European Journal of Sport Science

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tejs20

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Publisher: Taylor & Francis & European College of Sport Science
Journal: *European Journal of Sport Science*
DOI: 10.1080/17461391.2020.1817153

Music attenuates a widened central pulse pressure caused by resistance exercise: a randomized, single-blinded, sham-controlled, crossover study

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Abstract

Increasing central blood pressure is an independent predictor of cardiovascular disease and is an acute effect of high-intensity resistance exercise. It has been shown that classical music suppresses increased peripheral pressure during exercise. We hypothesized that classical music would suppress increased central pressure induced by high-intensity resistance exercise. To confirm this hypothesis, we examined the effect of classical music on central pressure following high-intensity resistance exercise in 18 young men. A randomized, single-blinded, sham-controlled, crossover trial was conducted under parallel experimental conditions on four separate days. The order of experiments was randomized between sham control (seated rest), music (20-min classical music track compilation), resistance exercise (5 sets of 10 repetitions at 75% of 1 repetition maximum), and resistance exercise with music conditions. Aortic pressure was measured in all subjects. No significant interaction between time, music, and resistance exercise was observed for aortic systolic pressure and diastolic pressure. In contrast, aortic pulse pressure showed a significant interaction; that is, aortic pulse pressure significantly widened after resistance exercise, whereas music significantly attenuated this widening. No significant change was observed in aortic pulse pressure in sham control and music conditions. The present findings suggest that music attenuates resistance exercise-induced increase in central pressure.

Keywords: environment**,** classical music, bicep curls, pulsatile pressure, central hemodynamics

Introduction

The guidelines of the American College of Sports Medicine (ACSM) and American Heart Association (AHA) recommend performing regular resistance exercise (Garber et al. 2011; Williams et al. 2007), because regular resistance exercise can provide an effective method for improving muscular function, preventing and managing a variety of chronic medical conditions, and enhancing psychosocial well-being. Habitual resistance exercise can substantially improve some health-related factors such as muscle strength, bone mineral density, fasting plasma glucose, triglycerides, and insulin sensitivity (Bemben and Bemben 2011; Jorge et al. 2011; Mitchell et al. 2014). Hence, resistance exercise is an important form of exercise for the maintenance and improvement of health. Nevertheless, a single-bout of high-intensity resistance exercise (i.e., greater than or equal to 75% 1-repetition maximum [1RM]) can increase central blood pressure (DeVan et al. 2005). DeVan et al. demonstrated that a single-bout of high-intensity resistance exercise (75% 1RM to failure) increased central systolic blood pressure at immediate post, and central pulse pressure (PP) at immediate post and 30 min post. Regular high-intensity resistance exercise can also increase central blood pressure (Bertovic et al. 1999; Kawano et al. 2008). Therefore, regular high-intensity resistance exercise-induced increased central pressure may be due to the chronic effects of repeated single bouts of high-intensity resistance exercise. Blood pressure is a major risk factor for cardiovascular disease (Vlachopoulos et al. 2010); importantly, central pressure is a better predictor of cardiovascular outcomes than brachial pressure (Roman et al. 2007; Safar et al. 2002). Thus, developing a prophylaxis for high-intensity resistance exercise-induced elevations of central blood pressure would be beneficial.

Central blood pressure is closely associated with aortic stiffness and augmentation index (AIx) (Vlachopoulos et al. 2010). The stiffened arterial tree elicits an increase in central blood pressure (Nichols et al. 2011). Also, AIx is the ratio of aortic late systolic pressure to aortic PP and reflects left ventricular afterload (Hashimoto et al. 2008). When the researchers investigate the effect of exercise on central blood pressure, it should be exhaustively investigated the relationships between exercise and central hemodynamics.

Recently, music has been increasingly used as a therapeutic tool in the treatment of patients with Parkinson or stroke diseases (Bernatzky et al. 2004; Särkämö et al. 2008). In addition, it has been reported that music ameliorates arterial elastic properties and left ventricular afterload (Vlachopoulos et al. 2015). Classical music does not induce acute changes in blood pressure (peripheral and central), but it decreases aortic stiffness and AIx (Vlachopoulos et al. 2015). Based on this report, it has been suggested that classical music can improve central hemodynamics (except blood pressure). However, Szmedra and Bacharach (1998) reported that classical music suppresses increased brachial systolic blood pressure during exercise (treadmill running), but not diastolic blood pressure. Therefore, classical music might suppress the elevated central pulsatile pressure induced by exercise, despite an absence of a similar effect on the central pressure during no exercise.

