Habitual exercise decreases systolic blood pressure during low-intensity resistance exercise in healthy middle-aged and older individuals

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Running head: Habitual exercise & SBP during resistance exercise

Conflict of Interest: None

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Abstract
Since aerobic exercise (e.g., walking) and resistance exercise (e.g., lifting objects and mopping) are both parts of the activities of daily living, an exaggerated elevation in systolic blood pressure (SBP) during aerobic and resistance exercise is an early marker of cardiovascular disease. This study investigated the effects of habitual exercise on SBP during low-intensity resistance exercise using both cross-sectional and interventional approaches. First, in 57 normotensive women (61.9±1.0 years of age) daily physical activity level as assessed by triaxial accelerometry was correlated with SBP during resistance exercise at 20% and 40% of the one-repetition maximum ($r=−0.408$ and $r=−0.348$, respectively). Maximal oxygen uptake was correlated with SBP during exercise at 20% ($r=−0.385$) and 40% ($r=−0.457$). Physical activity level or maximal oxygen uptake was identified as a predictor of SBP during the exercise in stepwise regression analysis, independent of SBP at rest and other factors ($R^2=0.729$ to 0.781).

Second, 66 men and women (64.6±0.9 years of age) participated in a 6-week intervention as a part of the training (walking, 4.3±0.3 d/wk, 55.6±4.1 min/d, 70.7±1.2% of maximal heart rate) or control group. SBP during resistance exercise in the training group decreased after the intervention (before vs. after: 20%, 143±4 vs. 128±4 mmHg; and 40%, 148±5 vs. 134±4 mmHg). In the control group, there were no significant differences in SBP before and after the intervention. SBP during resistance exercise after the intervention was lower in the training group relative to the control group. These results suggest that habitual exercise decreases SBP during low-intensity resistance exercise.

New & Noteworthy
Systolic blood pressure (SBP) during aerobic and resistance exercise is an independent risk factor for cardiovascular disease. This is the first study to demonstrate that SBP during resistance exercise is correlated with daily physical activity level and decreased by aerobic exercise training in middle-aged and older individuals.

Key Words
Aerobic exercise training; daily physical activity; low-intensity resistance exercise; maximal oxygen uptake; systolic blood pressure
Introduction

Blood pressure transiently increases during exercise as a response to the increased demand for blood flow to the muscles. The transient elevations in blood pressure increase 24-h ambulatory blood pressure, an independent risk factor for cardiovascular disease (15, 38). Since aerobic exercise (e.g., walking and cycling) and resistance exercise (e.g., lifting objects, mopping, and climbing stairs) are both parts of the activities of daily living, an exaggerated blood pressure response to aerobic (31) and resistance (3) exercise is a risk factor for future cardiovascular disease. Lifestyle modification to decrease blood pressure during aerobic and resistance exercise may be of significance because ischemic heart disease and stroke are major public health problems that have resulted in 14.1 million deaths in 2012 according to the World Health Organization. Habitual exercise attenuates blood pressure elevation during aerobic exercise (treadmill exercise or cycling) in middle-aged and older individuals (11, 12, 27). However, effects of habitual exercise on blood pressure during resistance exercise are equivocal. In previous studies, 12 or 19 weeks of resistance training did not decrease blood pressure during resistance exercise at 50–100% one repetition maximum (1RM) when the exercise tests before and after the training period were performed at a similar intensity (i.e., % 1RM) (14, 30). These results may be due to the intensive training load on the skeletal muscles. For example, resistance training on a regular basis increases arterial stiffness, a determinant of blood pressure (5, 17). However, habitual exercise that does not require intense muscle contraction (e.g., increased levels of daily physical activity and aerobic exercise training) may attenuate blood pressure elevation during resistance exercise, because aerobic exercise training improves arterial stiffness (5, 36) and vascular conductance (5, 26) and blunting of sympathetic vasoconstriction during exercise (20).
This study investigated whether habitual exercise decreases blood pressure during resistance exercise using both cross-sectional and interventional approaches. First, relationships between daily physical activity level and blood pressure during resistance exercise were investigated. Second, the effects of 6 weeks of aerobic exercise training on blood pressure during resistance exercise were examined. We measured blood pressure during flexion and extension of the elbow (one-hand arm curl exercise) at 20% and 40% 1RM because various upper-arm activities at low intensity are needed during activities of daily living and it allows for non-invasive brachial blood pressure measurements during exercise.

