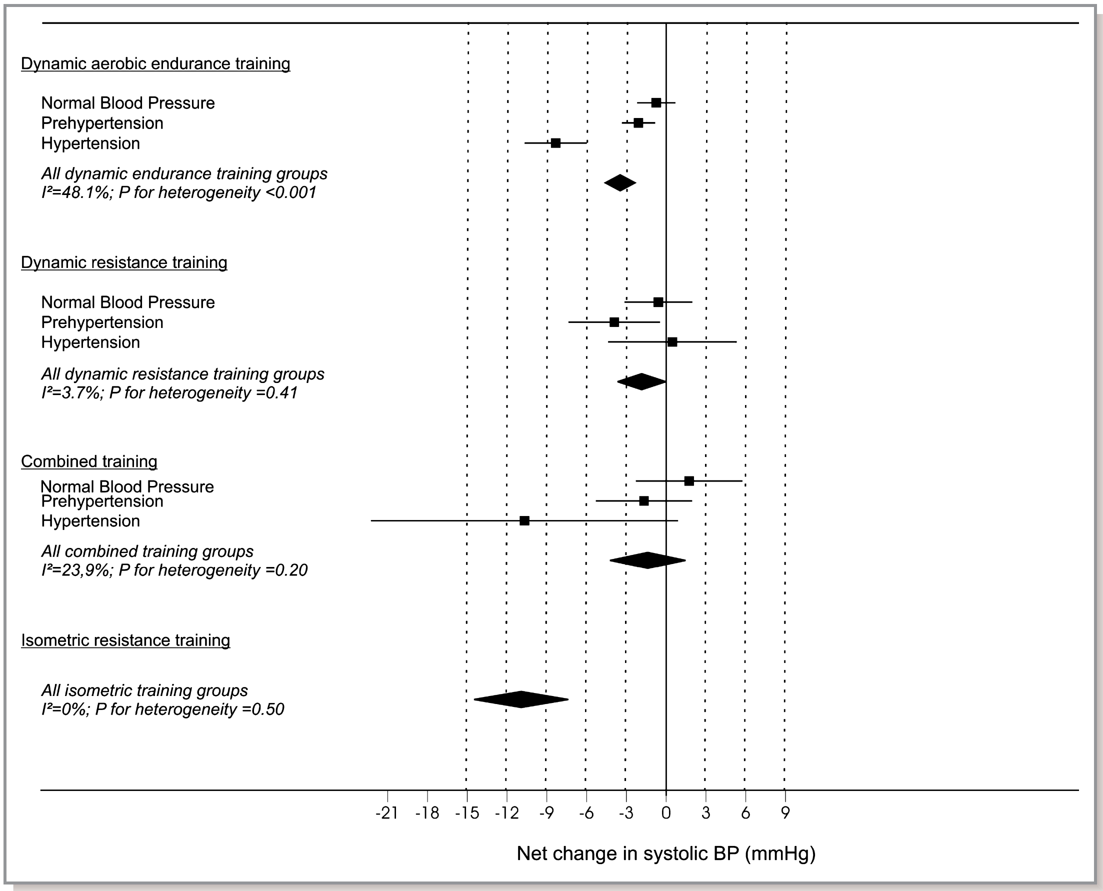

Figure 2. Net changes in systolic blood pressure (BP) after different exercise modalities using random-effects analyses. Data are reported as net mean changes, adjusted for control data (95% confidence limits).

SBP (P=0.032) and DBP (P=0.030). Less than 210 minutes of weekly endurance training showed significantly larger SBP (P<0.05) and borderline but not significant DBP (P=0.198) reductions. Individual exercise session durations of 30 to 45 minutes showed larger reductions in SBP and DBP, although they were statistically significant only for DBP (P<0.001). The following subanalyses suggested no difference between subgroups: age >50 versus <50 years and weekly exercise training frequency. Furthermore, we observed a tendency for larger reductions in SBP ($\beta 1$=0.49, P=0.08) and DBP ($\beta 1$=0.45; P=0.06) with greater reductions in weight after dynamic endurance training.

Subgroup analyses for DRT are given in Table 2. SBP and DBP reductions after dynamic resistance training were not significantly different with regard to sex, age category, duration of the exercise program, or training intensity.

Publication Bias and Sensitivity Analyses

The funnel plots of the primary analyses are shown in Figures S1 through S8. Funnel plots including Egger regression tests (P>0.10 for all) for the different analyses did not suggest publication bias, nor did Duval and Tweedie's trim and fill computation change the results.

Discussion

Our meta-analysis of published randomized controlled parallel-design studies of exercise training in subclinical populations is the largest such analysis of exercise training on BP to date, containing data on >5000 participants. Our results demonstrate that endurance training, dynamic resistance training, combined training, and isometric resistance training significantly reduce DBP and all except combined training reduce SBP. Furthermore, this meta-analysis demonstrates the largest effect sizes are observed after isometric handgrip or leg exercise, but there is a current paucity of published studies that examine this type of intervention. No significant differences in effect size were observed between endurance training and dynamic resistance training, although our analyses suggest that in those with HTN, endurance training might be superior to dynamic resistance training or combined training. Finally, larger BP reductions after endurance training were observed from shorter exercise program durations at

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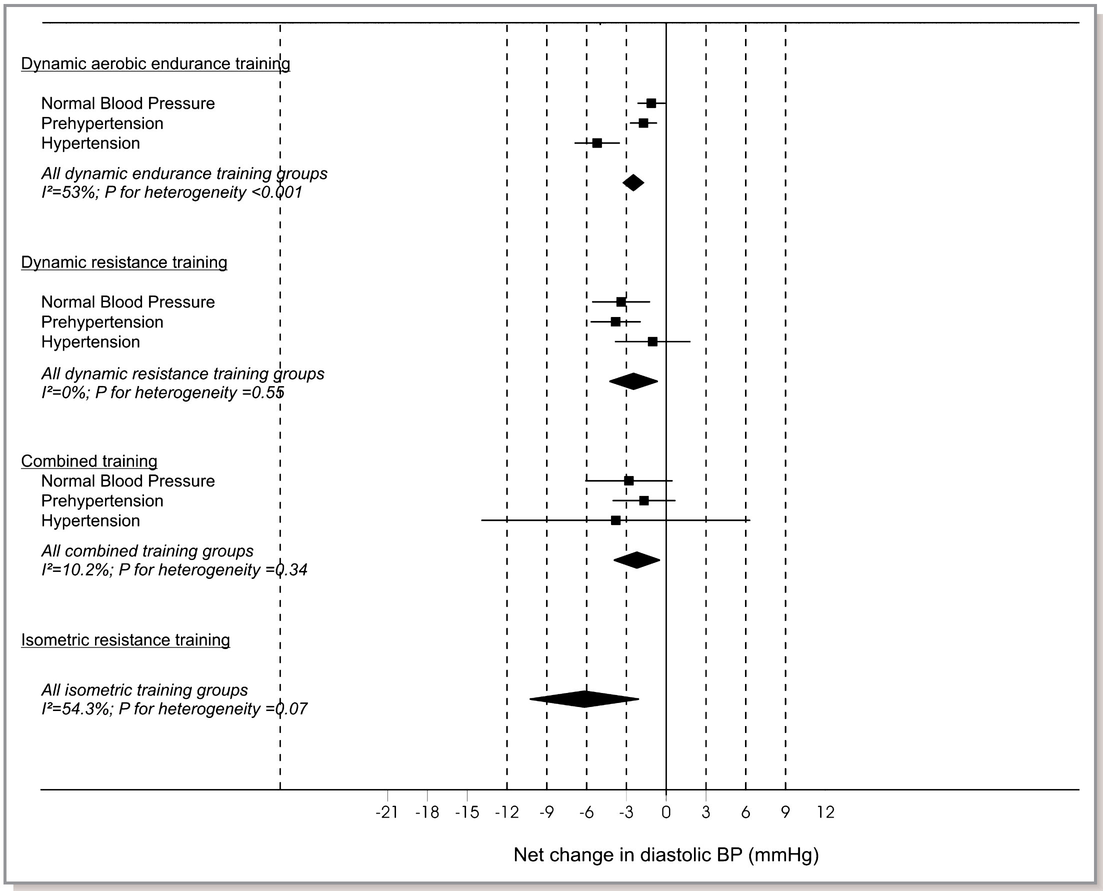

Figure 3. Net changes in diastolic blood pressure (BP) after different exercise modalities using random effects analyses. Data are reported as net mean changes, adjusted for control data (95% confidence limits).

moderate to high intensity and <210 minutes of weekly exercise. Collectively, these findings have implications for exercise training prescription and delivery for BP management.

Dynamic endurance training, dynamic resistance training, and combined training were each associated with decreases in SBP and DBP, and magnitudes of these reductions were similar across these 3 exercise modalities. After dynamic endurance training, we found BP decreases were most pronounced in male participants and hypertensive participants, but significant reductions were also observed in participants with normal BP and prehypertension. However, after dynamic resistance training, reductions in SBP and DBP were largest in the study groups of prehypertensive participants. Moreover, the effects of endurance training, dynamic resistance training, and combined training on SBP and DBP in the individual with normal BP or prehypertension were similar, underlining the value of dynamic resistance training as an adjunct therapy for the prevention of high BP in these preclinical populations. Our results suggest endurance training might be superior to dynamic resistance training for hypertensive individuals, although it should be noted only 4 of 29 dynamic resistance study groups involved hypertensive patients. Therefore, until clearer evidence emerges, it may be prudent to prescribe endurance training rather than dynamic resistance training for the hypertensive individual if lower BP is desired.

Our findings further demonstrate that isometric handgrip training and isometric leg training result in larger reductions in SBP and a trend toward lower DBP compared with the 3 other exercise modalities, but the paucity of studies to date limits the strength of this conclusion. As stated earlier, there is no between-trial heterogeneity among the 5 isometric training groups,[8] and lack of significant publication bias suggests the findings are robust, although generalizability of the results might be premature as data were available from only 4 trials (5 study groups).

Subgroup analyses of endurance training further demonstrate exercise programs of <6 months induced larger BP reductions compared with programs of longer duration; this concurs with previous meta-analyses and might be explained by unsupervised exercise sessions, a characteristic of the longer program durations and associated with reduced adherence. Indeed, subgroup analyses of dynamic resistance

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Table 1. Subgroup Analyses for the Effect of Dynamic Endurance Training on Resting BP Using a Random-Effects Model

	Systolic BP		Diastolic BP	
	N	Effect Size (95% CL)	N	Effect Size (95% CL)
Sex				
Male	28	−4.7 (−2.2 to −1.6)	28	−2.8 (−1.3 to −4.5)
Female	38	−0.87 (−2.2 to +0.46)	35	−0.56 (−1.39 to +0.27)
Age, y				
<50	54	−2.8 (−3.9 to −1.8)	50	−3.0 (−4.3 to −1.7)
≥50	50	−3.9 (−5.9 to −2.0)	52	−1.8 (−2.7 to −1.0)
Hypertensive status				
Normal BP	29	−0.75 (−2.2 to +0.69)	29	−1.1 (−2.2 to −0.068)
Prehypertension	50	−2.1 (−3.3 to −0.83)	47	−1.7 (−2.7 to −0.68)
Hypertension	26	−8.3 (−10.7 to −6.0)	26	−5.2 (−6.9 to −3.4)
Duration of the intervention, wk				
<12	19	−6.4 (−9.9 to −2.9)	17	−4.0 (−6.4 to −1.6)
12 to 24	51	−4.1 (−5.2 to −3.0)	50	−3.0 (−4.0 to −1.9)
>24	35	−0.77 (−1.9 to +0.40)	35	−1.7 (−2.2 to −0.17)
Exercise frequency, times weekly				
<3	11	−3.9 (−7.4 to −0.39)	11	−2.8 (−4.8 to −0.75)
3 or 4	63	−3.5 (−5.0 to −2.0)	63	−2.4 (−3.6 to −1.3)
>4	31	−3.2 (−4.9 to −1.5)	28	−2.4 (−3.4 to −1.4)
Exercise intensity[5]				
Low	7	+0.073 (−2.8 to +2.9)	7	+0.32 (−1.9 to +2.5)
Moderate	32	−4.8 (−7.5 to −2.2)	31	−2.3 (−3.3 to −1.3)
High	57	−3.6 (−4.7 to −2.5)	55	−3.1 (−4.3 to −1.9)
Session duration, min/session				
<30	9	−0.43 (−3.4 to +2.5)	9	+0.62 (−1.0 to +2.3)
30 to 45	55	−3.8 (−4.9 to −2.6)	53	−3.3 (−4.4 to −2.2)
>45	38	−2.8 (−5.0 to −0.62)	38	−1.9 (−3.1 to −0.70)
Weekly exercise time, min/wk				
<150	43	−3.6 (−4.9 to −2.2)	43	−2.7 (−4.0 to −1.4)
150 to 210	46	−3.9 (−5.8 to −2.0)	44	−2.7 (−3.8 to −1.6)
>210	13	+0.2 (−2.3 to +2.8)	13	−0.92 (−2.6 to +0.79)

BP indicates blood pressure; CL, confidence limit; N, number of study groups.

training showed no difference between programs of shorter and longer durations, perhaps because most trials provided supervised sessions and previous work shows facility-based exercise programs yield the highest adherence rates.[19]

BP reductions after low-intensity endurance training (<40% heart rate reserve or <55% heart rate maximum) were smaller compared with moderate- or high-intensity training, and no significant differences in BP responses were observed between low-, moderate-, and high-intensity dynamic resistance training. This might be explained by the fact that most dynamic resistance training study groups exercise at higher intensity (>69% 1-repetition maximum), with only 7 dynamic resistance groups performing at low intensity. Training frequency and exercise session duration did not significantly affect the BP response to endurance training, but >210 minutes of weekly exercise produced the smallest reductions in BP, which appears counterintuitive as one would presume exercise training-induced BP reductions follow a dose–response relationship. One possible explanation might be that programs with a total of >210 minutes per week are performed at lower intensity. Given that multivariable analyses were not possible we took into consideration that the

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Table 2. Subgroup Analyses for the Effect of Dynamic Resistance Training on Resting BP Using a Random-Effects Model

	Systolic BP		Diastolic BP	
	N	Effect Size (95% CL)	N	Effect Size (95% CL)
Sex				
Male	8	−3.9 (−6.9 to −0.91)	8	−0.80 (−3.8 to +2.2)
Female	9	−3.1 (−5.7 to −0.58)	9	−2.6 (−7.0 to +1.76)
Age, y				
<50	13	−0.99 (−3.3 to +1.4)	13	−3.1 (−5.2 to −1.1)
≥50	16	−3.1 (−6.1 to +0.12)	16	−3.4 (−5.3 to −1.6)
Hypertensive status				
Normal BP	12	−0.59 (−3.1 to +2.0)	12	−3.4 (−5.6 to −1.2)
Prehypertension	13	−4.3 (−7.7 to −0.90)	13	−3.8 (−5.7 to −1.9)
Hypertension	4	+0.47 (−4.4 to +5.3)	4	−1.0 (−3.9 to +1.9)
Duration of the intervention, wk				
<12	5	−1.6 (−7.2 to +3.9)	5	−2.3 (−5.8 to +1.2)
12 to 24	18	−2.0 (−4.7 to +0.62)	18	−3.4 (−4.9 to −1.8)
>24	6	−2.6 (−6.9 to +1.8)	6	−3.6 (−6.6 to −0.59)
Exercise intensity[5]				
Low	2	−5.8 (−14.8 to +3.1)	2	−4.7 (−10.4 to +1.0)
Moderate	5	−3.2 (−8.6 to +2.3)	5	−4.5 (−9.5 to +0.46)
High	20	−2.0 (−4.4 to +0.22)	20	−3.0 (−4.6 to −1.5)

BP indicates blood pressure; CL, confidence limit.

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overall recommendation is that higher volume (product of intensity, frequency, and duration) is associated with larger health benefits. Finally, after endurance training, we observed a tendency for larger changes in BP associated with larger reductions in weight. Although this relation did not reach statistical significance, the observed trend does not exclude a causal role in the BP response to training because of the many differences between study groups and the multiple potential mechanisms involved in the BP response.

