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George, Kelley. Dynamic resistance exercise and resting blood pressure in adults: a meta-analysis. *J. Appl. Physiol.* 82(5): 1559–1565, 1997.—With the use of the meta-analytic approach, the purpose of this study was to examine the effects of dynamic resistance exercise, i.e., weight training, on resting systolic and diastolic blood pressure in adults. A total of nine studies consisting of 259 subjects (144 exercise, 115 control) and 18 groups (9 exercise, 9 control) were included in this analysis. With the use of the bootstrap technique (10,000 samples), significant treatment effect (Δ_3) reductions were found across all designs and categories for both systolic and diastolic blood pressure [systolic, mean ± SD = −4.55 ± 1.75 mmHg, 95% confidence interval (CI) = −1.56 to −8.56; diastolic, mean ± SD = −3.79 + 1.12 mmHg, 95% confidence interval CI = −1.89 to −6.33]. Δ_3 changes corresponded with relative decreases of ~3 and 4% in resting systolic and diastolic blood pressure, respectively. In conclusion, meta-analytic review of included studies suggests that dynamic resistance exercise reduces resting systolic and diastolic blood pressure in adults. However, it is premature to form strong conclusions regarding the effects of dynamic resistance exercise on resting blood pressure. A need exists for additional, well-designed studies on this topic before a recommendation can be made regarding the efficacy of dynamic resistance exercise as a nonpharmacological therapy for reducing resting blood pressure in adults, especially in hypertensive adults.

research synthesis; cardiovascular; physical activity

AEROBIC EXERCISE is currently being promoted as a lifestyle modification that lowers resting blood pressure, especially in persons with elevated levels (1). However, the effects of dynamic resistance exercise, i.e., weight training, on resting blood pressure have not been clearly established. Indeed, controlled clinical studies on this topic have led to conflicting results, with four studies reporting no significant changes in either resting systolic or diastolic blood pressure (3, 5, 15, 21), two reporting significant decreases in both resting systolic and diastolic blood pressure (17, 19), one reporting significant decreases in resting diastolic blood pressure only (12), another reporting significant decreases in resting systolic blood pressure only (23), and one final study reporting decreases in supine resting diastolic blood pressure but no changes in supine systolic or standing systolic and diastolic blood pressure (14).

A recent position paper on this topic concluded that, with the exception of circuit weight training, insufficient evidence exists for recommending strength training as the only form of exercise training for reducing resting blood pressure in hypertensive individuals (1). Other recent reviews on this topic have also been cautious about concluding that dynamic resistance exercise reduces resting blood pressure in adults (2, 9, 22, 24). Unfortunately, all of these reviews relied on the traditional (narrative) approach, that is, on chronologically arranging and then describing studies. Synthesizing research in this manner generally results in subjective, nonreplicable conclusions. Contemporary research synthesis requires statistical and technical, as well as narrative and rhetorical, approaches.

Meta-analysis is a method of pooling the results of separate studies in a systematic, explicit, comprehensive, and replicable manner (8, 20). It is a quantitative approach for increasing statistical power for primary end points (units of analysis) and subgroups, addressing uncertainty when studies disagree, improving estimates of effect sizes, and answering questions not posed at the start of individual trials (8). Meta-analysis is especially useful in summarizing prior research when the number of studies is small and the number of subjects within each study is small (20). This is the case with the dynamic resistance exercise and blood pressure literature. Knowledge regarding the potential benefit of dynamic resistance exercise on resting blood pressure is important because it represents a potential cost-effective nonpharmacological method for controlling blood pressure.

A need exists to examine the literature regarding the effects of dynamic resistance exercise on resting systolic and diastolic blood pressure in adults. Thus the purpose of this study was to use the meta-analytic approach to examine the effects of dynamic resistance exercise on resting systolic and diastolic blood pressure in adults.

METHODS

Literature Search

The review of literature was limited to clinical training studies published between January 1966 and December 1995. Studies were obtained from a Medline computer search as well as from hand searches and cross-referencing. The search for studies in foreign language journals was limited to a Medline computer search only. Inclusion criteria were as follows: *1*) subjects were adult humans, ages 18 yr and older, *2*) dynamic resistance exercise was the only mode of training, *3*) training studies could be of any duration, *4*) changes in resting systolic and diastolic blood pressure needed to be reported, *5*) nonexercise control group needed to be included, and *6*) studies needed to be published in journals.