**Methods**

**Participants**

We recruited subjects older than 40 years through the Ryugasaki city's public relations magazine. In the advertisement for subjects, we specified that the inclusion criteria of this study included the absence of any disorders in which exercise is contraindicated (e.g., unstable ischemia, acute low back pain, etc.). In the cross-sectional study, subjects that had treated or untreated hypertension (systolic blood pressure [SBP]/diastolic blood pressure [DBP] $\geq 140/90$ mmHg), were on hormone replacement therapy, or smoked tobacco were excluded, because these factors can affect associations between physical activity level and blood pressure. The formulae to calculate daily physical activity level used in this study were different between men and women. There are sex differences in maximal oxygen uptake (32). These sex differences might affect correlations between blood pressure and physical activity level or maximal oxygen uptake. Since the number of male subjects who met the inclusion criteria was only 18, the remaining 57 women
between 45 and 74 years of age were analyzed (Table 1). In the interventional study, 76 men and women chose the control or training group and volunteered to participate in this study. However, only 66 subjects between 46 and 74 years of age enrolled and completed the study protocol (Table 2). Since the aim of interventional study was to compare blood pressure before and after the intervention period, men and women were included. Subjects refrained from alcohol consumption and intense physical activity starting on the day before testing and caffeine consumption on the day of testing.

A power calculation was performed for Pearson’s correlation coefficients between daily physical activity level and SBP during exercise in the cross-sectional study and for repeated measures two-way analysis of variance (ANOVA) in SBP during exercise of the intervention study using G*Power 3 (9). The sample size of this study was enough to detect the exercise effects at 90% power and with an $\alpha$ of 5% when effect size was assumed as intermediate between the medium and large (4).

This study was approved by the Ethics Committee of Ryutsu Keizai University and conformed to the principles of the Helsinki Declaration. All participants gave their written informed consent prior to study participation.

**Resistance exercise test protocol**

Subjects performed two sets of 10 repetitions of the one-hand arm curl exercise at 20% 1RM using an arm curl bench and dumbbells. Each repetition was performed for 8 s (3 s of concentric contraction, 1 s of maintaining full flexion, 3 s of eccentric contraction, and 1 s of maintaining a slightly flexed position) according to the Exercise Guide 2006.
Blood pressure and heart rate measurement

Resting blood pressure was measured in quintuplicate by oscillometry after at least 30 minutes of rest (DINAMAP; GE Healthcare, Buckinghamshire, UK). A three-lead electrocardiogram (ECG) was recorded at 1,000 Hz to calculate the heart rate (HR: LRR-03; GMS, Tokyo, Japan). During resistance exercise, blood pressure measurements were taken by oscillometry 20 s after the onset of exercise until the end of exercise. Exercise was performed with the dominant arm and blood pressure was measured in the non-dominant arm. The mean value of each parameter over two sets at 20% and 40% 1RM, respectively, was calculated.

Daily physical activity level assessment

Daily physical activity levels were measured using an accelerometer (Active Style Pro; Omron Healthcare, Kyoto, Japan). This device estimates the intensity of physical activity (metabolic equivalents, METs) over 10 s intervals based on accelerations in three dimensions (sampling rate, 32 Hz). The estimation of METs for household and locomotive activities using this device has been validated (22). The device automatically calculates physical activity levels (kcal/d) based on all levels of METs and basal metabolic rate estimated from age, sex, height, and body weight, but the manufacturer...
has not disclosed how it does so in detail. All subjects wore an accelerometer on the waist continuously for 14 days, except during sleeping and bathing. However, subjects sometimes forgot to wear the accelerometer and spent a day as unusual (e.g., staying in bed due to poor health). In addition, especially in the first few days, wearing the accelerometer could have psychological influence on behavior of subjects. Therefore, data from a continuous seven-day period that began three to four days after the commencement of monitoring were used to assess the level of daily physical activity (34). The accelerometer measures non-wear time, defined as periods with no acceleration for longer than 20 min. All subjects wore the accelerometer over 10 hours per day for at least 7 days.