Limitations

A number of potential limitations of the current meta-analysis have to be considered. First, there are limitations inherent to the primary literature. (1) Participants are aware of their allocation to a control or intervention group in exercise studies. (2) Several important scientific criteria have not always been observed, such as regular follow-up of the control subjects, assessment of compliance to the training program, attention to changes in other lifestyle factors, and lack of blinded or automated measurements. The small number of studies that conducted an intent-to-treat analysis makes it impossible to quantify the impact of study withdrawals. With regard to the latter, it is recommended that future studies report both per-protocol and intent-to-treat analyses so that one can determine both the efficacy and effectiveness of the different interventions on BP. (3) To examine dose–response effects, additional information on energy expenditure or a detailed description of the duration of each exercise at a given intensity should be provided in future studies.

Other limitations are associated with the meta-analytic technique itself as it should be acknowledged that meta-analysis is no substitute for large well-designed randomized controlled trials. However, the meta-analytical technique is probably the best method currently available to systematically review previous work.[20] Advantages are the greater precision of the estimates and the enhanced statistical power. Potential disadvantages included the heterogeneity of studies and potential publication bias. Nevertheless, despite strict selection criteria, studies may differ in several respects, but this potential problem is addressed by applying a random-effects models and by exploring the heterogeneity and inconsistency of studies. Furthermore, analyses of asymmetry of the funnel plot by Begg and Egger test did not suggest any publication bias. A final potential limitation is the large number of statistical tests that were conducted in this meta-analysis. As a result, some of the significant findings could have been merely chance. However, as suggested by others,[21,22] adjustments for multiple tests were not made because of the problems associated with such. Furthermore, given that all of our conclusions are based on P values <0.01, we hypothesize that risk for type I error is low. Nevertheless, findings based on meta-analyses always need to be confirmed with large, well-designed randomized controlled trials.

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Disclosures

None.

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SUPPLEMENTARY MATERIAL

EXERCISE TRAINING FOR BLOOD PRESSURE: A SYSTEMATIC REVIEW AND META-ANALYSIS

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TABLE S1. Characteristics of Included Trials.

Study (year)	Origin	Participants included in the final analysis	Training characteristics at the end of the intervention
I. Trials including only dynamic endurance training arms			
Gettman et al (1976)[23]	USA	55 men optimal BP randomized to 1-day (n=11, age 22), 3-day (n=20, age 24), 5-day (n=13, age 25) or control (n=11, age 26)	20 weeks of supervised walking/jogging, 1 (1 day group), 3 (3-day group) or 5 days (5-day group) per week, 30 minutes per session at 85-90% HR res
Lansimies et al (1979)[43]	FINLAND	100 pre-hypertensive men (mean age 42.5 yrs) randomized to exercise (n=44) or control (n=46)	16 weeks of supervised jogging/skiing/swimming/cycling, 3-4 sessions per week, 30 minutes/session at 66% of HR res
Deplaen et al (1980)[14]	BELGIUM	7 hypertensive men and 3 hypertensive women randomized to exercise (n=6, age 44yrs) or control (n=4, age 47 yrs)	12 weeks supervised walking/jogging/cycling/ calisthenics, 3x30minute sessions weekly at 60-70% VO_2peak
Kukkonen et al (1982)[41]	FINLAND	34 pre-hypertensive men (age 39 yrs) and 25 hypertensive men (age 42 yrs) randomized to exercise (n=30) or control (n=29)	16 weeks of walking/cycling/jogging/cross country skiing, 3 sessions per week, 50 minutes per session at 56% of HR res
Duncan et al (1985)[16]	USA	56 hypertensive men (mean age 30.4 yrs) randomized to exercise (n=44) or control (n=12)	16 weeks of walking and jogging, 3 sessions per week, 60 minutes/session at 75% HR peak
Fortmann et al (1988)[21]	USA	77 men with optimal BP randomized to exercise (n=42, age 44 yrs) or control (n=35, age 45 yrs)	52 weeks of supervised walking/jogging/calisthenics, 3 weekly sessions, 60 minutes per session at 70-85% HRpeak
Vroman et al (1988)[86]	USA	11 men with optimal BP randomized to exercise (n=6, age 23.8) or control (n=5, age 25.6)	12 weeks of supervised cycling, 4 sessions per week, 30 minutes per session at 75-85% VO_2peak
Hagberg et al (1989)[26]	USA	30 hypertensive men and women (mean age 64 yrs) randomized to low intensity exercise (n=11), moderate intensity exercise (n=9) or control (n=10)	Low intensity group: 37 weeks of partly supervised walking, 3.1 sessions per week, 51 minutes per session at 53% VO_2max. Moderate intensity group: 37 weeks of supervised walking/jogging/cycling, 2.5 sessions per week, 51minutes per session at 73% VO_2max.
Tanabe et al (1989)[73]	JAPAN	15 hypertensive men and 16 hypertensive women randomized to exercise (n=21, age 50.9) or control (n=10, age 46.8)	10 weeks of cycling, 3 sessions per week, 60 minutes per session at 40-60% of VO_2peak
Martin et al (1990)[48]	USA	27 hypertensive men randomized to exercise (13, age 44.4) or control (n=14, age 42.6)	10 weeks partly supervised walking/jogging/cycling, 4 weekly sessions, 30 minutes per session at 65-80% HR peak
Duncan et al (1991)[17]	USA	59 women (mean age 20-40 yrs) with optimal BP randomized to aerobic walkers (n=16), brisk walkers (n=12), strollers (n=18) or control (n=13)	24 weeks of supervised walking 4.8 km/session, 5 sessions/week at 4.8km/hour (strollers), 6.4 km/hour (brisk walkers) or 8km/hour (aerobic walkers).
King et al (1991)[37]	USA	168 men and 132 women with optimal BP (mean age 57.5) randomized to higher intensity group exercise HIG (40 men, 34 women), higher intensity home (HIH)exercise (n=42 men, n=35 women), lower intensity home (LIH)exercise (n=45 men, 29 women) or control (n=41 men, n=34 women)	52 weeks. HIG: supervised walking/jogging/cycling, 3 sessions per week, 40 minutes per session at 73-88% of HR peak. HIH:walking/jogging/cycling, 3 sessions per week, 40 minutes per session at 73-88% of HR peak; LIH: walking/jogging/cycling, 3 sessions per week, 40 minutes per session at 60-73% HR peak

Albright et al (1992)[1]	USA	40 women and 43 men with optimal BP randomized to exercise (n= 19 women, age 47 and n=23 men, age49) or control (n=21 women, age 46 and 20 men, age 48)	26 weeks walking/jogging, 5 weekly sessions, 47 minutes (men), 54 minutes (women)/session at 65-77%HRpeak
Posner et al (1992)[61]	USA	247 men and women with optimal BP (mean age 68.6 yrs) randomized to exercise (n=166) or control (n=81)	16 weeks of supervised cycling, 3 sessions per week, 30 minutes per session at 70% HR res
Braith et al (1994)[7]	USA	20 men and 24 women with prehypertension randomized to moderate intensity exercise (n=19, age 66 yrs), high intensity exercise (n=14, age 65 yrs) or control (n=11, age 66 yrs)	26 weeks of supervised walking, 3 sessions per week, 45 minutes at 70% of HR res (moderate intensity) or 35 minutes at 85% HR res (high intensity)
Lindheim et al (1994)[45]	USA	45 women with optimal BP randomized to exercise (n=25, age 48.8)) or control (n=20, age 50.8)	26 weeks of supervised walking/cycling, 3 sessions/week, 30 minutes per session at 70% HR peak
Anderssen et al (1995)[2]	NORWAY	N=90 (mean age 45 yrs) randomized to exercise (n=13 optimal BP, n=16 pre-hypertension, n=20 hypertension) or control (n= 13 optimal BP, n=14 pre-hypertension, n=14 hypertension)	52 weeks of supervised walking and jogging, 3 sessions per week, 60 minutes per session at 60-80% HR peak
Kokkinos et al (1995)[38]	USA	46 hypertensive men randomized to exercise (n=23, age 57) or control (n=23, age 58)	16 weeks of supervised cycle ergometry, 3 sessions per week, 44 minutes per session at 74% of predicted HR max
Anshel (1996)[3]	AUSTRALIA	30 men with optimal BP (mean age 21.9 yrs) randomized to exercise (n=15) or control (n=15)	10 weeks of supervised cycle ergometry, 3 sessions/week, 30 minutes per session at 75% HF peak
Ready et al (1996)[62]	CANADA	53 pre-hypertensive women (mean age 61.3 yrs) randomized to thrice weekly (n=18), 5 times weekly (n=17) or control (n=18)	24 weeks of partly supervised walking, 3 sessions per week, 60 minutes per session at 60% of VO_2peak or 60 minutes per session at 60% of VO_2peak 5 times weekly
Tanaka et al (1997)[74]	JAPAN	10 hypertensive men and 8 hypertensive women randomized to exercise (n=12, age 47) or control (n=6, age 49)	10 weeks of supervised swimming, 3 sessions per week, 45 minutes per session at 60% VO_2peak
Duey et al (1998)[15]	USA	25 African-American women with optimal BP randomized to exercise (n=16, age 23.6 yrs) or control (n=9, age 22.2 yrs)	6 weeks of supervised cycling, 3 sessions per week, 20 minutes per session at 60% VO_2peak
Jessup et al (1998)[33]	USA	10 men, 11 women both pre-hypertensive randomized to exercise (n=11, age 68) or control (n=10, age 69)	16 weeks of supervised walking/stair climbing, 3 sessions/week, 45 minutes per session at 85% HR peak
Murphy et al (1998)[52]	USA	34 pre-hypertensive women randomized to long bout group (n=12, age 48), short bout group (n=12, age 45) or control (n=10, age 47)	10 weeks supervised walking, 5x 30 minutes weekly accumulated in one bout (long bout group) or three bouts of 10 minutes daily (short bout group) at 70-80% HR peak
Sakai et al (1998)[63]	USA	5 hypertensive men and 24 hypertensive women randomized to exercise (n=16, age 56) or control (n=13, age 52)	4 weeks of supervised cycling, 3 sessions per week, 60 minutes per session at 40-60% VO_2peak
Stefanick et al (1998)[71]	USA	93 men, optimal BP (mean age 47.8 yrs) 88 pre-hypertensive women (mean age 56.9yrs) randomized to exercise (n=43 women, 47 men) or control (n=45 women, 46 men)	38 weeks brisk walking/jogging, 3 sessions weekly, ~60 minutes per session aiming at 16 km (10mi) weekly
Hamdorf et al (1999)[27]	AUSTRALIA	38 hypertensive women randomized to exercise (n=18, age 82.4 yrs) or control (n=20, age 83.1 yrs)	26 weeks of supervised walking, 2 sessions per week, 25 minutes per session at 40% HR res

Higashi et al (1999)[31]	JAPAN	20 hypertensive men and 7 hypertensive women (mean age 52) randomized to exercise (n=20) or control (n=7)	12 weeks of walking/jogging, 5-7 sessions per week, 30 minutes per session at 52% VO_2peak
Higashi et al (1999)[30]	JAPAN	13 hypertensive men and 4 hypertensive women randomized to exercise (n=10, age 49) or control (n=7, age 44)	12 weeks of walking/jogging, 5-7 sessions per week, 30 minutes per session at 52% VO_2peak
Georgiades et al (2000)[22]	USA	31 hypertensive men and 24 hypertensive women randomized to exercise (n=36, age 47.6 yrs) or control (n=19, age 47.7 yrs)	26 weeks of supervised walking/cycling, 3-4 sessions/week, 45 minutes per session at 70-85% HR res
Hass et al (2001)[29]	USA	26 pre-hypertensive men and women randomized to exercise (n=17, age 49 yrs) or control (n=9, age 46 yrs)	12 weeks of supervised total body recumbent step training, 3 sessions per week, 40 minutes per session at 75% of HR res.
Moreau et al (2001)[51]	USA	24 hypertensive women randomized to exercise (n=15, age 53) or control (n=9, age 55)	24 weeks of home-based daily walking (~9700 steps/day).
Myslivecek et al (2002)[55]	CANADA	32 Women, 4 groups -menopausal (M) and post-menopausal (PM) with and without exercise training	12 weeks walking, 5 times weekly at RPE 12-13, 0.6-4.0km daily
Staffileno et al (2001)[70]	USA	18 hypertensive women randomized to exercise (n=9, age 57.1) or control (n=9, age 62.2)	8 weeks of walking/cycling/other, 5 sessions/week, 3x10 minutes bouts per day at 50-60% HR res
Tsai et al (2002)[78]	JAPAN	23 hypertensive men and 19 hypertensive women (white coat hypertension) randomized to exercise (n=22, age 45.5) or control (n=20, age 36.6)	12 weeks of supervised walking/jogging, 3 sessions per week, 30 minutes per session at 60-70% HR peak
Tsai et al (2002b)[79]	JAPAN	12 hypertensive men and 11 hypertensive women randomized to exercise (n=12, age 49.6) or control (n=11, age 46.2	12 weeks of supervised walking/jogging, 3 sessions per week, 30 minutes per session at 60-70% HR peak
Asikainen et al (2003a)[5]	FINLAND	130 pre-hypertensive women randomized to W1 (n=46, age 58), W2 (n=43, age 58) or control (n=45, age 57)	15 weeks of partly supervised walking, 5 days per week, one (W1) or two (W2) sessions/exercise day, expending a total of 300kcal per exercise day at 65% of VO_2 peak
Asikainen et al (2003b)[5]	FINLAND	116 pre-hypertensive women randomized to W3 (n= 21, age 57), W4 (n=18, age 54), W5 (n=21, age 55), W6 (n=40, age 56)	24 weeks of partly supervised walking, 5 days per week, W3: 55% VO_2peak and 300 kcal/session, , W4: 45%VO_2max and 300kcal/session, W5: 55%VO_2max and 200kcal/session, W6, 45% VO_2max and 200kcal/session
Jessup et al (2003)[34]	USA	30 hypertensive men and women randomized to exercise (n=15, age 75.9 yrs) or control (n=15, age 76.9 yrs)	16 weeks of supervised walking/cycling/stair climbing, 2 sessions per week, 45 minutes per session at 75% HR peak
Tsuda et al (2003)[80]	Japan	16 hypertensive men randomized to exercise (n=8, age 46.2) or control (n=8, age 49)	26 weeks, 2 supervised sessions weekly-15 minutes jogging at AT, 5 minutes walking and 30 minutes calisthenics.
Santa-Clara et al (2003)[64]	USA	27 pre-hypertensive African-American (AA) women and 33 pre-hypertensive Cauasian (CA)women randomized to exercise (n=15 AA, age 58; 17 CA, age 59) or control (n=12 AA, age 55, 16 CA, age 57)	26 weeks of supervised walking/cycling/rowing, 3-4 sessions per week, 45-60 minutes per session at 70-85% of HR peak
Maeda et al (2004)[47]	Japan	15 pre-hypertensive women randomized to exercise (n=10, age 63 yrs) or control (n=5, age 64 yrs)	12 weeks of cycling, 5 sessions per week, 30 minutes per session at 80% VT