Coding and Classifying Variables

All studies that met the criteria for inclusion were coded. To avoid bias in selecting and rejecting studies, the decision to include a paper was made by examining the methods and results separately under coded conditions. A coding sheet was

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developed that could hold up to 96 variables. The major categories coded included *1*) study characteristics, *2*) physical characteristics of subjects, *3*) blood pressure assessment characteristics, *4*) training program characteristics, and *5*) blood pressure results. The major study characteristics that were coded included year of publication, number of groups, number of subjects, percentage of men, percent compliance (percentage of subjects who completed the study), study design (randomized controlled vs. nonrandomized controlled), and ethnic group. Major physical characteristics that were coded for included age, body weight, percent body fat, body mass index, maximum oxygen consumption, resting heart rate, and strength, assessed as one repetition maximum (1RM). Blood pressure assessment variables that were coded for included position, number of recordings at each assessment period, Korotkoff phase for diastolic pressure, time of day, rest period before assessment, length of time after the last training session before assessment, and instrument used. Training program characteristics (exercise groups only) that were coded for included length of training, frequency, sets, repetitions, rest between sets, number of exercises, equipment used, adherence (percentage of exercise sessions completed), and percent intensity (1RM). Blood pressure variables that were coded included pre- and posttraining measurements for resting systolic and diastolic blood pressure.

Statistical Analysis

Main effects. The "treatment effect" (Δ_3) was calculated to account for changes in resting systolic and diastolic blood pressure (25). This was accomplished by subtracting the posttraining value from the pretraining value for both exercise (Δ_1) and control groups (Δ_2) and then subtracting Δ_2 from Δ_1 to yield Δ_3. Ninety-five percent confidence limits were established for Δ_3. Because of the small sample size in this investigation, the bootstrap technique (10,000 repeat samples, 95% confidence intervals) was used to estimate the reliability of Δ_3 changes (6). The bootstrap technique is a computer-generated nonparametric method of estimating the reliability of the original sample estimate. By randomly drawing from the available sample, with replacement, samples of the same size as the original are generated. Each time an observation is selected for a new sample, each of the elements of the original sample has an equal chance of being selected. This is similar to replicating each member of a sample 10,000 times and sampling without replacement. The main advantage of this approach is that the estimate desired is not based on some theoretical distribution but, rather, on the sample itself. This frees one from the constraints of the central limit theorem.

Because no relationships between number of subjects and changes in resting systolic and diastolic blood pressure were found, no weighting procedures were employed. Graphic analysis (box plots) was used to identify outliers beyond the 10th and 90th percentiles (28). If outliers were identified, each individual outlier was examined to see whether there was any physiological reason for their exclusion from the analysis. If not, the outlier remained in the analysis.

Subgroup analysis. Independent *t*-tests were used to assess differences between Δ_3 changes partitioned according to selected variables. However, if normality and/or equal variance was violated, Mann Whitney rank sum tests were used. Treatment effects Δ_3 were partitioned according to study design (randomized controlled vs. nonrandomized controlled), position of subject during blood pressure measurement (sitting vs. supine), and blood pressure category (hypertensive vs. normotensive). Hypertension was defined as a resting systolic and/or diastolic blood pressure ≥140/90 mmHg. Treatment effects Δ_3 were also examined by partitioning data according to whether femen were included as subjects.

Correlational analysis. Pearson product moment or Spearman rank order correlations were used to examine relationships between Δ_3 changes in resting systolic and diastolic blood pressure and selected variables. Variables correlated included study characteristics (year of publication, number of subjects, percentage of men, percent compliance), initial and final physical characteristics (age, body weight, body mass index, percent fat, lean body mass, maximum oxygen consumption, resting heart rate), blood pressure protocols (number of measures, rest period before assessment of blood pressure), training program characteristics (length, frequency, duration, number of sets, rest between sets, number of exercises, percent adherence), and initial resting blood pressure.