Maximal oxygen uptake estimation

Three-lead ECG (LRR-03; GMS) and breath-by-breath oxygen uptake (AE300S; Minato Medical Science, Osaka, Japan) were monitored during incremental cycling (4 min at 30 W, with a 20 W [male] or 15 W [female] increase every 2 min to 85% of age-predicted maximum HR [208 − 0.7 × age (37)]). The linear regression line between HR and oxygen uptake was determined using values from the last 30 s of each workload. Oxygen uptake corresponding to the maximum HR was considered the maximal oxygen uptake.

1RM assessment

The one-hand arm curl 1RM was assessed using an arm curl bench and dumbbells. Subjects performed a single repetition of the exercise using their dominant arm with progressively heavier weights; the heaviest weight that a subject could lift once through a complete range of movement was considered his or her individual 1RM.
Blood samples were collected from the antecubital vein by venipuncture after an overnight fast. Serum concentrations of cholesterol, triglycerides, and insulin, as well as plasma level of glucose, were determined according to our previous study (23). In the interventions study, serum high sensitivity C-reactive protein (hsCRP) concentrations and creatine kinase (CK) activity were measured by using a commercial immunonephelometry kit (CardioPhase hsCRP; Siemens Healthcare Diagnostics, Tokyo, Japan) and the Japan Society of Clinical Chemistry (JSCC) transferable method kit (L-type CK; Wako Pure Chemical Industries, Osaka, Japan). In addition, plasma levels of interleukin-6 (IL-6) were determined by using an enzymatic kit (QuantiGlo Human IL-6, R&D systems, Minneapolis, U.S.A.).

Arterial stiffness assessment

In the interventions study, brachial-ankle pulse wave velocity (baPWV) was measured using air plethysmography as in our previous studies (24, 25). Briefly, in supine position, brachial and post-tibial artery pulse waves were obtained in triplicate (BP-203RPE II; Omron Colin, Tokyo, Japan). Pulse wave transit time was automatically determined by the device, as the delay between the proximal and distal waveforms. The distance traveled by the pulse waves was calculated based on each subject’s height. BaPWV was calculated as the distance divided by the transit time.

Exercise intervention

Subjects in the training group underwent supervised walking (35–50 min) once per week for 6 weeks. Initially, subjects walked at a relatively low intensity (60–65% maximal HR).
As their exercise tolerance improved, the intensity of walking was increased to 75% maximal HR. In addition, subjects walked 2–4 times a week on their own at the same pace as the supervised walking and recorded the actual duration of their walks. Adherences to the prescribed walking frequency and time were calculated without distinction between supervised and unsupervised walks. Mean HR during walking was calculated based on HR during supervised walking. Subjects in the control group participated in a muscle stretching class (30–45 min) at local community centers every other week.

Statistical analysis

Results are expressed as means ± SE. Relationships between two variables were investigated using Pearson’s correlation coefficients and partial correlation analysis. Stepwise regression was used to identify independent predictors of SBP during exercise. In the cross-sectional study, changes in blood pressure and HR during exercise were evaluated using repeated measures one-way ANOVA. Effects of intervention on blood pressure during exercise and other variables were tested using repeated measures two-way ANOVA. If a significant F value was found, a Fisher’s post hoc test was performed. The unpaired t-test or chi-squared test was used to detect intergroup differences in variables before the intervention, as appropriate. P values <0.05 were considered statistically significant.

Results

Cross-sectional study

SBP (rest, 114±2 mmHg; 20% 1RM, 136±3 mmHg; 40% 1RM, 142±3 mmHg), DBP
(66±1 mmHg, 78±1 mmHg, and 81±2 mmHg, respectively), HR (65±1 bpm, 75±1 bpm, and 78±1 bpm, respectively), and rating of perceived exertion (RPE, Borg’s 6–20 scale; 20% 1RM, 10.6±0.2; 40% 1RM, 13.0±0.2) increased during resistance exercise in an exercise-intensity dependent manner.