Tsai et al (2004)[79]	JAPAN	47 hypertensive men and 55 hypertensive women randomized to exercise (n=52, age 48.8) or control (n=50, age 49.3)	10 weeks of supervised walking/jogging, 3 sessions per week, 30 minutes per session at 60-70% HR peak
Murtagh et al (2005)[54]	IRELAND	17 pre-hypertensive men and 31 pre-hypertensive women (mean age 45.7 yrs) randomized to once daily (n=19), twice daily (n=18) or control (n=11)	12 weeks of partly supervised walking, 3 sessions per week, one bout of 20 minutes per session at 73.1 % HR peak (once daily group) or 2x10 minutes per day at 72.1 %HR peak
Tully et al (2005)[82]	IRELAND	26 pre-hypertensive men and women randomized to exercise (n=17, age 55.5) or control (n=9, age 57.8)	12 weeks of walking, 5 sessions per week, 30 minutes per session a pace faster than normal that left the individual slightly breathless but still able to converse.
Wang et al (2005)[87]	TAIWAN	30 men with optimal BP randomized to exercise (n=15, age 23.5) or control (n=15, age 24.7)	8 weeks of cycling, 5 sessions per week, 30 minutes per session at 60% VO_2peak
Murphy et al (2006)[53]	USA	33 men and women with optimal BP randomized to exercise (n=21, age 41.4) or control (n=12, age 40.8)	8 weeks of walking, 2 sessions per week, 45 minutes per session at own walking speed
Church et al (2007)[9]	USA	464 women with prehypertension randomized to 4 kcal/kg/wk (n=155; age 57.2), 8 kcal/kg/wk (n=104, age 57.7) ,12 kcal/kg/wk (n=103, age 57.3) or control (n=102, age 56.6)	26 weeks of supervised walking/jogging/cycling, 2.6 sessions per week for 28 minutes per session at 50%VO_2peak (4kcal/kg/wk) or 2.8 sessions per week for 49 minutes per session at 50% VO_2peak (8kcal/kg/wk) or 3.1 sessions per week for 62 minutes per session at 50% VO_2peak (12 kcal/kg/wk)
Tully et al (2007)[83]	IRELAND	93 pre-hypertensive men and women randomized to 3 sessions/wk (n=39, age 47.8), 5 sessions/wk (n=36, age 46.4) or control (n=18, age 49)	12 weeks of walking, 3 sessions per week (3-day group), 5 sessions per week (5-day group), 30 minutes per session at a pace faster than normal that left the individual slightly breathless but still able to converse
Brixius et al (2008)[8]	GERMANY	21 pre-hypertensive men randomized to running (n=7, age 58.7), cycling (n=7, age 58.9) or control (n=7, age 52.6)	6 weeks of running or cycling, 3 sessions per week, -/60 minutes (running group) at 3 mmol/L lactate or 90 minutes (cycling group) at 3 mmol/L lactate
Gormley et al (2008)[24]	UK	19 men and 36 women with optimal BP randomized to moderate (n=14, age 23 yrs), vigorous exercise (n=13, age 22 yrs), near maximal exercise (n=15, age21 yrs) or control (n=13, age 22yrs)	6 weeks of supervised cycling, 4 sessions per week for 60 minutes per session at 50% HR res (moderate group), 4 sessions per week for 40 minutes per session at 75% HR res (vigorous group) or 3 sessions per week for 5x (5 min 90-100% HR res; 5 min 50% HR res) (near maximal group)
Westhoff et al (2008)[88]	Germany	11 hypertensive men and 13 hypertensive women randomized to exercise (n=12, age 66.1) or control (n=12, age 68.4)	12 weeks of supervised upper-limb cycling,; 3 sessions per week, 30 minutes per session at 2mmol/L lactate

Krustrup et al (2009)[40]	Denmark	32 pre-hypertensive men (age 20-43 yrs) randomized to soccer (n=12), running (n=10) or control (n=10)	Soccer group: 12 weeks of soccer, 2.3 sessions per week, 60 minutes per session at 82% of HR peak. Running group: 12 weeks of running, 2.5 sessions per week, 60 minutes per session at 82% of HR peak.
Dalleck et al (2009)[13]	USA	26 women randomized to 30 minutes exercise (n=8 pre-hypertensives, age 59.3), 45 minutes of exercise (n=8 optimal BP, age 55.4) or control (n=10, age 57.4)	12 weeks of partly supervised walking, 5 sessions per week, 30 minutes or 45 minutes /session at 50% VO_2 reserve
Hua et al (2009)[32]	CANADA	20 hypertensive men and 20 hypertensive women randomized to exercise (n=20, age 56 yrs) or control (n=20, age 57.2 yrs)	12 weeks of walking; 4 sessions per week, 4.8 km/session at 35-40% HR res
Yoshizawa et al (2009a)[92]	JAPAN	25 women with optimal BP randomized to exercise (n=12, age 57) or control (n=13, age 59)	8 weeks of partly supervised walking/cycling, 4.4 sessions/week, 45 minutes per session at 70-75%HRpeak
Finucane et al (2010)[20]	UK	96 men and women (mean age 71.4 yrs, 44% women)) randomized to exercise (n=46) or control (n=46)	12 weeks of supervised cycling, 3 sessions per week, 60 minutes per session at 70% WLmax
Lamina et al (2010)[42]	NIGERIA	357 hypertensive men randomized to continuous exercise (n=112, age 58.6±7.2), interval exercise (n=140, age 58.2±7.4) or control (n=105, age58.3±6.2)	8 weeks of cycling, 3 sessions per week for 60 minutes per session at 60-79% HR res
Saremi et al (2010)[65]	IRAN	18 pre-hypertensive men (mean age 43.1 yrs) randomized to exercise (n=9) or control (n=9)	12 weeks of supervised walking/running, 5 sessions per week, 50-60 minutes per session at 80-85%HR peak
Pitsavos et al (2011)[60]	GREECE	40 pre-hypertensive men randomized to exercise (n=20, age 51.7 ±8.2) or control (n=20, age 55.3±6.4)	16 weeks of cycling, 3sessions per week, 44 minutes per session at 60-80% HR peak
II. Trials including only dynamic resistance training arms			
Harris et al. (1987)[28]	USA	26 hypertensive men randomized to exercise (n=10, age=32.7±5.2 yrs) or control (n=16; age= 31.4±6.2 yrs)	9 weeks of supervised circuit weight training, 3 sessions weekly, 40% 1RM, 10 exercises, 3 sets, 20-25 reps/set
Katz et al (1992)[35]	USA	26 women with optimal BP randomized to an exercise (n=13, age 22) and control (n=13, age 18.8 yrs) group	6 weeks of resistance training on Nautilus exercise machines, 3 sessions per week, 30% of 1RM, 13 exercise, 1 set/exercise, 14-15 reps/set for LB, 11-12 reps/set for UB
Vanhoof et al (1996)[84]	BELGIUM	19 pre-hypertensive men randomized to an exercise (n=8, age 38) and control (n=11, age=38 yrs) group	16 weeks supervised strength training, 3 sessions/week, 70-90% of 1RM, 6 exercises, 3 sets/exercise, 10 reps/set
Tsutsumi et al (1997)[81]	JAPAN	41 (33 men) individuals with normal BP or prehypertension randomized to EXH (n=13, age 67.8±4.9), EXL (n=14, age 68.9±7.5) or control group (n=14, age 69.8±4.6)	12 weeks of supervised strength training by using dynamic variable resistance machines - 11 exercises, 3 sessions weekly, 2 sets, 75-85% of 1RM (EXH), 8-12 resp/set (EXH), 55-65% of 1RM (EXL), 12-16 reps/set (EXL)
Elliott et al (2002)[18]	UK	15 postmenopausal women randomized to exercise (n=8) or control group (n=7)	8 weeks of supervised resistance training using 5 weight machines, 3 sessions/week, 3 sets/exercise, 8 reps/set, 80% of 10RM, 2 min rest between sets

Vincent et al (2003)[85]	USA	62 (28 men) prehypertensive individuals randomized to EXL (n=24, age 67.6±6yrs) or EXH (n=22, age 66.6±7yrs) or control (n=16, age71±5yrs)	6 months of resistance training using MedX resistance machines involving 13 exercises, 3 sessions/week, 1 set/exercise, 8 reps/ex (HEX), 13 reps/ex (LEX), 50% of 1RM LEX, 80% of 1RM (HEX)
Miyachi et al (2004)[4]	JAPAN	28 men with optimal BP randomized to exercise (n=14, age 22±1yrs) and control (n=14, age 22±1yrs)	16 weeks of supervised resistance training, 3 sessions/week, 8-12 exercises, 3 sets/exercise, 80% of 1RM, 12 reps/set for set 1 and 2, as many reps/set in set 3
Anton et al (2006)[50]	USA	26 (7 men) individuals with normal BP randomized to exercise (n=13; 52±2 yrs) or control (n=13; 53±2 yrs)	13 weeks of supervised resistance training involving 9 exercises, 75% of 1RM, 1 set, 12 reps/set.
Okamoto et al (2006)[57]	JAPAN	29 women with optimal BP randomized to CRT (n=10, age 19.1+0.3), ERTn=10, age18.9+0.3) or control group (n=9; age 19.9+1.2)	8 weeks of supervised ERT or CRT using arm curl, 3 sessions/week, 100% of 1RM (ERT), 80% of 1RM (CRT), 5 sets/exercise, 10 reps/set
Olson et al (2007)[59]	USA	28 women with optimal BP randomized to exercise (n=16; age 39±5yrs) or control (n=12, age 38±6yrs) group	52 weeks of resistance training on isotonic variable resistance machines and free weights (first 16 weeks: supervised, thereafter meeting twice every 12 weeks), 2 sessions/week, 3 sets, 8-10 reps/set
Colado et al (2009)[10]	SPAIN	31 pre-hypertensive women randomized to exercise (n=21; age 54+2.8) and control (n=10, age 52.1+1.9) group	24 weeks of supervised circuit resistance exercise using thera-bands, 3 sessions/week,8-16 exercise, 2 sets, 15-30 reps/set
Lovell et al (2009)[46]	AUSTRALIA	24 pre-hypertensive men randomized to exercise (n=12, age 74.1±2.7yrs) and control (n=12; age: 73.5±3.3yrs)	16 weeks of supervised resistance exercise on incline squat machine, 70-90% of 1RM, 3 sessions/week, 1 exercise, 3 sets, 6-10 reps/set
Tanimoto et al (2009)[75]	JAPAN	36 men with optimal BP randomized to LEX (n=12, age 19+0.2), HEX (n=12, age 19.5) or control (n=12, age 19)	13 weeks of resistance training consisting of 5 exercises, 8RM, 55-60% of 1RM with slow movement and tonic force generation and no relaxation phase(LEX), 89-90% of 1RM with normal speed (HEX), 3 sets/ex, 2 sessions/week

III. Trials including only a combination (endurance + resistance) exercise arm			
Laterza et al (2007)[44]	BRAZIL	20 (13 men) hypertensive individuals (mean age 44 yrs) randomized to exercise (n=11) or control (n=9)	16 weeks of supervised combination training, 3 sessions per week, 60 minutes per session including 40 minutes of cycling at 70% VO_2 peak and 10 minutes of local strengthening exercises
Okamoto et al (2008)	JAPAN	33 (11 men) individuals with normal BP randomized to BRT (n=11, age18.5±0.66), ART (n=11, age 18.5±0.66) or control (n=11, age 18.8±0.66)	8 weeks of combination training, 2 sessions per week involving 20 minutes of treadmill running at 60% Heart rate Reserve (HRR) performed before (BRT) or after (ART) resistance training (7 exercises, 5 sets/exercise, 8-10 RM)

Guimaraes et al (2010)[25]	BRAZIL	56 (13 men) pre-hypertensive individuals randomized to COMint (n=16, age 45±9), COMcont(n=16, age 50±8) or control group (n=11, age 47±6)	16 weeks of partly supervised (2/3) combination training, 3sessions per week, 40 min of continuous treadmill exercise at 60% HRR (COMcont) or 40 minutes of alternating 2 min 50% HRR – 1 min 80% HRR (COMint) followed by 20% of submaximal strength training
Figueroa et al (2011)[19]	SOUTH-KOREA	24 prehypertensive women randomized to exercise (n=12, age 54±7) or control (n=12, age 54±3.5)	12 weeks of supervised combination training, 3 sessions per week including 20 minutes of treadmill walking at 60% predicted HRmax and 20 minutes of circuit resistance training (9 exercises)
Ohkubo et al. (2001)[56]	JAPAN	39 (19 men) prehypertensive individuals randomized to exercise (n=22, age 67.5))or control (n=17, age 66.8)	25 weeks of supervised combination training, 2-3 sessions per week including 25 minutes of cycling at 60% Hrres and 5 resistance exercises (Thera-Band resistive exercises)
IV. Trials including only isometric resistance training arms			
Wiley et al (1992)[90]	USA	15 prehypertensive participants (20-35 yrs) randomized to exercise (n=8) or control (n=7)	8 weeks of isometric handgrip training, 4x 2 min isometric contractions at 30% MVC using dominant arm and 3 min rest period between contractions, 3 sessions per week
Taylor et al (2003)[76]	CANADA	17 hypertensive men and women randomized to exercise (n=9, age 69.3±6) or control (n=8, age 64.2±5.5)	10 weeks of isometric handgrip training,4x2 min bilateral isometric contractions at 30% MVC, 1 min rest period between contractions, 3 sessions/week
Millar et al (2008)[49]	CANADA	21 men and 28 women with optimal BP randomized to exercise (n=25, age 66±1 yrs) and control (n=24, age 67±2)	8 weeks of isometric handgrip training, 4x2 min bilateral isometric contractions at 30-40% MVC, 1 min rest period between contractions, 3 sessions/week
Wiles et al (2010)[89]	UK	33 men with optimal BP (age 18-34 yrs) randomized to HI (n=11), LI (n=11) or control (n=11)	8 weeks of supervised isometric leg extension exercise, 4x2 min bouts of isometric leg extension 3 sessions/week at a subject specific EMG corresponding on average at 10% MVC (LI) or 21% MVC (HI), 3 sessions per week
V. Trials including different exercise arms			
Blumenthal et al (1991)[6]	USA	57 hypertensive men and 35 hypertensive women randomized to dynamic endurance exercise (n=39, age 44.3), dynamic resistance exercise (n=31, age=46±7 yrs) and control (n=22, age 45.7±7.8 yrs)	16 weeks of supervised circuit weight training, 2-3 sessions per week, 30 minutes/session (resistance group) or 16 weeks of supervised walking/jogging, 3 sessions per week, 35 minutes per session at 70% VO_2 peak
Cononie et al (1991)[11]	USA	23 men and 26 women (age 72+2.6 yrs) randomized to dynamic endurance exercise (n=11 pre-hypertensives and n=6 hypertensives), dynamic resistance exercise (n=14 pre-hypertensives and 6 hypertensives) or control (n=7 pre-hypertensives and 5 hypertensives)	26 weeks of supervised DRT on Nautilus machines, 10 exercises, 3 sessions/week, 8-12 RM, 1 set/exercise, 12 reps/set (resistance group) or 26 weeks of supervised interval training (jogging/brisk walking, uphill treadmill running and walking), 3 sessions/week, 35-45 minutes per session at 75-85% VO_2 peak (endurance group)

Kraemer et al (2001)[39]	FINLAND	35 women randomized to 25 min group (n=8 optimal BP, age 31.8), 40 min group (n=12 pre-hypertensive, age 37.3) , SAR group (n=9 pre-hypertensive, age 33) or control (n=6, age 27.8)	12 weeks of supervised step aerobics, 3 sessions per week, 25 minutes per session (25 min group), 40 minutes per session (40 min group) at 80-90% of HR peak or 25 min of step-aerobics and a multiple-set upper and lower body resistance exercise (SAR)
Wood et al (2001)[91]	USA	17 pre-hypertensive men and 19 pre-hypertensive women randomized to dynamic aerobic endurance exercise, (n=11, age 69.1), dynamic resistance exercise (n=10; 69.8±6yrs), combination training (n=6; 66.1±5.5yrs) or control (n=6; age 68±5.4yrs) group	12 weeks DRT using Med-X brand devices, 3 sessions/week, 8 exercises, 8-12 RM, 2 sets/exercise (resistance group) or 12 weeks cycling/walking, 3 sessions/week, 45 minutes/session at 60-70% of predicted HR res (endurance group) or 12 weeks combination
Kawano et al (2006)[36]	JAPAN	39 men with optimal BP randomized to resistance exercise (n=12, age 20±1yrs), combination exercise (n=11, age 21±1) or control (n=16, age 22±1yrs)	4 months of supervised resistance training involving 14-16 exercises, 50% of 1 repetition maximum (1RM), 3 sessions/week, 45 minutes/session, 3 sets/exercise or supervised combination training (8-12 resistance exercise, 80% 1RM, 3 sets/exercise followed by 30 min cycling at 60% HR peak),
Sarsan et al (2006)[66]	TURKEY	60 pre-hypertensive women randomized to dynamic aerobic endurance exercise (n=20; age 41.6), dynamic resistance exercise (n=20; 42.5±10.07) or control (n=20, age = 43.6±6.46)	12 weeks of supervised DRT using a stationary exercise unit, 75-80% of 1RM, 3 sessions/week; 6 exercises, 3 sets/exercise, 10 reps/set (resistance group) or 12 weeks of supervised walking/cycling, 5sessions per week, 30-45 minutes per session at 50-85% HR res (endurance group)
Simons et al (2006)[69]	USA	59 (15 men) pre-hypertensive individuals randomized to dynamic aerobic endurance exercise (n=18, age 81.6) or dynamic resistance exercise (n=21, age 84.6±4.5yrs) and control (n=21, age 84±3.3yrs)	16 weeks of supervised DRT on Keiser machines, 2 sessions/week, 75% of 1RM, 6 exercises, one set/exercise, 10 reps/set (resistance group) or 16 weeks of supervised walking, 2 sessions per week at a self-selected pace
Cortez-Cooper et al (2008)[12]	USA	37 men and women with optimal BP randomized to resistance exercise (n=13, age 52±2), combination exercise (n=12, age 51±1) or control (n=12, age 54±2)	13 weeks of supervised whole body DRT using 10 devices, 3 sessions/week, 1 set per exercise, 8-12 reps/set, 70% of 1RM or combination training (2 sessions/week resistance exercise and 2 sessions/week endurance exercise walking or cycling at 60–75% of heart rate reserve for 30-45 min)
Sillanpää et al (2009)[67]	FINLAND	62 pre-hypertensive women randomized to dynamic aerobic endurance exercise (n=15, age 51.7yrs), dynamic resistance exercise (n=17, age 50.8±7.9yrs), combination training (n=18, age 48.9±6.8) or control (n=12, age51.4±7.8yrs)	21 weeks of supervised DRT, 2 sessions/week, 7-8 exercises ,70-90% of 1RM, 6-8 reps/set, 3-4 sets/exercise (resistance group) or 21 weeks of supervised cycling, 2 sessions per week, 60-90 minutes per session above AT or 21 weeks of combination training