Differences between other exercise and control group variables. With the exception of changes in resting systolic and diastolic blood pressure, independent *t*-tests were used to assess differences between exercise and control group variables. However, if normality and/or equal variance was violated, Mann-Whitney rank sum tests were used. Variables assessed included study characteristics (number of subjects, percentage of men, percent compliance) and initial physical characteristics (age, body weight, percent body fat, body mass index, maximum oxygen consumption, resting heart rate, resting systolic and diastolic blood pressure). Outcome characteristics assessed included the following: body weight, percent body fat, body mass index, maximum oxygen consumption, and resting heart rate. Insufficient data were reported to compare percent change in 1RM strength between exercise and control groups. The significance level was set at $P \leq 0.05$ for all tests.

RESULTS

Study Characteristics

Study characteristics for included studies are shown in Table 1. A total of nine studies consisting of 259 subjects (144 exercise, 115 control) and 18 groups (9 exercise, 9 control) were included in this analysis (3, 5, 12, 14, 15, 17, 19, 21, 23). Four of the studies included in this analysis randomized subjects to an exercise or control group (3, 5, 12, 15). For the five nonrandomized trials (14, 17, 19, 21, 23), no matching procedures were

Table 1. *Study characteristics*

Reference	No. of Subjects (Ex/Con)	%Men (Ex/Con)	%Compliance (Ex/Con)	Randomized? (Yes/No)
Blumenthal et al. (3)	31/22	58/68	89/96	Yes
Cononie et al. (5)	20/12	55/33	91/92	Yes
Harris and Holly (12)	10/16	100/100	100/100	Yes
Hurley et al. (14)	11/10	100/100	100/100	No
Katz and Wilson (15)	13/8	0/0	100/61	Yes
Lightfoot et al. (17)	12/8	100/NA	100/100	No
Norris et al. (19)	24/25	100/100	48/50	No
Smutok et al. (21)	14/10	100/NA	87/83	No
Stone et al. (23)	9/4	100/100	NA/NA	No

%Men, percentage of subjects who were men; %Compliance, percentage of subjects who completed the study; Ex/Con, exercise and control groups, respectively; NA, data not available.

Table 2. *Mean exercise and control group values for physical characteristics*

Reference	Age, yr	Weight, kg	Body Fat, %	BMI, kg/m²	$\dot{V}O_{2\,max}$, ml·min⁻¹·kg⁻¹	RHR, beats/min
Blumenthal et al. (3)	46 ± 7/46 ± 8	81 ± 15/81 ± 18	28 ± 7/29 ± 4	27 ± 3/26 ± 3	30 ± 6/31 ± 5	77 ± 9/75 ± 11
Cononie et al. (5)	72 ± 3/72 ± 3	74 ± 14/65 ± 1	28 ± NA/30 ± NA	NA/NA	22/22	63 ± 8/67 ± 14
Harris and Holly (12)	33 ± 16/31 ± 24	86 ± 39/84 ± 31	26 ± 15/25 ± 12	26 ± NA/25 ± NA	41 ± 20/42 ± 29	76 ± 32/74 ± 39
Hurley et al. (14)	44 ± 3/52 ± 2	87 ± 12/87 ± 10	22 ± 5/20 ± 3	NA/NA	36 ± 5/30 ± 6	NA/NA
Katz and Wilson (15)	22 ± NA/19 ± NA	NA/NA	NA/NA	NA/NA	NA/NA	NA/NA
Lightfoot et al. (17)	20 ± 1/25 ± 2	78 ± 2/75 ± 2	NA/NA	NA/NA	52 ± 1/51 ± 3	65 ± 3/57 ± 3
Norris et al. (19)	NA/NA	NA/NA	NA/NA	NA/NA	NA/NA	77 ± 10/79 ± 8
Smutok et al. (21)	48 ± 12/50 ± 8	89 ± 12/89 ± 15	26 ± 5/27 ± 5	29 ± NA/29 ± NA	33 ± 8/28	NA/NA
Stone et al. (23)	NA/NA	81 ± 13/NA	19 ± 6/NA	NA/NA	40 ± 4/NA	64 ± 9/NA

Data are means ± SD. BMI, body mass index; $\dot{V}O_{2\,max}$, maximal oxygen uptake; RHR, resting heart rate.

reported. Approximately 79% of the exercising subjects and 72% of the control subjects were men. Compliance, defined as the percentage of subjects who did not drop out of the study, ranged from 48 to 100% (mean ± SD = 92 ± 15%) in the exercise groups and from 50 to 100% (mean ± SD = 88 ± 17%) in the control groups. No significant differences were observed between exercise and control groups in relation to number of subjects, percentage of men, or percent compliance.