Physical activity level (Figure 1) and maximal oxygen uptake (Figure 2) were correlated with SBP during resistance exercise at 20% and 40% 1RM. In partial correlation analysis, physical activity level and maximal oxygen uptake were correlated with SBP at 20% and 40% 1RM, independent of resting SBP (partial $r = -0.318$ to $-0.464$, $P = 0.01$ to 0.0002). Physical activity level or maximal oxygen uptake, age, and SBP at rest were identified as independent predictors of SBP during exercise in the stepwise regression analysis that included 1RM, body mass index, DBP at rest, and blood levels of cholesterol, triglycerides, glucose, and insulin (Table 3).

Physical activity level was not associated with DBP and HR both at rest and during resistance exercise. Maximal oxygen uptake was correlated with DBP (rest, $r = -0.389$, $P = 0.002$; 20% 1RM, $r = -0.480$, $P = 0.0001$; and 40% 1RM, $r = -0.432$, $P = 0.0007$) and HR ($r = -0.286$, $P = 0.03$; $r = -0.366$, $P = 0.004$; and $r = -0.370$, $P = 0.004$; respectively). In partial correlation analysis, only DPB at 20% 1RM was correlated with maximal oxygen uptake, independent of the resting value (partial $r = -0.306$, $P = 0.02$).

**Interventional study**

There were no intergroup differences in male-to-female ratio, age, BMI, laboratory values, and exercise parameters before the intervention (Table 2). Subjects in the training
group exercised for an average of 4.3±0.3 d/wk and 55.6±4.1 min/d at 70.7±1.2% of maximal HR. Subjects in the control group participated in the stretching class for an average of 0.3±0.3 d/wk. The subjects did not change their lifestyle during the experimental period except for participation in this study. There was an interaction between group and training period in maximal oxygen uptake; maximal oxygen uptake increased in the training group after the intervention (Table 2).

An interaction between group and exercise intensity was identified in SBP (Figure 3). In the training group SBP at 20% and 40% 1RM were lower after the intervention compared to before the intervention, whereas there were no differences in SBP in the control group between before and after the intervention. After the intervention, SBP at 20% and 40% 1RM were lower in the training group than in the control group, but there were no intergroup differences in SBP before the intervention. There were no differences in resting SBP between groups and between before and after the intervention. ANOVA demonstrated that trends in DBP changes during exercise were affected by the exercise training, although these multiple comparisons did not reach statistical significance. Results in women were similar to results in all subjects, although the decrease in SBP at 40% 1RM of the training group from before to after the intervention did not reach statistical significance ($P = 0.05$).

There was an interaction between group and training period in baPWV; baPWV in the training group decreased after the training period compared to baseline (Figure 4). Changes in baPWV of the training group from before to after the intervention were correlated with the changes in SBP at 20% ($r = 0.488$, $P = 0.003$) and at 40% ($r =$
Discussion

The main new findings of our study are as follows. In the cross-sectional study, daily physical activity level and maximal oxygen uptake were independently correlated with SBP during resistance exercise at 20% and 40% 1RM. In the interventional study, SBP during resistance exercise at 20% and 40% 1RM decreased after a 6-week aerobic exercise training program. In addition, SBP during resistance exercise after the intervention was lower in the training group relative to the control group. These results suggest that habitual exercise decreases SBP during low-intensity resistance exercise.

SBP during low-intensity resistance exercise may be a more sensitive marker of the effects of habitual exercise than SBP at rest. Even though resting SBPs in the normotensive subjects with higher and lower levels of physical activity are similar, SBP during exercise may be lower in those who are more physically active. These results do not contradict previous studies that demonstrated that there are individuals with exaggerated blood pressure responses to exercise even though resting blood pressure is normal (3, 13, 18). In the interventional study, SBP during resistance exercise decreased after the 6-week aerobic exercise training program, whereas changes in SBP at rest did not reach statistical significance possibly due to the normotensive level at the time of enrollment. In previous studies, exercise training decreased not only SBP during aerobic exercise, but also SBP at rest (11, 27). However, pre-intervention resting SBP was higher in previous studies [138 and 131 mmHg, respectively (11, 27)] than in this study (115 mmHg). Improvements in the cardiovascular system due to aerobic exercise training in
normotensive individuals without changes in resting blood pressure are frequently observed (34, 36). SBP during low-intensity resistance exercise also seems to be lowered by habitual exercise, independent of SBP at rest.