Accordingly, the working hypothesis was that classical music would restrain high-intensity resistance exercise-induced elevations of central systolic pressure and PP, but not diastolic pressure. The secondary hypothesis was that suppressions in increased central PP by resistance exercise with classical music would be mediated by incident pressure wave height, a surrogate marker of forward propagating wave. To test these hypotheses, we examined the effect of classical music on central hemodynamics following high-intensity resistance exercise. The present study aimed to explore whether classical music reduces high-intensity resistance exercise-induced elevation of central pressure.

Materials and methods

Subjects

This trial was a single-center study organized at a site in Tsukuba, Ibaraki, Japan. We studied 18 healthy young men (age, 22–33 years) on five separate sessions (four different experimental conditions plus strength-testing day). The exclusion criteria of the present study were as follows: (a) presence of overt diseases, (b) smoking, (c) medications, (d) women, (e) uses of anabolic steroids or others supplementation, (f) exercise-trained individuals (habitual exercise for the past 1 year), and (g) persons who listening to classical music on a daily basis. These exclusion criteria were assessed by questionnaires. All subjects gave informed consent and this study was approved by the Ethics Committee of the University of Tsukuba as approval number tai 30-6.

Sample size estimation

The sample size was calculated based on our previous study (Ra et al. 2018) that demonstrated the effect of supplement intake on brachial systolic pressure in healthy subjects with similar characteristics to the present study population. Many stimulus (e.g., supplement intake, combined exercise and supplement, and lifestyle modification) decrease central systolic pressure and/or PP in the same manner as brachial systolic pressure (Sugawara et al. 2012; Yang et al. 2019; Yoshikawa et al. 2018). Since we perceive an effect size (partial η^2) of 0.5 with a power of 0.80 and an α level of 0.05, a sample size of 11 subjects was estimated to be necessary. To provide a better confidence level, we decided to set a sample size of 18 subjects.

Experimental design

The present study was a randomized, single-blinded, sham-controlled, crossover design, and consisted of four arms (sham control, music, resistance exercise, and resistance exercise with music sessions). Because the purpose of the present study was to explore whether classical music reduces resistance exercise-induced increased central pressure, researchers were blinded to with or without listening to music and were unblinded to with or without performing to resistance exercise. Each subject visited our unit on five different occasions to eliminate possible carry-over effects; each session (except strength-testing day) was conducted at least two weeks apart from each other (Nosaka et al. 2003). Vascular measures were performed at the same time of day among four different experimental conditions to control for the potential influence of diurnal variation on the measures. The subjects listened to classical music (music and resistance exercise with music sessions), while during the sham control and resistance exercise sessions nothing was played back for the same amount of time.

At least one-week before the resistance exercise or resistance exercise with music sessions, bicep curls were used to test strength (in first session); for example, when resistance exercise session was performed prior to resistance exercise with music session, subjects underwent strength testing before resistance exercise session, but not resistance exercise with music session. In addition, all subjects performed resistance exercise (resistance exercise and resistance exercise with music sessions), whereas the sham control and music sessions were performed seated rest and listening to music for 20 min, respectively.

Figure S1 illustrates the experimental time-course in a schematic way. Subjects were asked to avoid any exercise 24 hours prior to testing. Subjects refrained from caffeine intake and fasted for at least 12 hours. All measurements were performed in a quiet room with a constant temperature of 24–26°C. Hemodynamics variables were collected in triplicate, and the average was used for data analysis. Baseline measurements for evaluating hemodynamics (peripheral and central) were taken after subjects had rested in a supine position for at least 50 min. Measurements were made immediately (for 10 min after end of each condition) and 30 min after each condition in the following conditions: sham control, music, resistance exercise, or resistance exercise with music. Each stimulus (i.e., sham control, resistance exercise, music, or combined resistance exercise and music) was for 20 min period. Also, age was assessed by questionnaires.

Measurements

Hemodynamics

Aortic pulse wave velocity (PWV) was measured between the carotid and femoral arteries to evaluate the aortic stiffness. The carotid and femoral arterial pressure waveforms were obtained by two applanation tonometry sensors; incorporating an array of 15 transducers (form PWV/ABI; Colin Medical Technology, Komaki, Japan). Aortic PWV was calculated by using the distance between the common carotid and femoral arteries recording sites divided by the transit time. The standardized aortic PWV was calculated to 80% of the direct distance between carotid and femoral arteries recording sites (Reference Values for Arterial Stiffness' Collaboration 2010; Van Bortel et al., 2012). Brachial blood pressure (systolic and diastolic blood pressure) and heart rate were measured using the oscillometric and electrocardiography (ECG) methods (form PWV/ABI; Colin Medical Technology, Komaki, Japan). Brachial blood pressure was measured to evaluate the peripheral blood pressure.