Physical Characteristics of Subjects

Table 2 lists the initial physical characteristics of the subjects for each of the studies included in this analysis. The mean age for each study ranged from 20 to 72 yr (mean ± SD, exercise = 40 ± 17 yr; control = 41 ± 17 yr). Initial mean body weight of the subjects in the exercise and control groups combined ranged from ~74 to 89 kg (mean ± SD, exercise = 82 ± 5 kg; control = 80 ± 9 kg). Initial mean percent body fat for exercise and control groups combined ranged from ~19 to 30% (mean ± SD, exercise = 25 ± 4%; control = 26 ± 4%). Initial mean body mass index (weight in kg divided by height in m²) ranged from 25 to 29 kg/m² for both exercise and control groups combined (mean ± SD, exercise = 27 ± 2 kg/m²; control = 27 ± 2 kg/m²). Maximum oxygen consumption ranged from 22 to 52 ml·min⁻¹·kg⁻¹ (mean ± SD, exercise = 36 ± 9 ml·min⁻¹·kg⁻¹; control = 34 ± 10 ml·min⁻¹·kg⁻¹). Initial mean resting heart rate ranged from 57 to 79 beats/min (mean ± SD, exercise = 70 ± 7 beats/min; control = 70 ± 8 beats/min). No statistically significant differences between exercise and control groups were found for any of the initial or outcome characteristics listed in Table 2. An increase of ~39% in 1RM strength was found for the resistance-trained groups after completion of the training protocol.

Protocols for Blood Pressure Assessment

A summary of protocols for blood pressure measurement is shown in Table 3. All of the studies used the auscultatory cuff method for measuring resting blood pressure. Approximately 55% of the studies measured resting blood pressure with the subject in the sitting position (3, 5, 12, 15, 21). One study also measured resting blood pressure with the subject in the standing position, but no data were reported for this position (12). Approximately 67% of the studies reported using an average of multiple measures for the determination of resting systolic and diastolic blood pressure (3, 5, 14, 15, 21, 23). Of these six studies, three (3, 5, 14) reported that resting blood pressure was assessed multiple times on separate days after the exercise protocol was completed. Only one study reported the length of time after the last exercise session (24 h) before the first series of blood pressure measurements were taken (5). Four studies reported the Korotkoff sound at which resting diastolic blood pressure was determined (3, 5, 15, 17) as well as the time of day at which blood pressure was assessed (5, 12, 14, 17). Five of the studies reported the rest period before the assessment of resting blood pressure (5, 12, 15, 17, 23).

Table 3. *Summary of protocols for blood pressure assessment*

Reference	Subject's Position	Number of Recordings	Diastolic Phase	Time, of Day	Rest, min	Instrument Description
Blumenthal et al. (3)	Sitting	Mean of 12	5	NA	NA	Random-zero sphygmomanometer
Cononie et al. (5)	Sitting	Mean of 9	5	AM	15	Hawksley random-zero sphygmomanometer
Harris and Holly (12)	Sitting	5	NA	Same	5	Sphygmomanometer
Hurley et al. (14)	Supine	Mean of 12	NA	Same	NA	Mercury sphygmomanometer
Katz and Wilson (15)	Sitting	Mean of 3	5	NA	10	Standard sphygmomanometer
Lightfoot et al. (17)	Supine	Once/min	4	Same	25	Colin STBP-680 automated machine
Norris et al. (19)	NA	NA	NA	NA	NA	Copal semiautomatic sphygmomanometer
Smutok et al. (21)	Sitting	Mean of 6	NA	NA	NA	NA
Stone et al. (23)	Supine	Mean of 2	NA	NA	10	NA

AM, before noon.

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Table 4. *Training program characteristics for included studies*

Reference	Length, wk	Frequency, days/wk	No. of Sets	No. of Reps	Rest, s	No. of Exercises	Equipment Description	Adherence, %
Blumenthal et al. (3)	16	2–3	NA	NA	NA	NA	NA	89
Cononie et al. (5)	26	3	1	8–12	60–120	10	Nautilus	95
Harris and Holly (12)	9	3	3	20–25	15	10	Universal	90
Hurley et al. (14)	16	3–4	1	8–20	15	14	Nautilus	NA
Katz and Wilson (15)	6	3	1	11–15	NA	13	Nautilus	NA
Lightfoot et al. (17)	12	3	4–5	5–8	NA	12	NA	94
Norris et al. (19)	10	3	3	NA	NA	7	Universal	NA
Smutok et al. (21)	20	3	2	12–15	90	11	Nautilus	NA
Stone et al. (23)	8	6	3–5	5–10	216	2–5	Free	NA

Adherence, %exercise sessions attended; free, free weights; reps, repetitions.