Blunting of sympathetic vasoconstriction during exercise (functional sympatholysis) may be associated with mechanisms responsible for the effects of habitual exercise on SBP during resistance exercise. Sympathetic vasoconstriction in contracting muscles is attenuated by local factors (e.g., endothelium-derived relaxing factor) during exercise. However, endothelial function decreases with aging (2, 7, 35). Thus, functional sympatholysis is impaired in older individuals with a sedentary lifestyle (8, 10). Aerobic exercise training improves endothelial function (1, 28) and functional sympatholysis (20).

In addition, Mortensen et al. reported that functional sympatholysis preserved in physically active older individuals (21). A decrease in vasoconstriction due to endothelial function lowers blood pressure via reduction of vascular resistance. In this study, an index of arterial stiffness (i.e., baPWV) was measured, because arterial endothelial function is a potent regulator of arterial stiffness (33, 39). BaPWV in the training group decreased after the training period compared to baseline. This result is in agreement with the previous studies that aerobic exercise delays or prevents age-related increases in arterial stiffness (5, 26, 36). In addition, the changes in baPWV from before to after the intervention were correlated with the changes in SBP during exercise. Improvement of functional sympatholysis may be implicated in the association between habitual exercise and lower SBP during low-intensity resistance exercise in middle-aged and older individuals.
Previous studies have reported that hsCRP and IL-6 were associated with blood pressure responses to aerobic exercise in normotensive women (16) and to muscle contractions in decerebrate rats (6). Therefore, blood levels of hsCRP, IL-6, and CK activity were measured in the intervention study to investigate whether reductions in vascular inflammation are associated with decreases in SBP during resistance exercise. However, there were no differences in these indices between before and after the intervention. In the present subjects, serum concentrations of hsCRP before the intervention were low; Ridker et al. have reported that the lowest quintile of blood hsCRP concentrations among men and women with no history of cardiovascular disease and cancer were 0.01 to 0.069 mg/dL (29). In individuals with low inflammation levels, other mechanisms such as nitric oxide bioavailability and antioxidant capacity may be implicated in the effects of aerobic exercise training on SBP during low-intensity resistance exercise.

The present results have implications for older individuals that exercise habitually. Daily physical activity of 200 kcal/d was associated with a 10-mmHg reduction in SBP during resistance exercise in the cross-sectional study (please see the regression equations of Figure 1). The 6-week walking program induced 15 mmHg decreases in SBP during exercise, although it might partly include familiarity with the exercise test. Schultz et al. reported that the relative risk of cardiovascular events and mortality increases 4% per 10-mmHg increase in SBP during moderate-intensity aerobic exercise (31). Physically active individuals may have a lower SBP not only during the arm curl exercise but also during activities of daily living such as lifting objects, mopping, and climbing stairs; these smaller responses may be lead to lower
This study has some limitations. First, subjects of the intervention study were not randomized. Second, subjects with known cardiovascular disease were excluded and most of subjects (cross-sectional study, 79%; intervention study, 76%) had a normal BMI for Japanese (18.5 to 24.9 kg/m²). A previous study reported that there were differences in effects of aerobic exercise training on exercise pressor reflex overactivity between normotensive and hypertensive rats (19). The present results may not be generalized to individuals with cardiovascular disease and to lean or obese individuals.

In conclusion, this study demonstrated that daily physical activity level was correlated with SBP during resistance exercise at 20% and 40% 1RM and that SBP during resistance exercise decreased after 6 weeks of aerobic exercise training. These results suggest that habitual exercise decreases SBP during low-intensity resistance exercise.
Acknowledgments

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Grants

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Disclosures

We have no financial or other relationships that might lead to a conflict of interest.
References


Figure Legends

Figure 1. Relationship between daily physical activity level and systolic blood pressure at rest (A) and 20% (B) and 40% (C) of one-repetition maximum of an arm curl exercise.

1RM, one-repetition maximum of an arm curl exercise; SBP, systolic blood pressure.

Figure 2. Relationship between maximal oxygen uptake and systolic blood pressure at rest (A) and 20% (B) and 40% (C) of one-repetition maximum of an arm curl exercise.

1RM, one-repetition maximum of an arm curl exercise; SBP, systolic blood pressure.