Sillanpaä et al (2009)[68]	FINLAND	63prehypertensive men randomized to dynamic aerobic endurance (n=17, age 52.6±7.9), dynamic resistance exercise (n=15, age 54.1±6), combination exercise (n=15, age 56.3 ±63.8) or control (n=14, age 53.8±7.7)	21 weeks of supervised DRT, 2 sessions/week, 7-8 exercises ,70-90% of 1RM, 6-8 reps/set, 3-4 sets/exercise (resistance group) or 21 weeks of supervised cycling, 2 sessions per wee, 60-90 minutes per session above AT or 21 weeks of combination training
Yoshizawa et al (2009)[93]	JAPAN	35 women with optimal BP randomized to dynamic aerobic endurance (n=12, age 47), dynamic resistance exercise (n=11; age 47) or control (n=12, age 49)	12 weeks of resistance training using resistance devices, 60% of 1RM 2 sessions/week, 6 exercise, 3 sets/exercise, 10 reps/set (resistance group) or 12 weeks of cycling, 2 sessions per week, 30 minutes per session at 60-70% VO_2 peak
Stensvold et al (2010)[72]	NORWAY	43 (17 men) hypertensive individuals randomized to dynamic aerobic endurance training (n=11, age49.9), dynamic resistance training (n=11, age 50.9), combination (n=10, age 52.9) or control (n=11, age 47.3)	12 weeks of resistance training using resistance devices, 80% 1RM, ,, 3 sessions per week, 3 sets per exercise (resistance group) or 12 weeks of supervised interval training on a treadmill, 3 sessions per week, 4X4 minute interval at 90-95%HRpeak with 3 minutes of active recovery in between at 70% HR peak or 12 weeks of AIT twice a week and ST once a week (COM)

TABLE S2: Quality metrics of included studies

Study name	**Eligibility criteria specified**	**Random allocation of participants**	**Allocation concealed**	**Groups similar at baseline**	**Assessors blinded**	**Outcome measures assessed in 85% of participants**	**Intention to treat analysis**	**Reporting of between group statistical comparison**	**Point measures and measures of variability reported for BP**	Overall pedro
Albright 1992[1]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Anderssen 1995[2]	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	8
Anshell 1996[3]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Anton 2006[4]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Asikainen 2003[5]	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	8
Blumenthal 1991[6]	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes	6
Braith 1994 [7]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Brixius 2008[8]	Yes	Yes	No	Yes	No	Yes	No	No	Yes	5
Church 2007[9]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	9
Colado 2009[10]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Cononie 1991 [11]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Cortez-Cooper 2008 [12]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Dalleck 2009 [13]	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	7
Deplaen 1980 [14]	Yes	Yes	No	Yes	Yes	No	No	No	Yes	5
Duey 1998 [15]	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	6
Duncan 1985 [16]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Duncan 1991 [17]	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes	6
Elliott 2002 [18]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Figueroa 2011 [19]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7

Finucane 2010 [20]	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	7
Fortmann 1988 [21]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Geogiades 2000 [22]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Gettmann Yes976[23]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Gormley 2008[24]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Guimaraes 2010 [25]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Hagberg 1989 [26]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Hamdorf 1999 [27]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Harris 1987 [28]	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes	6
Hass 2001 [29]	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes	6
Higashi 1999a[30]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Higashi 1999b [31]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Hua 2009 [32]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Jessup 1998 [33]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Jessup 2003[34]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Katz 1992 [35]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Kawano 2006 [36]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
King 1991 [37]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Kokkinos 1995 [38]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Kraemer 2001 [39]	No	Yes	No	Yes	No	Yes	No	Yes	Yes	5
Krustrup 2009 [40]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Kukkonen 1982 [41]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Lamina 2010 [42]	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	7
Lansimies 1979 [43]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Laterza 2007 [44]	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes	6
Lindheim 1994 [45]	Yes	Yes	No	Yes	No	Yes	No	No	Yes	5

Lovell 2009[46]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Maeda 2004 [47]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Martin 1990 [48]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Millar 2009 [49]	No	Yes	No	No	Yes	Yes	No	Yes	Yes	5
Miyachi 2004 [50]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Moreau 2001[51]	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes	6
Murphy 1998 [52]	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes	6
Murphy 2006 [53]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Murtagh 2002 [54]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Myslivecek 2002 [55]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Ohkubo 2001[56]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Okamoto 2006 [57]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Okamoto 2009 [58]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Olson 2007 [59]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Pitsavos 2011 [60]	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	7
Posner 1992 [61]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Ready 1996 [62]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Sakai 1998 [63]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Santa-Clara 2003 [64]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Saremi 2010 [65]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Sarsan 2006 [66]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Sillanpaa 2009a[67]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Sillanpaä 2009b [68]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Simons 2006 [69]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Staffileno 2001[70]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Stefanick 1998 [71]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7

Stensvold 2010[72]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Tanabe 1989 [73]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Tanaka 1997 [74]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Tanimoto 2009 [75]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Taylor 2003 [76]	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes	6
Tsai 2002 [77]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Tsai 2002 [78]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Tsai 2004 [79]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Tsuda 2003 [80]	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes	6
Tsutsumi 1997 [81]	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes	6
Tully 2005[82]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Tully 2007[83]	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	7
Vanhoof 1989 [84]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Vincent 2003 [85]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Vroman 1988 [86]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Wang 2005 [87]	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes	6
Westhoff 2008 [88]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Wiles 2010 [89]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Wiley 1992 [90]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Wood [91]	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes	6
Yoshizawa 2009a [92]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Yoshizawa 2009a [93]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6

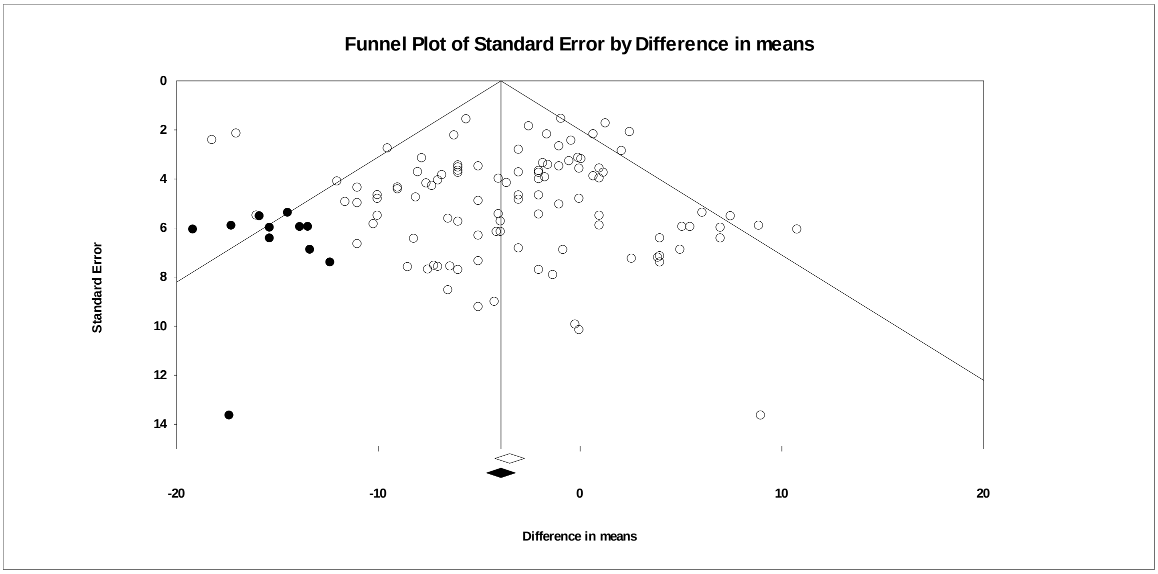

Figure S1: Funnel plot of each endurance study group observation effect size for systolic blood pressure versus standard error. Open circles:observed study groups, closed circles: imputed study groups by Trim and Fill computation. Egger regression test: two-sided P=0.68.

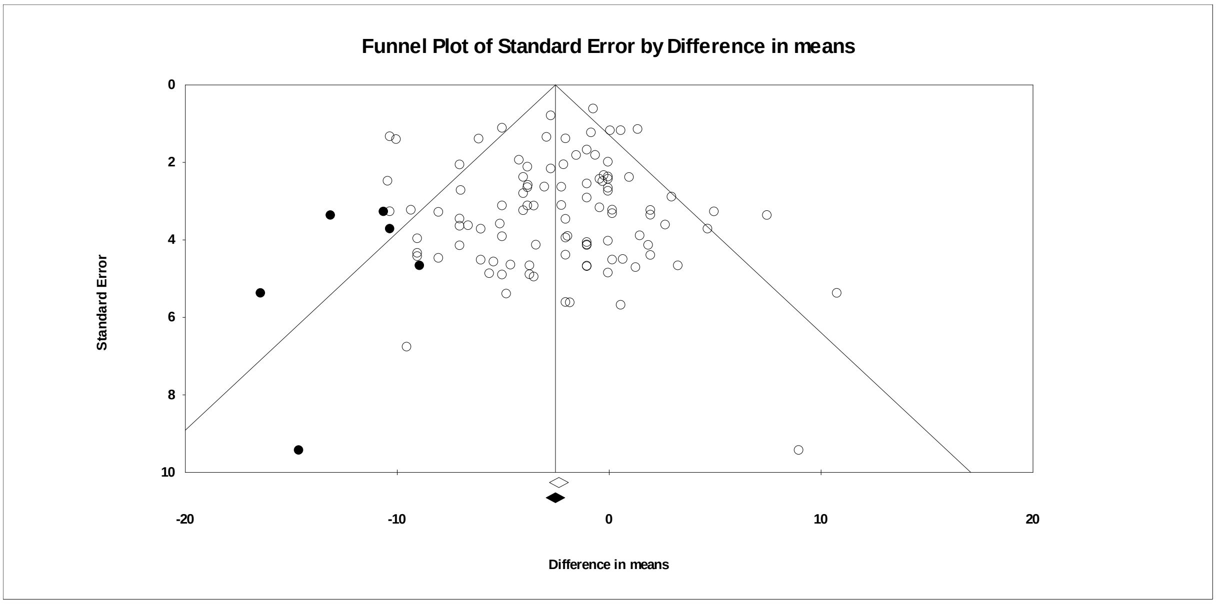

Figure S2: Funnel plot of each endurance study group observation effect size for diastolic blood pressure versus standard error. Open circles: observed study groups, closed circles: imputed study groups by Trim and Fill computation. Egger regression test: two-sided P=0.73.

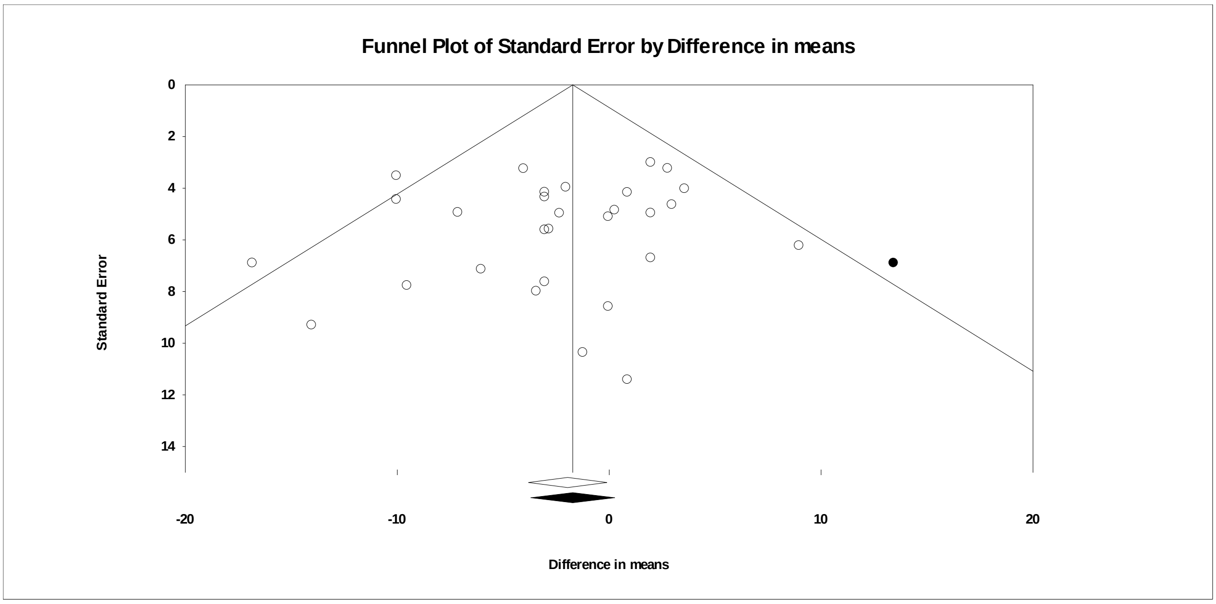

Figure S3: Funnel plot of each dynamic resistance study group observation effect size for systolic blood pressure versus standard error. Open circles:observed study groups, closed circles: imputed study groups by Trim and Fill computation Egger regression test: two-sided P=0.35.