Aortic pulse waveforms were noninvasively estimated using an applanation tonometer and software to assess the central hemodynamics (including central blood pressure) (SphygmoCor, AtCor Medical, Sydney, Australia). Carotid pressure waveforms were transferred into aortic pressure waveforms with a generalized transfer function. The estimated aortic waveforms were calibrated by brachial mean arterial pressure and diastolic blood pressure. Aortic AIx was calculated as the ratio of aortic augmented pressure (AP) to aortic PP. Daily coefficients of variation were 4.3% ± 3.3% and 6.1% ± 4.3% for aortic PP and AIx (adjusted for heart rate of 75 bpm), respectively (Tagawa et al. 2019). Furthermore, the incident pressure wave height was calculated as the difference between the diastolic pressure and pressure at the first systolic peak. It is generated by the cardiac ejection and is nearly peak value during systole in healthy adolescents (Tagawa et al. 2019).

Strength testing

Bicep curls were used to test the maximal muscular strength before an experiment. All subjects performed a warm-up exercise comprising of 10 repetitions of lifting 5-kg weights. Thereafter, a 1RM was obtained based on the established guidelines (Baechle and Earle 2008). The eccentric and concentric contraction times of repetitions during the test were each performed for 3 sec. Daily coefficients of variation were 1.0% ± 1.8% for 1RM, as described in our previous study (Tagawa et al. 2018a).

Body composition

Height was measured to the nearest 0.1 cm by utilizing a stadiometer (AD-6227R, A&D Co., Ltd., Tokyo, Japan). Body mass, body mass index, body fat percentage, and lean body mass were measured to the nearest 0.1 kg by using a multi-frequency bioelectrical impedance device (InBody 770, InBody Japan, Tokyo, Japan). Daily coefficients of variation for the two trials were 0.1% ± 0.1%, 0.2% ± 0.1%, 0.5% ± 0.2%, 3.4% ± 2.7%, and 0.4% ± 0.4% for height, body mass, body mass index, body fat percentage, and lean body mass, respectively (Tagawa et al. 2018b).

Resistance exercise

Each subject performed a supervised resistance exercise (resistance exercise and resistance exercise with music sessions) in the form of bicep curls for 5 sets of 10 repetitions at 75% of 1RM with 2 min intervals, as described in our previous study (Tagawa et al. 2019). Resistance exercise lasted for about 20 min. The resistance exercise was performed until concentric failure, afterward remaining sets were completed with the support of assistants. Furthermore, when the concentric failure was no more than 8 repetitions, the load was decreased by approximately 5% in the next set. The exercise volume was calculated as following: exercise intensity × repetitions × 6 sec (3 sec eccentric and 3 sec concentric muscle contraction times). The exercise volume was evaluated in each set to obtain a total exercise volume value.

Music

Each subject listened to a 20-min compilation of classical music (music and resistance exercise with music sessions). List of tracks are (a) Badinerie - Bach: Suites for Orchestra "Suite No. 2 in B Minor, BWV 1067: IV. Bourrée II" by Camerata Romana, Eugen Duvier (1’30); (b) Ave Maria, D839 di Franz Schubert eseguito de Arthur Grumiaux and Istvan Hajdu (4’10); (c) Canone di Pachelbel - Stuttgart Chamber Orchestra (4’30); (d) Notturno in C n.21 di Chopin eseguito da Vladimir Ashkenazy

(3'00); (e) Adagio for organ and strings di Tomaso Albinoni - Stuttgart Chamber Orchestra (6'30), as described in previous report with minor modifications (Vlachopoulos et al. 2015). The music was played back through headphones (volume was preset to a comfortable level and was stable for all subjects).

Statistical analysis

All data were expressed as means ± SDs unless otherwise indicated. We examined the degree of normality by Shapiro–Wilk test. The difference between exercise volume values in resistance exercise and resistance exercise with music conditions was assessed by Wilcoxon signed-rank test. A three-way ANOVA with repeated measures (time [baseline and immediately and 30 min after]*resistance exercise*music) was used to analyze brachial (systolic, diastolic, and pulse pressure) and central (systolic and pulse pressure) blood pressure, heart rate, AP, AIx, incident pressure wave height, and PWV. When a significant interaction was observed, the simple main effects of time, resistance exercise, or music were determined. Univariate linear relationships between changes in continuous variables immediately and 30 min after resistance exercise with music condition were analyzed by Pearson's correlation coefficients (r). In all analyses, $P < 0.05$

was taken as statistically significant. Statistical analyses were conducted using SPSS software version 25.0 (IBM SPSS Japan Inc., Japan).