Figure 3. Systolic blood pressure (A), diastolic blood pressure (B), and heart rate (C) before and after 6-week aerobic exercise training

Values are means ± SEs. 20%, arm curl exercise at 20% of the one-repetition maximum (1RM); 40%, arm curl exercise at 40% 1RM; ANOVA, analysis of variance; DBP, diastolic blood pressure; SBP, systolic blood pressure. *, P < 0.05 vs. control group at the same time point. †, P < 0.05 and ††, P < 0.005 vs. before intervention in the same group. Open symbols, before intervention; closed symbols, after intervention; triangles, control group; circles, training group.

Figure 4. Arterial stiffness before and after 6-week aerobic exercise training

Values are means ± SEs. ANOVA, analysis of variance; baPWV, brachial-ankle pulse wave velocity.
Table 1. Subjects characteristics of the cross-sectional study

<table>
<thead>
<tr>
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<th>Mean ± SE</th>
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<tbody>
<tr>
<td><strong>Age, years</strong></td>
<td>61.9 ± 1.0</td>
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<tr>
<td><strong>Height, m</strong></td>
<td>1.55 ± 0.01</td>
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<td><strong>Weight, kg</strong></td>
<td>52.4 ± 1.0</td>
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<td><strong>Body mass index, kg/m^2</strong></td>
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<td><strong>HDL cholesterol, mg/dL</strong></td>
<td>72 ± 3</td>
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<td><strong>LDL cholesterol, mg/dL</strong></td>
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<td><strong>Triglycerides, mg/dL</strong></td>
<td>100 ± 8</td>
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<tr>
<td><strong>Glucose, mg/dL</strong></td>
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<td><strong>Insulin, μU/mL</strong></td>
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<td><strong>Systolic blood pressure, mmHg</strong></td>
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<td><strong>Diastolic blood pressure, mmHg</strong></td>
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<tr>
<td><strong>Heart rate, bpm</strong></td>
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<tr>
<td><strong>Daily physical activity, kcal/d</strong></td>
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<td><strong>Maximal oxygen uptake, mL/kg/min</strong></td>
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<tr>
<td><strong>1RM, kg</strong></td>
<td>6.2 ± 0.2</td>
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1RM, one-repetition maximum of an arm curl exercise; HDL, high-density lipoprotein; LDL, low-density lipoprotein.
<table>
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<tr>
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<th>Before</th>
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<tr>
<td>Control</td>
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<tr>
<td>Training</td>
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<td>−</td>
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<tr>
<td><strong>Age, years</strong></td>
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<tr>
<td>Control</td>
<td>64.1 ± 1.1</td>
<td>−</td>
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<tr>
<td>Training</td>
<td>65.2 ± 1.5</td>
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<td><strong>Body mass index, kg/m²</strong></td>
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<td><strong>HDL cholesterol, mg/dL</strong></td>
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<td>61 ± 3</td>
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<td>127 ± 6</td>
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<td>Training</td>
<td>126 ± 5</td>
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<td><strong>Triglycerides, mg/dL</strong></td>
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<tr>
<td>Control</td>
<td>113 ± 12</td>
<td>116 ± 11</td>
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</tr>
<tr>
<td>Training</td>
<td>104 ± 9</td>
<td>103 ± 8</td>
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<td><strong>Glucose, mg/dL</strong></td>
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<td>104 ± 3</td>
<td>P = 0.93</td>
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<td><strong>Insulin, μU/mL</strong></td>
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<tr>
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<td>0.06 ± 0.01</td>
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<tr>
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<td>P = 0.37</td>
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<tr>
<td>Control</td>
<td>110 ± 11</td>
<td>108 ± 13</td>
<td>P = 0.35</td>
</tr>
<tr>
<td>Training</td>
<td>125 ± 20</td>
<td>106 ± 12</td>
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<tr>
<td><strong>Maximal oxygen uptake, mL/kg/min</strong></td>
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<tr>
<td>Control</td>
<td>24.8 ± 1.0</td>
<td>24.6 ± 0.9</td>
<td>P = 0.04</td>
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<td>Training</td>
<td>24.6 ± 0.7</td>
<td>26.0 ± 0.8</td>
<td></td>
</tr>
<tr>
<td><strong>1RM, kg</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>6.3 ± 0.5</td>
<td>6.6 ± 0.5</td>
<td>P = 0.10</td>
</tr>
<tr>
<td>Training</td>
<td>6.6 ± 0.4</td>
<td>6.6 ± 0.4</td>
<td></td>
</tr>
</tbody>
</table>