Training Program Characteristics

The training program characteristics of the subjects are summarized in Table 4. Length of training for the studies ranged from 6 to 26 wk (mean ± SD = 14 ± 6 wk). Most studies had subjects train 3 days/wk (range = 3–6 days/wk, mean ± SD = 3 ± 1 days/wk), 1–3 sets (mean ± SD = 2 ± 1 sets), for 5–25 repetitions. The mean number of repetitions for the studies could not be calculated because none of the studies reported such data. Only five of the studies (5, 12, 14, 21, 23) reported the rest period between exercises (range = 15–216 s). The number of exercises performed during each session ranged from 2 to 14 (mean ± SD = 11 ± 2 exercises). Only four studies (3, 5, 12, 17) reported the adherence rates (percentage of exercise sessions attended) of subjects to the dynamic resistance training program (range = 89–94%, mean ± SD = 92 ± 3%). Only one study reported the intensity (1RM) at which subjects trained (12).

Blood Pressure Results

Main effects. Blood pressure values for individual studies are shown in Table 5. Initial resting systolic blood pressure ranged from 113.30 to 148.12 mmHg for exercise groups (mean ± SD = 132.71 ± 11.27 mmHg) and from 115.20 to 146.10 mmHg for control groups (mean ± SD = 131.84 ± 10.22 mmHg). Initial resting diastolic blood pressure ranged from 69.00 to 95.80 mmHg for exercise groups (mean ± SD = 82.28 ± 10.62 mmHg) and from 70.40 to 95.00 mmHg for control groups (mean ± SD = 83.11 ± 9.12 mmHg). No statistically significant differences were found between exercise and control groups for initial resting systolic or diastolic blood pressure (systolic, $P = 0.87$, diastolic, $P = 0.87$). Across all designs and categories, Δ_3 reductions (mean ± SD) in resting blood pressure were as follows: systolic, −4.55 ± 5.69 mmHg, 95% confidence interval (CI) = −0.18 to −8.93; diastolic, −3.72 ± 3.46 mmHg, 95% CI = −1.06 to −6.38. Δ_3 changes in resting systolic blood pressure ranged from ~2 to −15 mmHg, whereas Δ_3 changes in resting diastolic blood pressure ranged from ~0 to −9 mmHg. Δ_3 changes corresponded with relative decreases of ~3 and 4% in resting systolic and diastolic blood pressure, respectively. Examination for outliers beyond the 10th and 90th percentiles revealed two outliers each for resting systolic (3, 19)

Table 5. *Exercise and control group blood pressure results*

Reference	Group	Systolic Pre	Systolic Post	Systolic Δ_3	Diastolic Pre	Diastolic Post	Diastolic Δ_3
Blumenthal et al. (3)	Ex	143 ± 10	136 ± 11		95 ± 5	89 ± 6	
	Con	142 ± 12	133 ± 9	2	95 ± 6	90 ± 6	−1
Cononie et al. (5)	Ex	132 ± 16	132 ± 17		78 ± 9	78 ± 11	
	Con	137 ± 16	140 ± 16	−3	81 ± 7	83 ± 6	−2
Harris and Holly (12)	Ex	142 ± 25	142 ± 24		96 ± 20	91 ± 25	
	Con	146 ± 26	146 ± 22	0	95 ± 12	93 ± 10	−2
Hurley et al. (14)	Ex	129 ± NA	129 ± NA		84 ± 7	79 ± 6	
	Con	128 ± 12	128 ± 10	0	81 ± 6	84 ± 6	−8
Katz and Wilson (15)	Ex	113 ± NA	99 ± NA		71 ± NA	62 ± NA	
	Con	115 ± NA	112 ± NA	−11	70 ± NA	68 ± NA	−7
Lightfoot et al. (17)	Ex	131 ± 10	121 ± 7		69 ± 10	65 ± 7	
	Con	123 ± 10	120 ± 10	−7	72 ± 10	70 ± 10	−2
Norris et al. (19)	Ex	148 ± 14	134 ± 13		92 ± 9	84 ± 7	
	Con	135 ± 12	136 ± 11	−15	87 ± 10	84 ± 10	−10
Smutok et al. (21)	Ex	137 ± 17	135 ± 15		85 ± 6	83 ± 7	
	Con	128 ± 9	129 ± 8	−3	84 ± 7	84 ± 9	−2
Stone et al. (23)	Ex	119 ± 13	115 ± 9		71 ± 8	71 ± 7	
	Con	NA ± NA	NA ± NA	−4	NA ± NA	NA ± NA	0