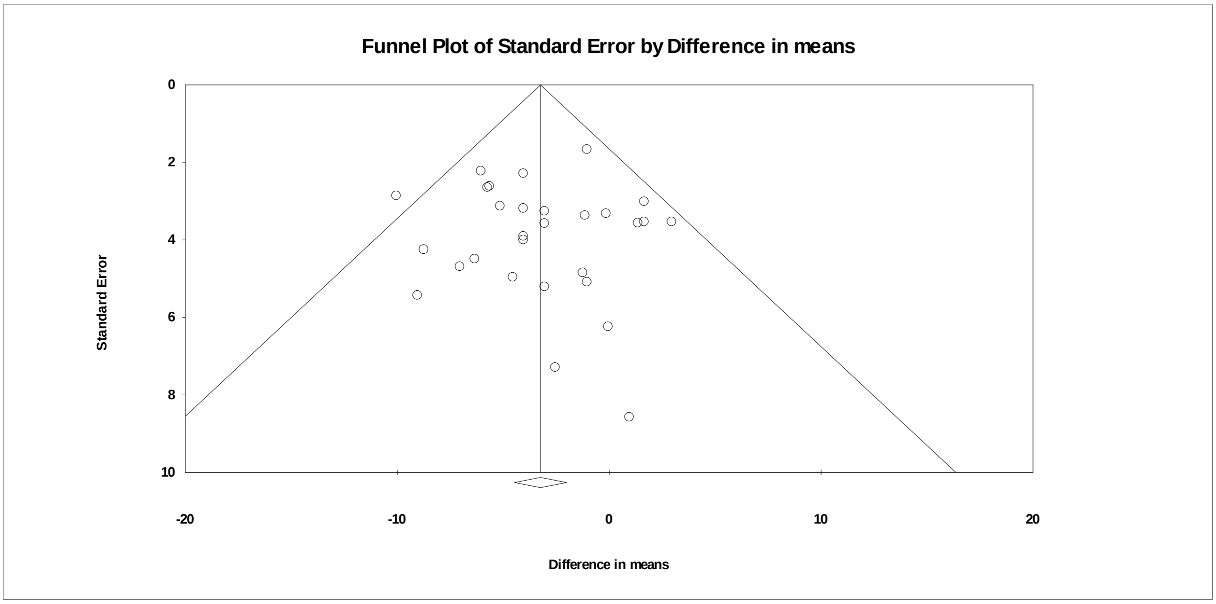

Figure S4: Funnel plot of each dynamic resistance study group observation effect size for diastolic blood pressure versus standard error. Open circles:observed study groups. No studies were added by Trim and Fill computation. Egger regression test: two-sided P=0.95

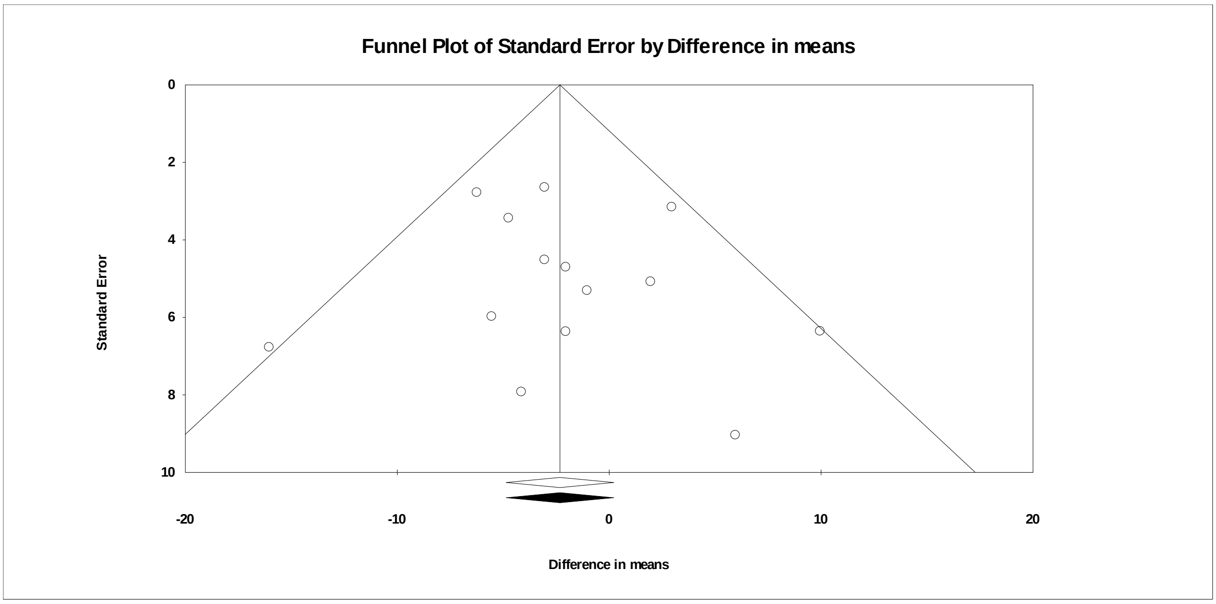

Figure S5: Funnel plot of each combined study group observation effect size for SBP versus standard error. Open circles:observed study groups. No studies were added by Trim and Fill computation. Egger regression test: two-sided P=0.61.

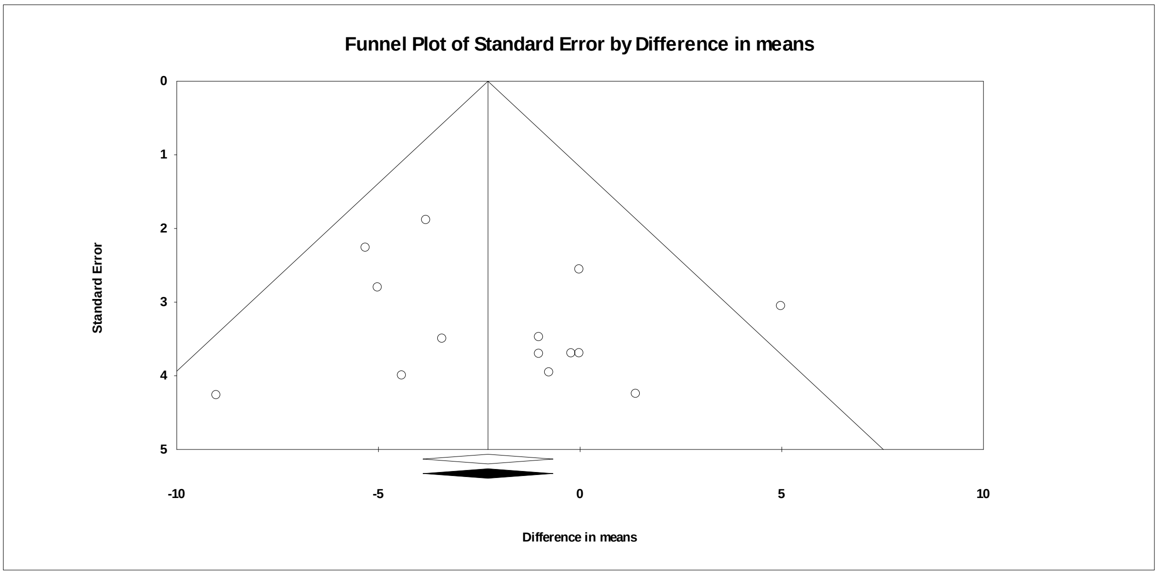

Figure S6: Funnel plot of each combined study group observation effect size for diastolic blood pressure versus standard error. Open circles:observed study groups. No studies were added by Trim and Fill computation. Egger regression test: two-sided P=0.40.

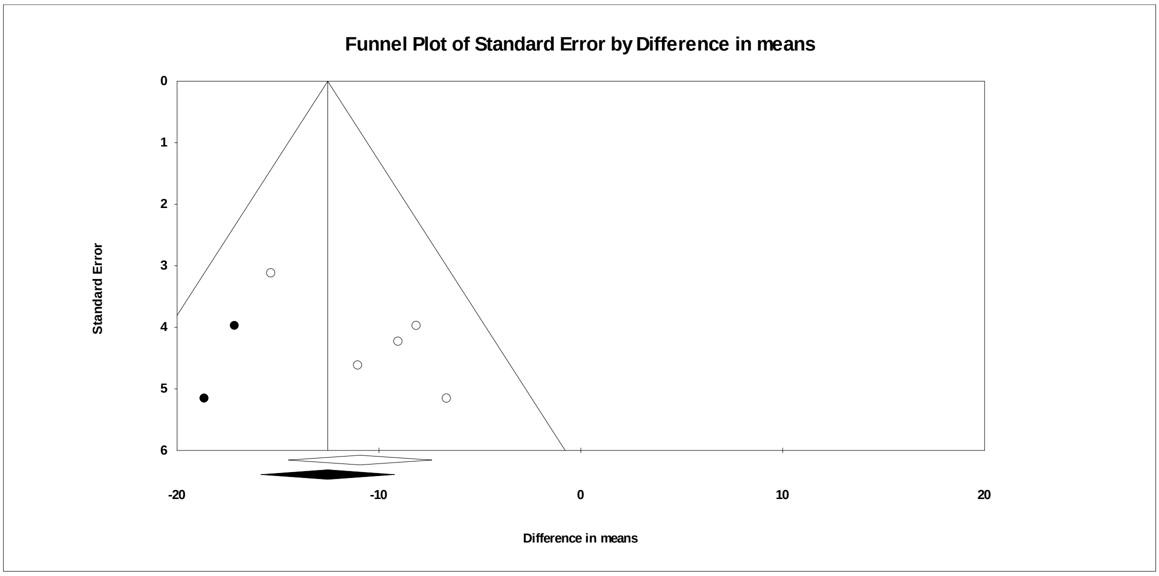

Figure S7: Funnel plot of each isometric resistance study group observation effect size for systolic blood pressure versus standard error. Open circles:observed study groups. No studies were added by Trim and Fill computation. Egger regression test: two-sided P=0.12.

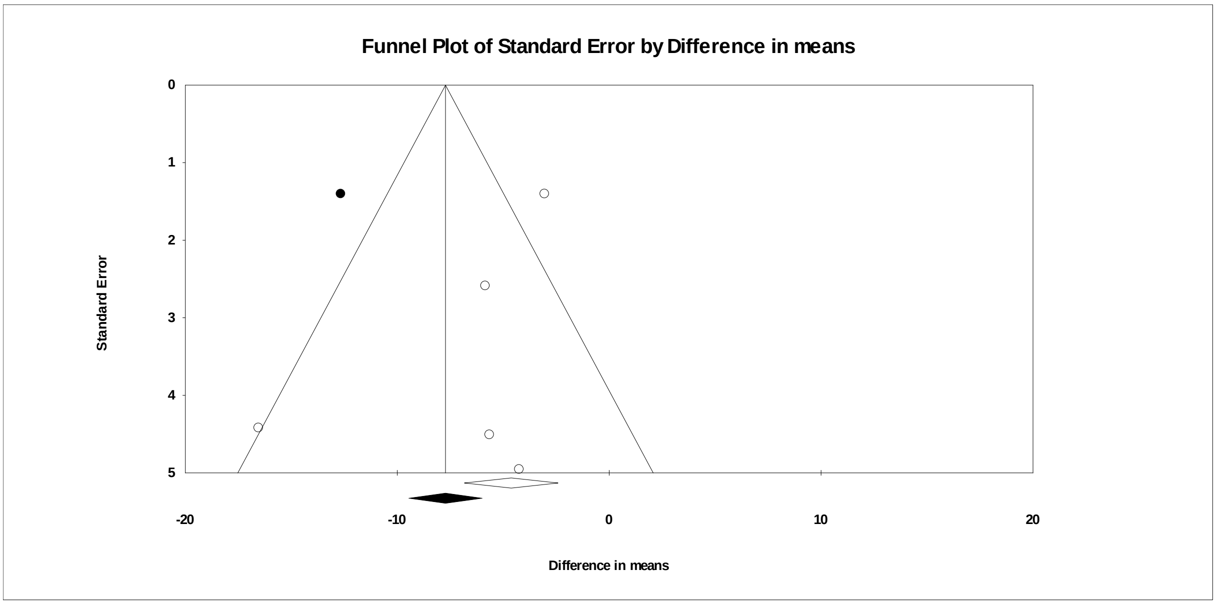

Figure S8: Funnel plot of each isometric resistance training group observation effect size for diastolic blood pressure versus standard error. Open circles: observed study groups, closed circles imputed study groups. Egger regression test: two-sided P=0.22.

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SUPPLEMENTARY MATERIAL

EXERCISE TRAINING FOR BLOOD PRESSURE: A SYSTEMATIC REVIEW AND META-ANALYSIS

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TABLE S1. Characteristics of Included Trials.

Study (year)	Origin	Participants included in the final analysis	Training characteristics at the end of the intervention
I. Trials including only dynamic endurance training arms			
Gettman et al (1976)[23]	USA	55 men optimal BP randomized to 1-day (n=11, age 22), 3-day (n=20, age 24), 5-day (n=13, age 25) or control (n=11, age 26)	20 weeks of supervised walking/jogging, 1 (1 day group), 3 (3-day group) or 5 days (5-day group) per week, 30 minutes per session at 85-90% HR res
Lansimies et al (1979)[43]	FINLAND	100 pre-hypertensive men (mean age 42.5 yrs) randomized to exercise (n=44) or control (n=46)	16 weeks of supervised jogging/skiing/swimming/cycling, 3-4 sessions per week, 30 minutes/session at 66% of HR res
Deplaen et al (1980)[14]	BELGIUM	7 hypertensive men and 3 hypertensive women randomized to exercise (n=6, age 44yrs) or control (n=4, age 47 yrs)	12 weeks supervised walking/jogging/cycling/ calisthenics, 3x30minute sessions weekly at 60-70% VO_2peak
Kukkonen et al (1982)[41]	FINLAND	34 pre-hypertensive men (age 39 yrs) and 25 hypertensive men (age 42 yrs) randomized to exercise (n=30) or control (n=29)	16 weeks of walking/cycling/jogging/cross country skiing, 3 sessions per week, 50 minutes per session at 56% of HR res
Duncan et al (1985)[16]	USA	56 hypertensive men (mean age 30.4 yrs) randomized to exercise (n=44) or control (n=12)	16 weeks of walking and jogging, 3 sessions per week, 60 minutes/session at 75% HR peak
Fortmann et al (1988)[21]	USA	77 men with optimal BP randomized to exercise (n=42, age 44 yrs) or control (n=35, age 45 yrs)	52 weeks of supervised walking/jogging/calisthenics, 3 weekly sessions, 60 minutes per session at 70-85% HRpeak
Vroman et al (1988)[86]	USA	11 men with optimal BP randomized to exercise (n=6, age 23.8) or control (n=5, age 25.6)	12 weeks of supervised cycling, 4 sessions per week, 30 minutes per session at 75-85% VO_2peak
Hagberg et al (1989)[26]	USA	30 hypertensive men and women (mean age 64 yrs) randomized to low intensity exercise (n=11), moderate intensity exercise (n=9) or control (n=10)	Low intensity group: 37 weeks of partly supervised walking, 3.1 sessions per week, 51 minutes per session at 53% VO_2max. Moderate intensity group: 37 weeks of supervised walking/jogging/cycling, 2.5 sessions per week, 51minutes per session at 73% VO_2max.
Tanabe et al (1989)[73]	JAPAN	15 hypertensive men and 16 hypertensive women randomized to exercise (n=21, age 50.9) or control (n=10, age 46.8)	10 weeks of cycling, 3 sessions per week, 60 minutes per session at 40-60% of VO_2peak
Martin et al (1990)[48]	USA	27 hypertensive men randomized to exercise (13, age 44.4) or control (n=14, age 42.6)	10 weeks partly supervised walking/jogging/cycling, 4 weekly sessions, 30 minutes per session at 65-80% HR peak
Duncan et al (1991)[17]	USA	59 women (mean age 20-40 yrs) with optimal BP randomized to aerobic walkers (n=16), brisk walkers (n=12), strollers (n=18) or control (n=13)	24 weeks of supervised walking 4.8 km/session, 5 sessions/week at 4.8km/hour (strollers), 6.4 km/hour (brisk walkers) or 8km/hour (aerobic walkers).
King et al (1991)[37]	USA	168 men and 132 women with optimal BP (mean age 57.5) randomized to higher intensity group exercise HIG (40 men, 34 women), higher intensity home (HIH)exercise (n=42 men, n=35 women), lower intensity home (LIH)exercise (n=45 men, 29 women) or control (n=41 men, n=34 women)	52 weeks. HIG: supervised walking/jogging/cycling, 3 sessions per week, 40 minutes per session at 73-88% of HR peak. HIH:walking/jogging/cycling, 3 sessions per week, 40 minutes per session at 73-88% of HR peak; LIH: walking/jogging/cycling, 3 sessions per week, 40 minutes per session at 60-73% HR peak