Values are means ± SEs. 1RM, one-repetition maximum of an arm curl exercise; ANOVA, analysis of variance; HDL, high-density lipoprotein; hsCRP, high sensitivity C-reactive protein; LDL, low-density lipoprotein. *, P < 0.05 vs. before intervention.
Table 3. Stepwise regression analysis to identify independent predictors of systolic blood pressure during resistance exercise.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model 1 (Daily physical activity)</th>
<th>Model 2 (Maximal oxygen uptake)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20%</td>
<td>40%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.753</td>
<td>0.729</td>
</tr>
<tr>
<td>$P$</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Daily physical activity (kcal/d)</td>
<td>RC</td>
<td>−0.03</td>
</tr>
<tr>
<td></td>
<td>SE</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>β</td>
<td>−0.216</td>
</tr>
<tr>
<td></td>
<td>$P$</td>
<td>0.005</td>
</tr>
<tr>
<td>Maximal oxygen uptake (mL/kg/min)</td>
<td>RC</td>
<td>−</td>
</tr>
<tr>
<td></td>
<td>SE</td>
<td>−</td>
</tr>
<tr>
<td></td>
<td>β</td>
<td>−</td>
</tr>
<tr>
<td></td>
<td>$P$</td>
<td>−</td>
</tr>
<tr>
<td>Age (years)</td>
<td>RC</td>
<td>0.62</td>
</tr>
<tr>
<td></td>
<td>SE</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>β</td>
<td>0.227</td>
</tr>
<tr>
<td></td>
<td>$P$</td>
<td>0.004</td>
</tr>
<tr>
<td>SBP at rest (mmHg)</td>
<td>RC</td>
<td>1.01</td>
</tr>
<tr>
<td></td>
<td>SE</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td>β</td>
<td>0.703</td>
</tr>
<tr>
<td></td>
<td>$P$</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

Excluded variables
1RM (kg), BMI (kg/m²), DBP at rest (mmHg), LDL cholesterol (mg/dL), HDL cholesterol (mg/dL), triglycerides (mg/dL), glucose (mg/dL), and insulin (μU/dL)

1RM, one-repetition maximum of an arm curl exercise; 20%, arm curl exercise at 20% 1RM; 40%, arm curl exercise at 40% 1RM; BMI, body mass index; DBP, diastolic blood pressure; HDL, high-density lipoprotein; LDL, low-density lipoprotein; RC, regression coefficient; SBP, systolic blood pressure.
Figure 1 (Otsuki et al.)

A

SBP at rest

$\begin{align*}
&n = 57 \\
r &= -0.163 \\
P &= 0.22
\end{align*}$

B

SBP at 20% 1RM

$\begin{align*}
&n = 57 \\
r &= -0.408 \\
P &= 0.001 \\
Y &= -0.054 X + 170
\end{align*}$

C

SBP at 40% 1RM

$\begin{align*}
&n = 57 \\
r &= -0.348 \\
P &= 0.009 \\
Y &= -0.051 X + 175
\end{align*}$

Daily physical activity
Figure 2 (Otsuki et al.)

A

SBP at rest

\[ n = 57 \]
\[ r = -0.249 \]
\[ P = 0.06 \]

B

SBP at 20% 1RM

\[ n = 57 \]
\[ r = -0.385 \]
\[ P = 0.002 \]

\[ Y = -1.43X + 170 \]

C

SBP at 40% 1RM

\[ n = 57 \]
\[ r = -0.457 \]
\[ P = 0.0003 \]

\[ Y = -1.87X + 187 \]
Figure 3 (Otsuki et al.)

A

**SBP (mmHg)**

ANOVA (Interaction)

* * P = 0.002

Rest 20% 40%

B

**DBP (mmHg)**

ANOVA (Interaction)

* * P = 0.01

Rest 20% 40%

C

**Heart rate (bpm)**

ANOVA (Interaction)

* P = 0.95

Rest 20% 40%
Figure 4 (Otsuki *et al.*).

ANOVA (Interaction)

Control

Training

Before

After

P = 0.03

P = 0.0005

baPWV (m/s)