Data are means ± SD. Pre, before start of exercise program; Post, after exercise program was completed; Δ_3, treatment effect change calculated as change in control group (Δ_2) minus change in exercise group (Δ_1).

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and diastolic (19, 23) blood pressure. However, since further examination of these outliers revealed no physiological reason for their exclusion compared with other outcomes, they remained in the analysis.

By using the bootstrap technique (10,000 samples) to estimate the reliability of original estimates for Δ_3 changes in resting blood pressure, significant Δ_3 reductions supporting original sample estimates were shown for both systolic and diastolic blood pressure (systolic, mean ± SD = −4.55 ± 1.75 mmHg, 95% CI = −1.56 to −8.56; diastolic, mean ± SD = −3.79 ± 1.12 mmHg, 95% CI = −1.89 to −6.33).

Subgroup analysis. No statistically significant differences were found between Δ_3 changes when studies were partitioned according to whether they were randomized controlled (n = 4) or nonrandomized controlled (n = 5) trials (mean ± SD, systolic: randomized controlled = −2.60 ± 5.35, nonrandomized controlled = −4.25 ± 3.77, P = 0.60; diastolic: randomized controlled = −3.13 ± 2.66, nonrandomized controlled = −4.19 ± 4.24, P = 0.67). In addition, position of blood pressure measurement in a subject (sitting, n = 5; supine, n = 3) did not affect Δ_3 changes for either type of blood pressure (mean ± SD, systolic: sitting = −2.94 ± 5.34, supine = −3.83 ± 3.55, P = 0.81; diastolic: sitting = −2.90 ± 2.36, supine = −3.20 ± 4.33, P = 0.90). When Δ_3 changes were partitioned according to whether groups were hypertensive (n = 3) or normotensive (n = 6), no significant differences were found for either systolic or diastolic pressure (mean ± SD, systolic: hypertensive = −4.33 ± 9.29 mmHg, normotensive = −4.67 ± 3.83 mmHg, P = 0.94; diastolic: hypertensive = −4.33 ± 4.93 mmHg, normotensive = −3.50 ± 3.21 mmHg, P = 0.76). Furthermore, no significant differences were observed when studies that included women (n = 3) were compared with those that did not (n = 6) (mean ± SD, systolic: women included = −4.20 ± 6.88 mmHg, women not included = −4.73 ± 5.72 mmHg, P = 0.91; diastolic: women included = −3.91 ± 3.85 mmHg, women not included = −3.33 ± 3.21 mmHg, P = 0.83).

Correlational analysis. No significant relationships were observed between either systolic or diastolic Δ_3 changes and study characteristics (year of publication, number of subjects, percentage of men, percent compliance), initial and final physical characteristics (age, body weight, body mass index, percent fat, lean body mass, maximum oxygen consumption, resting heart rate), blood pressure protocols (number of measures, rest period before assessment of blood pressure), training program characteristics (length, frequency, duration, number of sets, rest between sets, number of exercises, percent adherence), and initial resting blood pressure.

DISCUSSION

Previous narrative reviews (1, 2, 9, 22, 24) have suggested that resistance exercise does not increase, and may have potential benefits, on resting systolic and diastolic blood pressure. The overall results of this study suggest that dynamic resistance exercise reduces resting systolic and diastolic blood pressure by ~3 and 4%, respectively. The fact that bootstrap results for both systolic and diastolic outcomes (95% confidence intervals) compared very favorably with sample statistics gives one greater confidence in the reliability of the original sample estimates. While outliers were observed in this study, further examination of each individual study for unique characteristics that may account for the outlying outcome data could not be identified. As a result, the outliers remained in the analysis. Despite these positive results, the clinical importance regarding the magnitude of such reductions could be questioned. However, it has been shown that a reduction of 5 mmHg in resting blood pressure would result in a 40% reduction in stroke and ~15% reduction in myocardial infarction (4) among subjects with essential hypertension who sustain this blood pressure reduction.