Albright et al (1992)[1]	USA	40 women and 43 men with optimal BP randomized to exercise (n= 19 women, age 47 and n=23 men, age49) or control (n=21 women, age 46 and 20 men, age 48)	26 weeks walking/jogging, 5 weekly sessions, 47 minutes (men), 54 minutes (women)/session at 65-77%HRpeak
Posner et al (1992)[61]	USA	247 men and women with optimal BP (mean age 68.6 yrs) randomized to exercise (n=166) or control (n=81)	16 weeks of supervised cycling, 3 sessions per week, 30 minutes per session at 70% HR res
Braith et al (1994)[7]	USA	20 men and 24 women with prehypertension randomized to moderate intensity exercise (n=19, age 66 yrs), high intensity exercise (n=14, age 65 yrs) or control (n=11, age 66 yrs)	26 weeks of supervised walking, 3 sessions per week, 45 minutes at 70% of HR res (moderate intensity) or 35 minutes at 85% HR res (high intensity)
Lindheim et al (1994)[45]	USA	45 women with optimal BP randomized to exercise (n=25, age 48.8)) or control (n=20, age 50.8)	26 weeks of supervised walking/cycling, 3 sessions/week, 30 minutes per session at 70% HR peak
Anderssen et al (1995)[2]	NORWAY	N=90 (mean age 45 yrs) randomized to exercise (n=13 optimal BP, n=16 pre-hypertension, n=20 hypertension) or control (n= 13 optimal BP, n=14 pre-hypertension, n=14 hypertension)	52 weeks of supervised walking and jogging, 3 sessions per week, 60 minutes per session at 60-80% HR peak
Kokkinos et al (1995)[38]	USA	46 hypertensive men randomized to exercise (n=23, age 57) or control (n=23, age 58)	16 weeks of supervised cycle ergometry, 3 sessions per week, 44 minutes per session at 74% of predicted HR max
Anshel (1996)[3]	AUSTRALIA	30 men with optimal BP (mean age 21.9 yrs) randomized to exercise (n=15) or control (n=15)	10 weeks of supervised cycle ergometry, 3 sessions/week, 30 minutes per session at 75% HF peak
Ready et al (1996)[62]	CANADA	53 pre-hypertensive women (mean age 61.3 yrs) randomized to thrice weekly (n=18), 5 times weekly (n=17) or control (n=18)	24 weeks of partly supervised walking, 3 sessions per week, 60 minutes per session at 60% of VO_2peak or 60 minutes per session at 60% of VO_2peak 5 times weekly
Tanaka et al (1997)[74]	JAPAN	10 hypertensive men and 8 hypertensive women randomized to exercise (n=12, age 47) or control (n=6, age 49)	10 weeks of supervised swimming, 3 sessions per week, 45 minutes per session at 60% VO_2peak
Duey et al (1998)[15]	USA	25 African-American women with optimal BP randomized to exercise (n=16, age 23.6 yrs) or control (n=9, age 22.2 yrs)	6 weeks of supervised cycling, 3 sessions per week, 20 minutes per session at 60% VO_2peak
Jessup et al (1998)[33]	USA	10 men, 11 women both pre-hypertensive randomized to exercise (n=11, age 68) or control (n=10, age 69)	16 weeks of supervised walking/stair climbing, 3 sessions/week, 45 minutes per session at 85% HR peak
Murphy et al (1998)[52]	USA	34 pre-hypertensive women randomized to long bout group (n=12, age 48), short bout group (n=12, age 45) or control (n=10, age 47)	10 weeks supervised walking, 5x 30 minutes weekly accumulated in one bout (long bout group) or three bouts of 10 minutes daily (short bout group) at 70-80% HR peak
Sakai et al (1998)[63]	USA	5 hypertensive men and 24 hypertensive women randomized to exercise (n=16, age 56) or control (n=13, age 52)	4 weeks of supervised cycling, 3 sessions per week, 60 minutes per session at 40-60% VO_2peak
Stefanick et al (1998)[71]	USA	93 men, optimal BP (mean age 47.8 yrs) 88 pre-hypertensive women (mean age 56.9yrs) randomized to exercise (n=43 women, 47 men) or control (n=45 women, 46 men)	38 weeks brisk walking/jogging, 3 sessions weekly, ~60 minutes per session aiming at 16 km (10mi) weekly
Hamdorf et al (1999)[27]	AUSTRALIA	38 hypertensive women randomized to exercise (n=18, age 82.4 yrs) or control (n=20, age 83.1 yrs)	26 weeks of supervised walking, 2 sessions per week, 25 minutes per session at 40% HR res

Higashi et al (1999)[31]	JAPAN	20 hypertensive men and 7 hypertensive women (mean age 52) randomized to exercise (n=20) or control (n=7)	12 weeks of walking/jogging, 5-7 sessions per week, 30 minutes per session at 52% VO_2peak
Higashi et al (1999)[30]	JAPAN	13 hypertensive men and 4 hypertensive women randomized to exercise (n=10, age 49) or control (n=7, age 44)	12 weeks of walking/jogging, 5-7 sessions per week, 30 minutes per session at 52% VO_2peak
Georgiades et al (2000)[22]	USA	31 hypertensive men and 24 hypertensive women randomized to exercise (n=36, age 47.6 yrs) or control (n=19, age 47.7 yrs)	26 weeks of supervised walking/cycling, 3-4 sessions/week, 45 minutes per session at 70-85% HR res
Hass et al (2001)[29]	USA	26 pre-hypertensive men and women randomized to exercise (n=17, age 49 yrs) or control (n=9, age 46 yrs)	12 weeks of supervised total body recumbent step training, 3 sessions per week, 40 minutes per session at 75% of HR res.
Moreau et al (2001)[51]	USA	24 hypertensive women randomized to exercise (n=15, age 53) or control (n=9, age 55)	24 weeks of home-based daily walking (~9700 steps/day).
Myslivecek et al (2002)[55]	CANADA	32 Women, 4 groups -menopausal (M) and post-menopausal (PM) with and without exercise training	12 weeks walking, 5 times weekly at RPE 12-13, 0.6-4.0km daily
Staffileno et al (2001)[70]	USA	18 hypertensive women randomized to exercise (n=9, age 57.1) or control (n=9, age 62.2)	8 weeks of walking/cycling/other, 5 sessions/week, 3x10 minutes bouts per day at 50-60% HR res
Tsai et al (2002)[78]	JAPAN	23 hypertensive men and 19 hypertensive women (white coat hypertension) randomized to exercise (n=22, age 45.5) or control (n=20, age 36.6)	12 weeks of supervised walking/jogging, 3 sessions per week, 30 minutes per session at 60-70% HR peak
Tsai et al (2002b)[79]	JAPAN	12 hypertensive men and 11 hypertensive women randomized to exercise (n=12, age 49.6) or control (n=11, age 46.2	12 weeks of supervised walking/jogging, 3 sessions per week, 30 minutes per session at 60-70% HR peak
Asikainen et al (2003a)[5]	FINLAND	130 pre-hypertensive women randomized to W1 (n=46, age 58), W2 (n=43, age 58) or control (n=45, age 57)	15 weeks of partly supervised walking, 5 days per week, one (W1) or two (W2) sessions/exercise day, expending a total of 300kcal per exercise day at 65% of VO_2 peak
Asikainen et al (2003b)[5]	FINLAND	116 pre-hypertensive women randomized to W3 (n= 21, age 57), W4 (n=18, age 54), W5 (n=21, age 55), W6 (n=40, age 56)	24 weeks of partly supervised walking, 5 days per week, W3: 55% VO_2peak and 300 kcal/session, , W4: 45%VO_2max and 300kcal/session, W5: 55%VO_2max and 200kcal/session, W6, 45% VO_2max and 200kcal/session
Jessup et al (2003)[34]	USA	30 hypertensive men and women randomized to exercise (n=15, age 75.9 yrs) or control (n=15, age 76.9 yrs)	16 weeks of supervised walking/cycling/stair climbing, 2 sessions per week, 45 minutes per session at 75% HR peak
Tsuda et al (2003)[80]	Japan	16 hypertensive men randomized to exercise (n=8, age 46.2) or control (n=8, age 49)	26 weeks, 2 supervised sessions weekly-15 minutes jogging at AT, 5 minutes walking and 30 minutes calisthenics.
Santa-Clara et al (2003)[64]	USA	27 pre-hypertensive African-American (AA) women and 33 pre-hypertensive Cauasian (CA)women randomized to exercise (n=15 AA, age 58; 17 CA, age 59) or control (n=12 AA, age 55, 16 CA, age 57)	26 weeks of supervised walking/cycling/rowing, 3-4 sessions per week, 45-60 minutes per session at 70-85% of HR peak
Maeda et al (2004)[47]	Japan	15 pre-hypertensive women randomized to exercise (n=10, age 63 yrs) or control (n=5, age 64 yrs)	12 weeks of cycling, 5 sessions per week, 30 minutes per session at 80% VT

Tsai et al (2004)[79]	JAPAN	47 hypertensive men and 55 hypertensive women randomized to exercise (n=52, age 48.8) or control (n=50, age 49.3)	10 weeks of supervised walking/jogging, 3 sessions per week, 30 minutes per session at 60-70% HR peak
Murtagh et al (2005)[54]	IRELAND	17 pre-hypertensive men and 31 pre-hypertensive women (mean age 45.7 yrs) randomized to once daily (n=19), twice daily (n=18) or control (n=11)	12 weeks of partly supervised walking, 3 sessions per week, one bout of 20 minutes per session at 73.1 % HR peak (once daily group) or 2x10 minutes per day at 72.1 %HR peak
Tully et al (2005)[82]	IRELAND	26 pre-hypertensive men and women randomized to exercise (n=17, age 55.5) or control (n=9, age 57.8)	12 weeks of walking, 5 sessions per week, 30 minutes per session a pace faster than normal that left the individual slightly breathless but still able to converse.
Wang et al (2005)[87]	TAIWAN	30 men with optimal BP randomized to exercise (n=15, age 23.5) or control (n=15, age 24.7)	8 weeks of cycling, 5 sessions per week, 30 minutes per session at 60% VO_2peak
Murphy et al (2006)[53]	USA	33 men and women with optimal BP randomized to exercise (n=21, age 41.4) or control (n=12, age 40.8)	8 weeks of walking, 2 sessions per week, 45 minutes per session at own walking speed
Church et al (2007)[9]	USA	464 women with prehypertension randomized to 4 kcal/kg/wk (n=155; age 57.2), 8 kcal/kg/wk (n=104, age 57.7) ,12 kcal/kg/wk (n=103, age 57.3) or control (n=102, age 56.6)	26 weeks of supervised walking/jogging/cycling, 2.6 sessions per week for 28 minutes per session at 50%VO_2peak (4kcal/kg/wk) or 2.8 sessions per week for 49 minutes per session at 50% VO_2peak (8kcal/kg/wk) or 3.1 sessions per week for 62 minutes per session at 50% VO_2peak (12 kcal/kg/wk)
Tully et al (2007)[83]	IRELAND	93 pre-hypertensive men and women randomized to 3 sessions/wk (n=39, age 47.8), 5 sessions/wk (n=36, age 46.4) or control (n=18, age 49)	12 weeks of walking, 3 sessions per week (3-day group), 5 sessions per week (5-day group), 30 minutes per session at a pace faster than normal that left the individual slightly breathless but still able to converse
Brixius et al (2008)[8]	GERMANY	21 pre-hypertensive men randomized to running (n=7, age 58.7), cycling (n=7, age 58.9) or control (n=7, age 52.6)	6 weeks of running or cycling, 3 sessions per week, -/60 minutes (running group) at 3 mmol/L lactate or 90 minutes (cycling group) at 3 mmol/L lactate
Gormley et al (2008)[24]	UK	19 men and 36 women with optimal BP randomized to moderate (n=14, age 23 yrs), vigorous exercise (n=13, age 22 yrs), near maximal exercise (n=15, age21 yrs) or control (n=13, age 22yrs)	6 weeks of supervised cycling, 4 sessions per week for 60 minutes per session at 50% HR res (moderate group), 4 sessions per week for 40 minutes per session at 75% HR res (vigorous group) or 3 sessions per week for 5x (5 min 90-100% HR res; 5 min 50% HR res) (near maximal group)
Westhoff et al (2008)[88]	Germany	11 hypertensive men and 13 hypertensive women randomized to exercise (n=12, age 66.1) or control (n=12, age 68.4)	12 weeks of supervised upper-limb cycling,; 3 sessions per week, 30 minutes per session at 2mmol/L lactate

Krustrup et al (2009)[40]	Denmark	32 pre-hypertensive men (age 20-43 yrs) randomized to soccer (n=12), running (n=10) or control (n=10)	Soccer group: 12 weeks of soccer, 2.3 sessions per week, 60 minutes per session at 82% of HR peak. Running group: 12 weeks of running, 2.5 sessions per week, 60 minutes per session at 82% of HR peak.
Dalleck et al (2009)[13]	USA	26 women randomized to 30 minutes exercise (n=8 pre-hypertensives, age 59.3), 45 minutes of exercise (n=8 optimal BP, age 55.4) or control (n=10, age 57.4)	12 weeks of partly supervised walking, 5 sessions per week, 30 minutes or 45 minutes /session at 50% VO_2 reserve
Hua et al (2009)[32]	CANADA	20 hypertensive men and 20 hypertensive women randomized to exercise (n=20, age 56 yrs) or control (n=20, age 57.2 yrs)	12 weeks of walking; 4 sessions per week, 4.8 km/session at 35-40% HR res
Yoshizawa et al (2009a)[92]	JAPAN	25 women with optimal BP randomized to exercise (n=12, age 57) or control (n=13, age 59)	8 weeks of partly supervised walking/cycling, 4.4 sessions/week, 45 minutes per session at 70-75%HRpeak
Finucane et al (2010)[20]	UK	96 men and women (mean age 71.4 yrs, 44% women)) randomized to exercise (n=46) or control (n=46)	12 weeks of supervised cycling, 3 sessions per week, 60 minutes per session at 70% WLmax
Lamina et al (2010)[42]	NIGERIA	357 hypertensive men randomized to continuous exercise (n=112, age 58.6±7.2), interval exercise (n=140, age 58.2±7.4) or control (n=105, age58.3±6.2)	8 weeks of cycling, 3 sessions per week for 60 minutes per session at 60-79% HR res
Saremi et al (2010)[65]	IRAN	18 pre-hypertensive men (mean age 43.1 yrs) randomized to exercise (n=9) or control (n=9)	12 weeks of supervised walking/running, 5 sessions per week, 50-60 minutes per session at 80-85%HR peak
Pitsavos et al (2011)[60]	GREECE	40 pre-hypertensive men randomized to exercise (n=20, age 51.7 ±8.2) or control (n=20, age 55.3±6.4)	16 weeks of cycling, 3sessions per week, 44 minutes per session at 60-80% HR peak
II. Trials including only dynamic resistance training arms			
Harris et al. (1987)[28]	USA	26 hypertensive men randomized to exercise (n=10, age=32.7±5.2 yrs) or control (n=16; age= 31.4±6.2 yrs)	9 weeks of supervised circuit weight training, 3 sessions weekly, 40% 1RM, 10 exercises, 3 sets, 20-25 reps/set
Katz et al (1992)[35]	USA	26 women with optimal BP randomized to an exercise (n=13, age 22) and control (n=13, age 18.8 yrs) group	6 weeks of resistance training on Nautilus exercise machines, 3 sessions per week, 30% of 1RM, 13 exercise, 1 set/exercise, 14-15 reps/set for LB, 11-12 reps/set for UB
Vanhoof et al (1996)[84]	BELGIUM	19 pre-hypertensive men randomized to an exercise (n=8, age 38) and control (n=11, age=38 yrs) group	16 weeks supervised strength training, 3 sessions/week, 70-90% of 1RM, 6 exercises, 3 sets/exercise, 10 reps/set
Tsutsumi et al (1997)[81]	JAPAN	41 (33 men) individuals with normal BP or prehypertension randomized to EXH (n=13, age 67.8±4.9), EXL (n=14, age 68.9±7.5) or control group (n=14, age 69.8±4.6)	12 weeks of supervised strength training by using dynamic variable resistance machines - 11 exercises, 3 sessions weekly, 2 sets, 75-85% of 1RM (EXH), 8-12 resp/set (EXH), 55-65% of 1RM (EXL), 12-16 reps/set (EXL)
Elliott et al (2002)[18]	UK	15 postmenopausal women randomized to exercise (n=8) or control group (n=7)	8 weeks of supervised resistance training using 5 weight machines, 3 sessions/week, 3 sets/exercise, 8 reps/set, 80% of 10RM, 2 min rest between sets

Vincent et al (2003)[85]	USA	62 (28 men) prehypertensive individuals randomized to EXL (n=24, age 67.6±6yrs) or EXH (n=22, age 66.6±7yrs) or control (n=16, age71±5yrs)	6 months of resistance training using MedX resistance machines involving 13 exercises, 3 sessions/week, 1 set/exercise, 8 reps/ex (HEX), 13 reps/ex (LEX), 50% of 1RM LEX, 80% of 1RM (HEX)
Miyachi et al (2004)[4]	JAPAN	28 men with optimal BP randomized to exercise (n=14, age 22±1yrs) and control (n=14, age 22±1yrs)	16 weeks of supervised resistance training, 3 sessions/week, 8-12 exercises, 3 sets/exercise, 80% of 1RM, 12 reps/set for set 1 and 2, as many reps/set in set 3
Anton et al (2006)[50]	USA	26 (7 men) individuals with normal BP randomized to exercise (n=13; 52±2 yrs) or control (n=13; 53±2 yrs)	13 weeks of supervised resistance training involving 9 exercises, 75% of 1RM, 1 set, 12 reps/set.
Okamoto et al (2006)[57]	JAPAN	29 women with optimal BP randomized to CRT (n=10, age 19.1+0.3), ERTn=10, age18.9+0.3) or control group (n=9; age 19.9+1.2)	8 weeks of supervised ERT or CRT using arm curl, 3 sessions/week, 100% of 1RM (ERT), 80% of 1RM (CRT), 5 sets/exercise, 10 reps/set
Olson et al (2007)[59]	USA	28 women with optimal BP randomized to exercise (n=16; age 39±5yrs) or control (n=12, age 38±6yrs) group	52 weeks of resistance training on isotonic variable resistance machines and free weights (first 16 weeks: supervised, thereafter meeting twice every 12 weeks), 2 sessions/week, 3 sets, 8-10 reps/set
Colado et al (2009)[10]	SPAIN	31 pre-hypertensive women randomized to exercise (n=21; age 54+2.8) and control (n=10, age 52.1+1.9) group	24 weeks of supervised circuit resistance exercise using thera-bands, 3 sessions/week,8-16 exercise, 2 sets, 15-30 reps/set
Lovell et al (2009)[46]	AUSTRALIA	24 pre-hypertensive men randomized to exercise (n=12, age 74.1±2.7yrs) and control (n=12; age: 73.5±3.3yrs)	16 weeks of supervised resistance exercise on incline squat machine, 70-90% of 1RM, 3 sessions/week, 1 exercise, 3 sets, 6-10 reps/set
Tanimoto et al (2009)[75]	JAPAN	36 men with optimal BP randomized to LEX (n=12, age 19+0.2), HEX (n=12, age 19.5) or control (n=12, age 19)	13 weeks of resistance training consisting of 5 exercises, 8RM, 55-60% of 1RM with slow movement and tonic force generation and no relaxation phase(LEX), 89-90% of 1RM with normal speed (HEX), 3 sets/ex, 2 sessions/week