The decreases described above compare to reductions of ~4 mmHg found for both resting systolic and diastolic blood pressure in this investigation. More important than the finding that dynamic resistance exercise may reduce resting blood pressure is the fact that this investigation did not show an increase in either resting systolic or diastolic blood pressure. These results support previous studies in which a lack of hypertension was observed among strength and power athletes (7, 18). The increased resting blood pressure levels observed in some strength and power athletes may be the result of other factors. These include overtraining (13), large increases in muscle mass (27), and/or the use of androgens (29). While the mechanisms involved in the exercise-induced reduction of resting blood pressure are beyond the scope of this investigation, it has been suggested that such changes may be the result of one or more of the following: *1*) decreases in plasma norepinephrine levels (11, 26), *2*) decreases in total peripheral resistance (10), and *3*) alterations in renal function (16).

Whereas the results of this investigation provide some valuable information, this study must be viewed with regard to certain potential limitations. In general, the very nature of meta-analysis dictates that the meta-analysis itself inherits those potential limitations that exist in the literature. One significant limitation of this investigation was the paucity of available studies. This fact alone warrants extreme caution in the interpretation of results reported in this study. This may be especially true in relation to subgroup analysis where the existing data set is broken into smaller sets and compared. For example, whereas there were no significant differences for either systolic or diastolic blood pressure when Δ_3 results were partitioned by blood pressure category (hypertensive vs. normotensive), these results were based on a total of only nine outcome measurements (3, 5, 12, 14, 15, 17, 19, 21, 23), with only three (3, 12, 19) of the nine outcomes classified as hypertensive. The real importance regarding the role of resistance training in lowering blood pressure is whether it does so in individuals with high blood pressure. It is generally believed that aerobic exercise training lowers resting blood pressure more in patients with moderate-to-severe hypertension, compared with individuals with mild hypertension. The least effects usually occur in subjects with normal blood pressure. It would seem prudent to recommend that future studies examining the effects of dynamic resistance exercise on resting blood pressure make a special effort to include hypertensive patients as subjects in their investigations.

A second limitation of this study, common to meta-analytic research, was the absence of data for selected variables. For example, only five studies reported the rest period before the assessment of blood pressure (5, 12, 15, 17, 23), four reported the time of day in which blood pressure was assessed (5, 12, 14, 17), and four reported the diastolic phase in which blood pressure was recorded (3, 5, 15, 17). In addition, only one study reported the length of time between the last exercise session and the first series of blood pressure measurements (5). Because blood pressure is extremely variable, future investigations should include a more complete description of blood pressure measurement techniques. This should include the type, position, number of recordings, Korotkoff sound at which diastolic blood pressure is assessed, time of day, number of days, rest interval between measurements, and the length of time after the last exercise session before blood pressure is assessed. This latter factor is important because of the hypotensive effect that occurs postexercise.

A second example was the lack of information on the dynamic resistance training protocol used. Only one study reported the intensity (percentage of 1RM) at which subjects trained (12), four reported the adherence rate of subjects to the training program (3, 5, 12, 17), and five reported the amount of time that subjects rested between exercises (5, 12, 14, 21, 23). It seems appropriate to recommend that future investigations provide detailed information on the length, frequency, intensity, and duration of the training program, as well as the types of exercises performed, number of sets, repetitions, and exercises, rest period between sets and exercises, type of equipment used, and adherence rates of the subjects to the training program. Such information will allow one to more accurately quantify the training stimulus. In the future, it is recommended that authors report sufficient data on this topic and that journal editors allow such data to be included in the authors' manuscript. Consequently, readers may arrive at a more accurate conclusion regarding the quality of the study and its findings.

In conclusion, meta-analytic review of included studies suggests that dynamic resistance exercise reduces resting systolic and diastolic blood pressure in adults. However, it is premature to form strong conclusions regarding the effects of dynamic resistance exercise on resting blood pressure. A need exists for additional, well-designed studies on this topic before a decision can be made regarding the efficacy of dynamic resistance exercise as a nonpharmacological therapy for reducing resting blood pressure in adults, especially hypertensive adults.

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