III. Trials including only a combination (endurance + resistance) exercise arm			
Laterza et al (2007)[44]	BRAZIL	20 (13 men) hypertensive individuals (mean age 44 yrs) randomized to exercise (n=11) or control (n=9)	16 weeks of supervised combination training, 3 sessions per week, 60 minutes per session including 40 minutes of cycling at 70% VO_2 peak and 10 minutes of local strengthening exercises
Okamoto et al (2008)	JAPAN	33 (11 men) individuals with normal BP randomized to BRT (n=11, age18.5±0.66), ART (n=11, age 18.5±0.66) or control (n=11, age 18.8±0.66)	8 weeks of combination training, 2 sessions per week involving 20 minutes of treadmill running at 60% Heart rate Reserve (HRR) performed before (BRT) or after (ART) resistance training (7 exercises, 5 sets/exercise, 8-10 RM)

Guimaraes et al (2010)[25]	BRAZIL	56 (13 men) pre-hypertensive individuals randomized to COMint (n=16, age 45±9), COMcont(n=16, age 50±8) or control group (n=11, age 47±6)	16 weeks of partly supervised (2/3) combination training, 3sessions per week, 40 min of continuous treadmill exercise at 60% HRR (COMcont) or 40 minutes of alternating 2 min 50% HRR – 1 min 80% HRR (COMint) followed by 20% of submaximal strength training
Figueroa et al (2011)[19]	SOUTH-KOREA	24 prehypertensive women randomized to exercise (n=12, age 54±7) or control (n=12, age 54±3.5)	12 weeks of supervised combination training, 3 sessions per week including 20 minutes of treadmill walking at 60% predicted HRmax and 20 minutes of circuit resistance training (9 exercises)
Ohkubo et al. (2001)[56]	JAPAN	39 (19 men) prehypertensive individuals randomized to exercise (n=22, age 67.5))or control (n=17, age 66.8)	25 weeks of supervised combination training, 2-3 sessions per week including 25 minutes of cycling at 60% Hrres and 5 resistance exercises (Thera-Band resistive exercises)
IV. Trials including only isometric resistance training arms			
Wiley et al (1992)[90]	USA	15 prehypertensive participants (20-35 yrs) randomized to exercise (n=8) or control (n=7)	8 weeks of isometric handgrip training, 4x 2 min isometric contractions at 30% MVC using dominant arm and 3 min rest period between contractions, 3 sessions per week
Taylor et al (2003)[76]	CANADA	17 hypertensive men and women randomized to exercise (n=9, age 69.3±6) or control (n=8, age 64.2±5.5)	10 weeks of isometric handgrip training,4x2 min bilateral isometric contractions at 30% MVC, 1 min rest period between contractions, 3 sessions/week
Millar et al (2008)[49]	CANADA	21 men and 28 women with optimal BP randomized to exercise (n=25, age 66±1 yrs) and control (n=24, age 67±2)	8 weeks of isometric handgrip training, 4x2 min bilateral isometric contractions at 30-40% MVC, 1 min rest period between contractions, 3 sessions/week
Wiles et al (2010)[89]	UK	33 men with optimal BP (age 18-34 yrs) randomized to HI (n=11), LI (n=11) or control (n=11)	8 weeks of supervised isometric leg extension exercise, 4x2 min bouts of isometric leg extension 3 sessions/week at a subject specific EMG corresponding on average at 10% MVC (LI) or 21% MVC (HI), 3 sessions per week
V. Trials including different exercise arms			
Blumenthal et al (1991)[6]	USA	57 hypertensive men and 35 hypertensive women randomized to dynamic endurance exercise (n=39, age 44.3), dynamic resistance exercise (n=31, age=46±7 yrs) and control (n=22, age 45.7±7.8 yrs)	16 weeks of supervised circuit weight training, 2-3 sessions per week, 30 minutes/session (resistance group) or 16 weeks of supervised walking/jogging, 3 sessions per week, 35 minutes per session at 70% VO_2 peak
Cononie et al (1991)[11]	USA	23 men and 26 women (age 72+2.6 yrs) randomized to dynamic endurance exercise (n=11 pre-hypertensives and n=6 hypertensives), dynamic resistance exercise (n=14 pre-hypertensives and 6 hypertensives) or control (n=7 pre-hypertensives and 5 hypertensives)	26 weeks of supervised DRT on Nautilus machines, 10 exercises, 3 sessions/week, 8-12 RM, 1 set/exercise, 12 reps/set (resistance group) or 26 weeks of supervised interval training (jogging/brisk walking, uphill treadmill running and walking), 3 sessions/week, 35-45 minutes per session at 75-85% VO_2 peak (endurance group)

Kraemer et al (2001)[39]	FINLAND	35 women randomized to 25 min group (n=8 optimal BP, age 31.8), 40 min group (n=12 pre-hypertensive, age 37.3) , SAR group (n=9 pre-hypertensive, age 33) or control (n=6, age 27.8)	12 weeks of supervised step aerobics, 3 sessions per week, 25 minutes per session (25 min group), 40 minutes per session (40 min group) at 80-90% of HR peak or 25 min of step-aerobics and a multiple-set upper and lower body resistance exercise (SAR)
Wood et al (2001)[91]	USA	17 pre-hypertensive men and 19 pre-hypertensive women randomized to dynamic aerobic endurance exercise, (n=11, age 69.1), dynamic resistance exercise (n=10; 69.8±6yrs), combination training (n=6; 66.1±5.5yrs) or control (n=6; age 68±5.4yrs) group	12 weeks DRT using Med-X brand devices, 3 sessions/week, 8 exercises, 8-12 RM, 2 sets/exercise (resistance group) or 12 weeks cycling/walking, 3 sessions/week, 45 minutes/session at 60-70% of predicted HR res (endurance group) or 12 weeks combination
Kawano et al (2006)[36]	JAPAN	39 men with optimal BP randomized to resistance exercise (n=12, age 20±1yrs), combination exercise (n=11, age 21±1) or control (n=16, age 22±1yrs)	4 months of supervised resistance training involving 14-16 exercises, 50% of 1 repetition maximum (1RM), 3 sessions/week, 45 minutes/session, 3 sets/exercise or supervised combination training (8-12 resistance exercise, 80% 1RM, 3 sets/exercise followed by 30 min cycling at 60% HR peak),
Sarsan et al (2006)[66]	TURKEY	60 pre-hypertensive women randomized to dynamic aerobic endurance exercise (n=20; age 41.6), dynamic resistance exercise (n=20; 42.5±10.07) or control (n=20, age = 43.6±6.46)	12 weeks of supervised DRT using a stationary exercise unit, 75-80% of 1RM, 3 sessions/week; 6 exercises, 3 sets/exercise, 10 reps/set (resistance group) or 12 weeks of supervised walking/cycling, 5sessions per week, 30-45 minutes per session at 50-85% HR res (endurance group)
Simons et al (2006)[69]	USA	59 (15 men) pre-hypertensive individuals randomized to dynamic aerobic endurance exercise (n=18, age 81.6) or dynamic resistance exercise (n=21, age 84.6±4.5yrs) and control (n=21, age 84±3.3yrs)	16 weeks of supervised DRT on Keiser machines, 2 sessions/week, 75% of 1RM, 6 exercises, one set/exercise, 10 reps/set (resistance group) or 16 weeks of supervised walking, 2 sessions per week at a self-selected pace
Cortez-Cooper et al (2008)[12]	USA	37 men and women with optimal BP randomized to resistance exercise (n=13, age 52±2), combination exercise (n=12, age 51±1) or control (n=12, age 54±2)	13 weeks of supervised whole body DRT using 10 devices, 3 sessions/week, 1 set per exercise, 8-12 reps/set, 70% of 1RM or combination training (2 sessions/week resistance exercise and 2 sessions/week endurance exercise walking or cycling at 60–75% of heart rate reserve for 30-45 min)
Sillanpää et al (2009)[67]	FINLAND	62 pre-hypertensive women randomized to dynamic aerobic endurance exercise (n=15, age 51.7yrs), dynamic resistance exercise (n=17, age 50.8±7.9yrs), combination training (n=18, age 48.9±6.8) or control (n=12, age51.4±7.8yrs)	21 weeks of supervised DRT, 2 sessions/week, 7-8 exercises ,70-90% of 1RM, 6-8 reps/set, 3-4 sets/exercise (resistance group) or 21 weeks of supervised cycling, 2 sessions per week, 60-90 minutes per session above AT or 21 weeks of combination training

Sillanpaä et al (2009)[68]	FINLAND	63prehypertensive men randomized to dynamic aerobic endurance (n=17, age 52.6±7.9), dynamic resistance exercise (n=15, age 54.1±6), combination exercise (n=15, age 56.3 ±63.8) or control (n=14, age 53.8±7.7)	21 weeks of supervised DRT, 2 sessions/week, 7-8 exercises ,70-90% of 1RM, 6-8 reps/set, 3-4 sets/exercise (resistance group) or 21 weeks of supervised cycling, 2 sessions per wee, 60-90 minutes per session above AT or 21 weeks of combination training
Yoshizawa et al (2009)[93]	JAPAN	35 women with optimal BP randomized to dynamic aerobic endurance (n=12, age 47), dynamic resistance exercise (n=11; age 47) or control (n=12, age 49)	12 weeks of resistance training using resistance devices, 60% of 1RM 2 sessions/week, 6 exercise, 3 sets/exercise, 10 reps/set (resistance group) or 12 weeks of cycling, 2 sessions per week, 30 minutes per session at 60-70% VO_2 peak
Stensvold et al (2010)[72]	NORWAY	43 (17 men) hypertensive individuals randomized to dynamic aerobic endurance training (n=11, age49.9), dynamic resistance training (n=11, age 50.9), combination (n=10, age 52.9) or control (n=11, age 47.3)	12 weeks of resistance training using resistance devices, 80% 1RM, ,, 3 sessions per week, 3 sets per exercise (resistance group) or 12 weeks of supervised interval training on a treadmill, 3 sessions per week, 4X4 minute interval at 90-95%HRpeak with 3 minutes of active recovery in between at 70% HR peak or 12 weeks of AIT twice a week and ST once a week (COM)

TABLE S2: Quality metrics of included studies

Study name	**Eligibility criteria specified**	**Random allocation of participants**	**Allocation concealed**	**Groups similar at baseline**	**Assessors blinded**	**Outcome measures assessed in 85% of participants**	**Intention to treat analysis**	**Reporting of between group statistical comparison**	**Point measures and measures of variability reported for BP**	Overall pedro
Albright 1992[1]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Anderssen 1995[2]	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	8
Anshell 1996[3]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Anton 2006[4]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Asikainen 2003[5]	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	8
Blumenthal 1991[6]	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes	6
Braith 1994 [7]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Brixius 2008[8]	Yes	Yes	No	Yes	No	Yes	No	No	Yes	5
Church 2007[9]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	9
Colado 2009[10]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Cononie 1991 [11]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Cortez-Cooper 2008 [12]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Dalleck 2009 [13]	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	7
Deplaen 1980 [14]	Yes	Yes	No	Yes	Yes	No	No	No	Yes	5
Duey 1998 [15]	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	6
Duncan 1985 [16]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Duncan 1991 [17]	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes	6
Elliott 2002 [18]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Figueroa 2011 [19]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7

Finucane 2010 [20]	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	7
Fortmann 1988 [21]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Geogiades 2000 [22]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Gettmann Yes976[23]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Gormley 2008[24]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Guimaraes 2010 [25]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Hagberg 1989 [26]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Hamdorf 1999 [27]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Harris 1987 [28]	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes	6
Hass 2001 [29]	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes	6
Higashi 1999a[30]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Higashi 1999b [31]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Hua 2009 [32]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Jessup 1998 [33]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Jessup 2003[34]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Katz 1992 [35]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Kawano 2006 [36]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
King 1991 [37]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Kokkinos 1995 [38]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Kraemer 2001 [39]	No	Yes	No	Yes	No	Yes	No	Yes	Yes	5
Krustrup 2009 [40]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Kukkonen 1982 [41]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Lamina 2010 [42]	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	7
Lansimies 1979 [43]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Laterza 2007 [44]	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes	6
Lindheim 1994 [45]	Yes	Yes	No	Yes	No	Yes	No	No	Yes	5

Lovell 2009[46]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Maeda 2004 [47]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Martin 1990 [48]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Millar 2009 [49]	No	Yes	No	No	Yes	Yes	No	Yes	Yes	5
Miyachi 2004 [50]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Moreau 2001[51]	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes	6
Murphy 1998 [52]	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes	6
Murphy 2006 [53]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Murtagh 2002 [54]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Myslivecek 2002 [55]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Ohkubo 2001[56]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Okamoto 2006 [57]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Okamoto 2009 [58]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Olson 2007 [59]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Pitsavos 2011 [60]	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	7
Posner 1992 [61]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Ready 1996 [62]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Sakai 1998 [63]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Santa-Clara 2003 [64]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Saremi 2010 [65]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Sarsan 2006 [66]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Sillanpaa 2009a[67]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Sillanpaä 2009b [68]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Simons 2006 [69]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Staffileno 2001[70]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Stefanick 1998 [71]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7

Stensvold 2010[72]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Tanabe 1989 [73]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Tanaka 1997 [74]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Tanimoto 2009 [75]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Taylor 2003 [76]	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes	6
Tsai 2002 [77]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Tsai 2002 [78]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Tsai 2004 [79]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6
Tsuda 2003 [80]	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes	6
Tsutsumi 1997 [81]	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes	6
Tully 2005[82]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Tully 2007[83]	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	7
Vanhoof 1989 [84]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Vincent 2003 [85]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Vroman 1988 [86]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Wang 2005 [87]	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes	6
Westhoff 2008 [88]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Wiles 2010 [89]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Wiley 1992 [90]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	5
Wood [91]	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes	6
Yoshizawa 2009a [92]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	7
Yoshizawa 2009a [93]	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	6

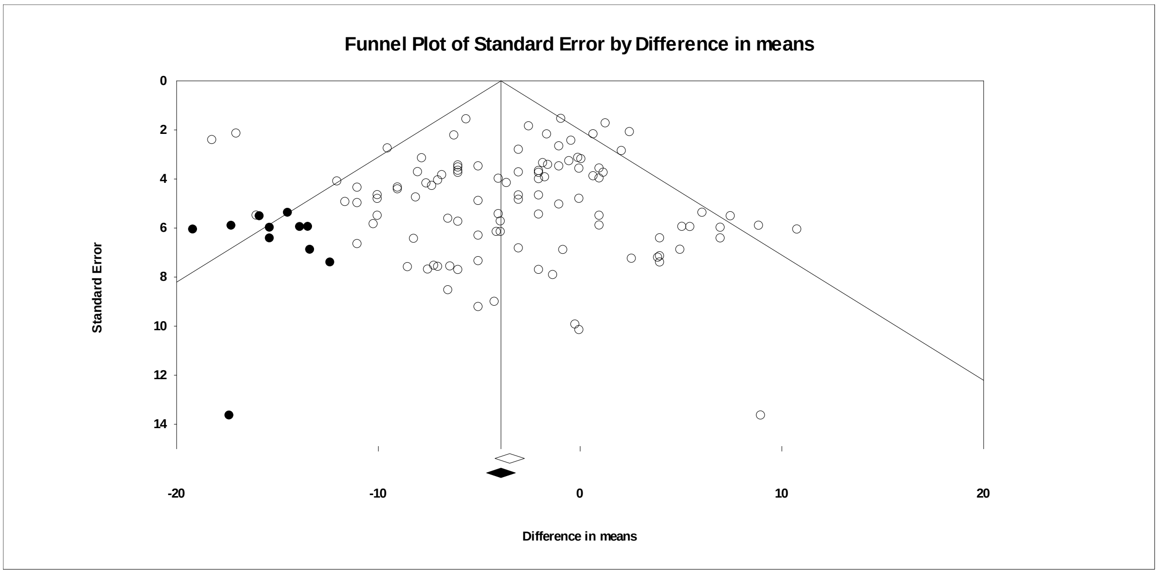

Figure S1: Funnel plot of each endurance study group observation effect size for systolic blood pressure versus standard error. Open circles:observed study groups, closed circles: imputed study groups by Trim and Fill computation. Egger regression test: two-sided P=0.68.

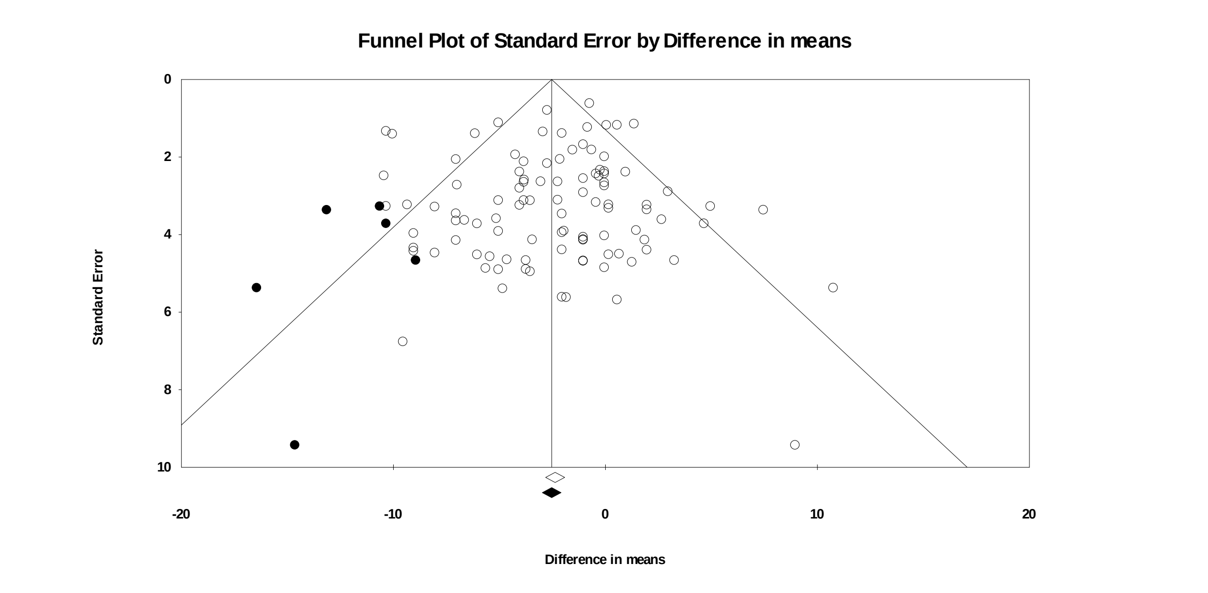

Figure S2: Funnel plot of each endurance study group observation effect size for diastolic blood pressure versus standard error. Open circles: observed study groups, closed circles: imputed study groups by Trim and Fill computation. Egger regression test: two-sided P=0.73.

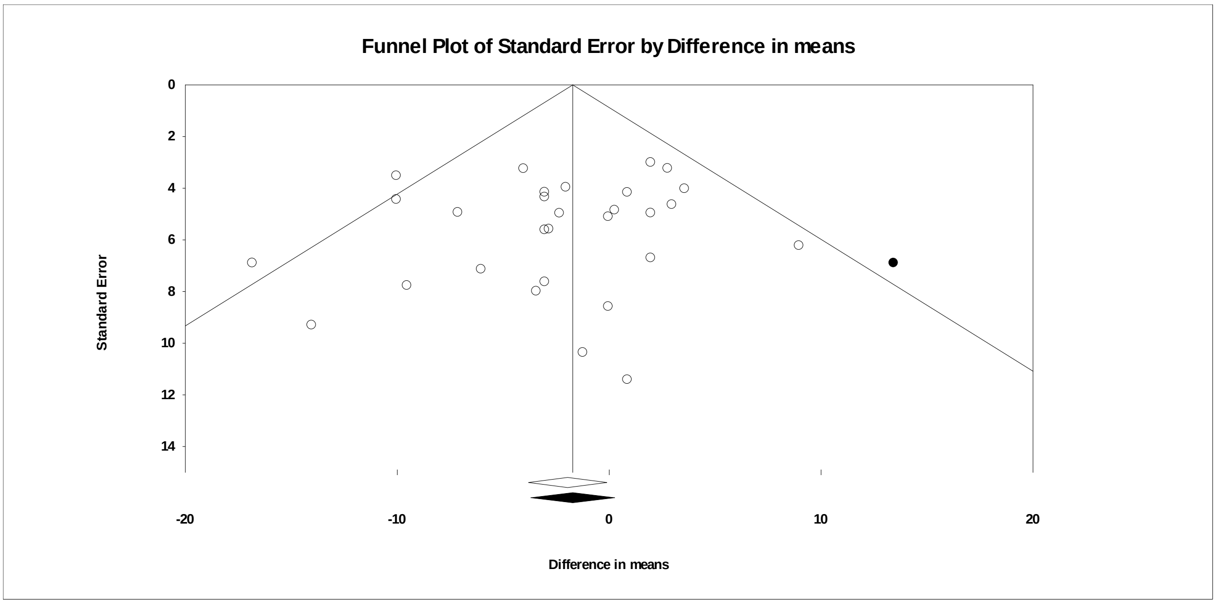

Figure S3: Funnel plot of each dynamic resistance study group observation effect size for systolic blood pressure versus standard error. Open circles:observed study groups, closed circles: imputed study groups by Trim and Fill computation Egger regression test: two-sided P=0.35.

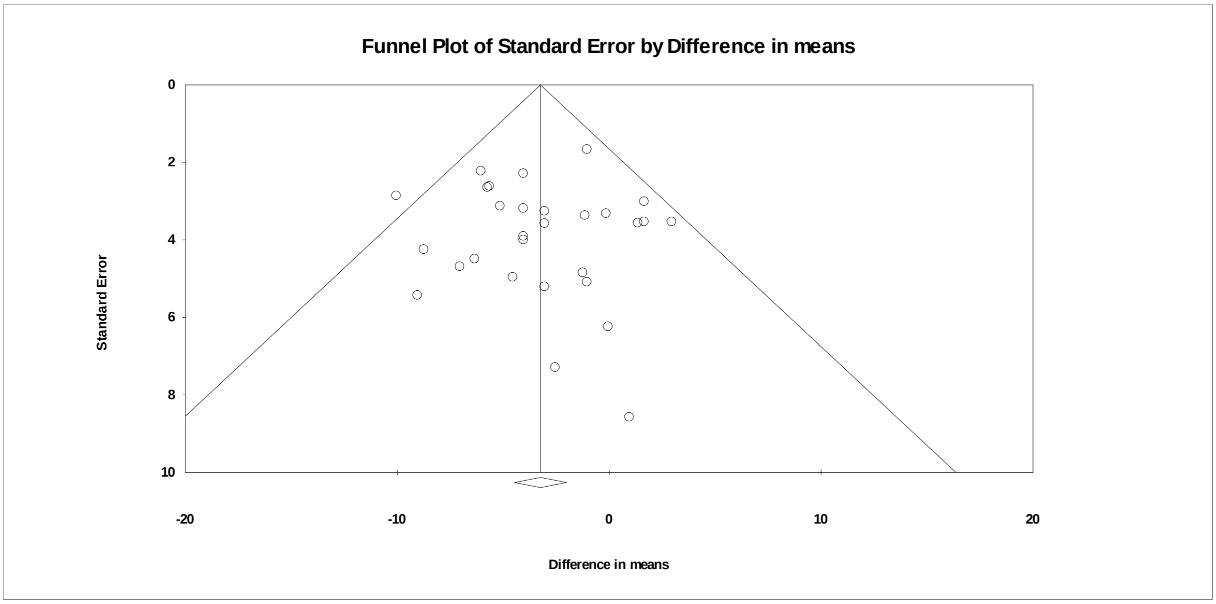

Figure S4: Funnel plot of each dynamic resistance study group observation effect size for diastolic blood pressure versus standard error. Open circles:observed study groups. No studies were added by Trim and Fill computation. Egger regression test: two-sided P=0.95

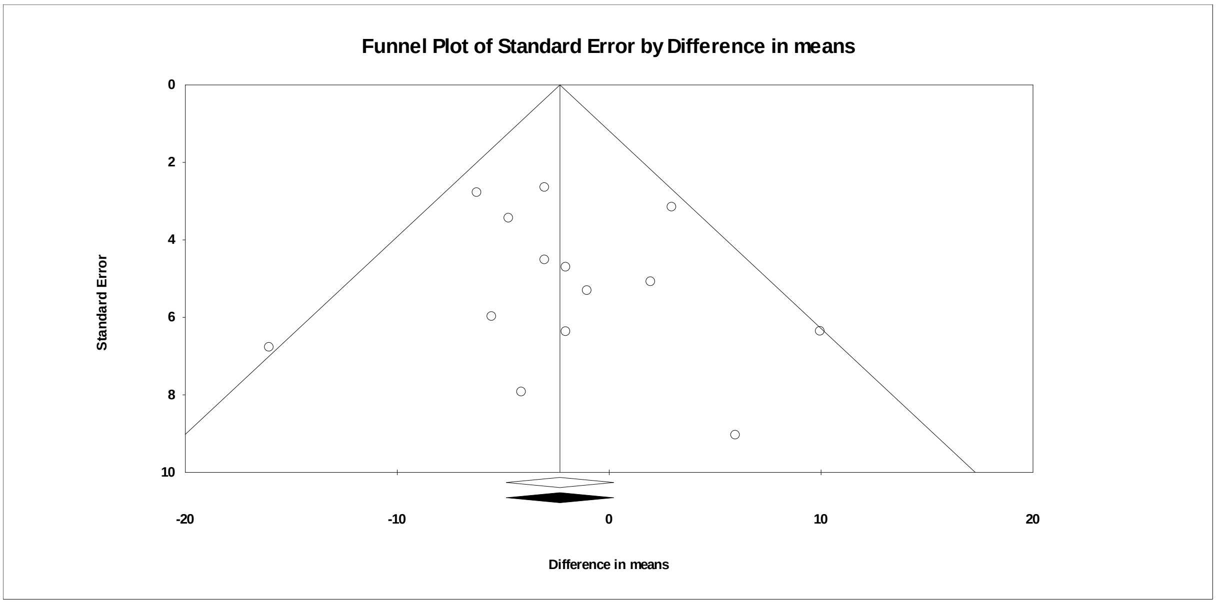

Figure S5: Funnel plot of each combined study group observation effect size for SBP versus standard error. Open circles:observed study groups. No studies were added by Trim and Fill computation. Egger regression test: two-sided P=0.61.

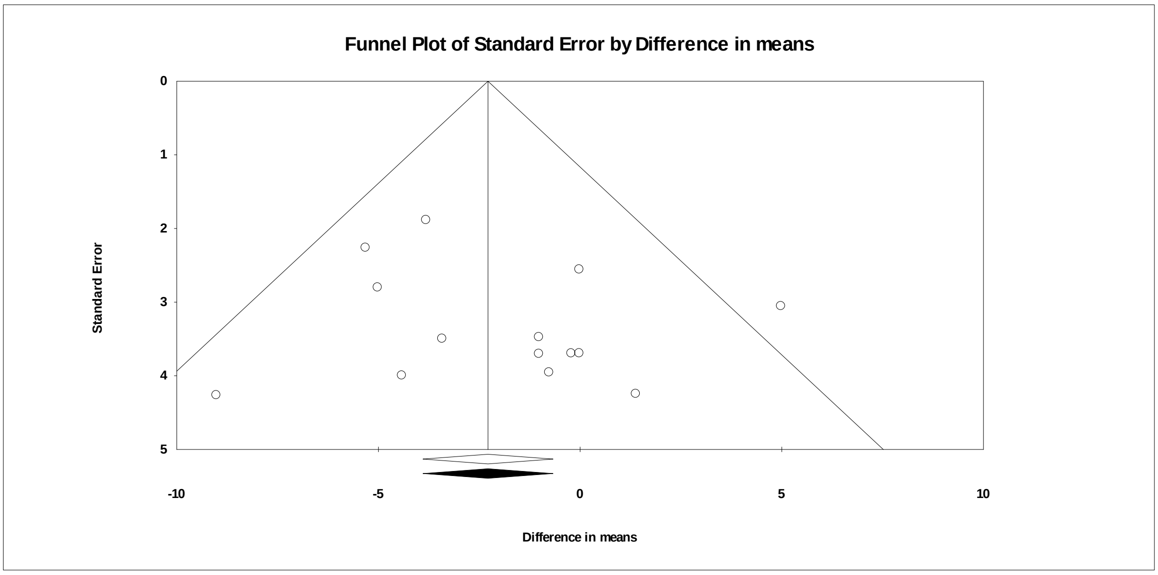

Figure S6: Funnel plot of each combined study group observation effect size for diastolic blood pressure versus standard error. Open circles:observed study groups. No studies were added by Trim and Fill computation. Egger regression test: two-sided P=0.40.

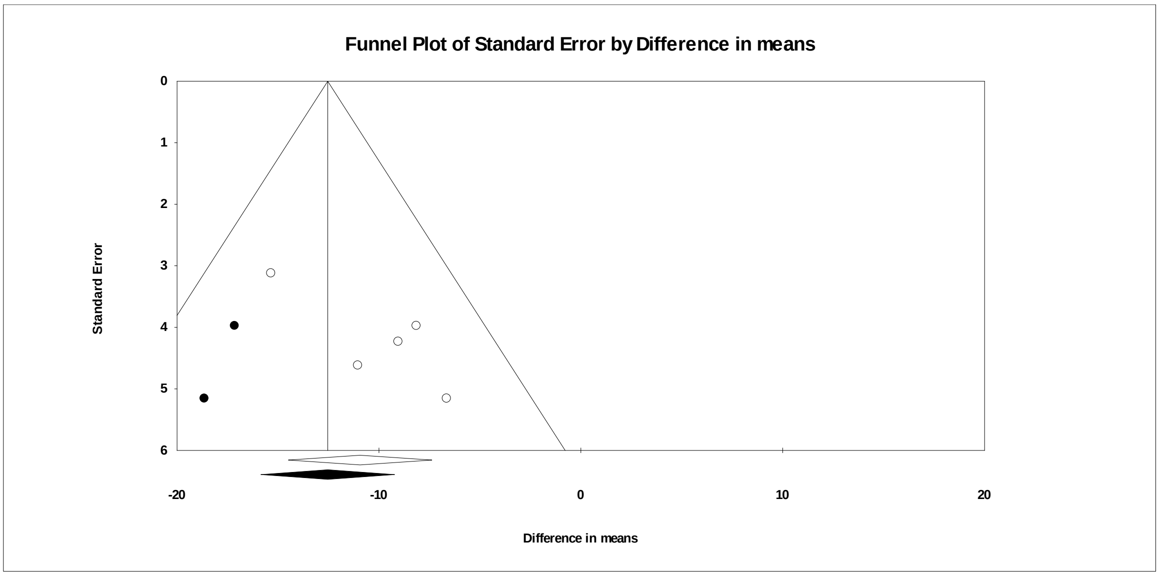

Figure S7: Funnel plot of each isometric resistance study group observation effect size for systolic blood pressure versus standard error. Open circles:observed study groups. No studies were added by Trim and Fill computation. Egger regression test: two-sided P=0.12.

Figure S8: Funnel plot of each isometric resistance training group observation effect size for diastolic blood pressure versus standard error. Open circles: observed study groups, closed circles imputed study groups. Egger regression test: two-sided P=0.22.