Results

Baseline characteristics of 18 subjects are presented in Table 1. The average values of age, height, body mass, body mass index, body fat percentage, lean body mass, and 1RM were 25 years, 172 cm, 70.6 kg, 23.7 kg·m^{-2}, 17.0 %, 58.4 kg, and 23 kg, respectively. Exercise volumes were not significantly different between resistance exercise and resistance exercise with music conditions (4812 ± 710 vs. 4877 ± 774 kg, P = 0.13).

Table 2 shows hemodynamics at baseline, immediately and 30 min after four experimental conditions. Although, brachial blood pressures (systolic and diastolic blood pressures), heart rate, and aortic systolic blood pressure showed significant effects of exercise (all $P < 0.05$), no significant interactions between the four different conditions were observed for these parameters (brachial systolic blood pressure: $P = 0.11$; brachial diastolic blood pressure: $P = 0.21$; heart rate: $P = 0.56$; aortic systolic blood pressure: $P = 0.24$). Three-way ANOVA showed a significant interaction for AP and AIx at 75 bpm and incident pressure wave height (all $P < 0.05$). AP ($P = 0.23$) and AIx ($P = 0.16$) did not significantly change following exercise in both resistance exercise conditions. In contrast, the incident pressure wave height significantly increased immediately and 30 min after resistance exercise (both $P < 0.05$), and music significantly suppressed these increases (both $P < 0.05$). Aortic PWV showed significant effect of exercise, but its interaction was not significant.

Figure 1 indicates the brachial and aortic PP in four separate sessions. There was a significant interaction with aortic PP (interaction: $F = 3.32$, $P < 0.05$, partial $\eta^2 = 0.16$; time effect: $F = 12.43$, $P < 0.05$, partial $\eta^2 = 0.42$; exercise effect: $F = 20.44$, $P < 0.05$, partial $\eta^2 = 0.55$; music effect: $F = 2.25$, $P = 0.15$, partial $\eta^2 = 0.12$). Aortic PP significantly widened immediately and 30 min after resistance exercise (both $P < 0.05$), conversely, music significantly attenuated the widening induced by resistance exercise (difference after exercise; $P < 0.05$). Similar to aortic PP, there was a significant interaction with brachial PP (interaction: $F = 4.55$, $P < 0.05$, partial $\eta^2 = 0.21$; time effect: $F = 46.15$, $P < 0.05$, partial $\eta^2 = 0.73$; exercise effect: $F = 176.09$, $P < 0.05$, partial $\eta^2 = 0.91$; music effect: $F = 2.57$, $P = 0.13$, partial $\eta^2 = 0.13$). Brachial PP significantly increased immediately and 30 min after resistance exercise (both $P < 0.05$), however music did not suppress brachial PP.

Figure 2 shows the correlation between changes in the incident pressure wave height and aortic PP in resistance exercise with music condition. Immediately and 30 min after resistance exercise with music, changes in aortic PP were significantly associated with not only the incident pressure wave height but also aortic systolic blood pressure (immediately after: $r = 0.92$, $P < 0.05$; 30 min after: $r = 0.83$, $P < 0.05$). In contrast, the relationship between changes in aortic PP and diastolic blood pressure was significant 30 min ($r = -0.50$, $P < 0.05$), but not immediately after resistance exercise with music ($r = -0.02$, $P = 0.95$). The changes in AP at 75 bpm and aortic PWV were not associated with those in the aortic PP immediately after (AP: $r = 0.21$, $P = 0.41$; aortic PWV: $r = -0.06$, $P = 0.81$) and 30 min after (AP: $r = -0.43$, $P = 0.07$; aortic PWV: $r = 0.07$, $P = 0.79$) resistance exercise with music.

Discussion

To explore whether classical music attenuates high-intensity resistance exercise-induced elevations in central pressure, the present randomized, single-blinded, sham-controlled, crossover study was implemented. Classical music did not significantly alter aortic PP (i.e., music condition), however, widened aortic PP following a single-bout of high-intensity resistance exercise was significantly reduced by the presence of classical music (listening to music during resistance exercise). The present findings suggest that classical music stimulus attenuates increased central pressure pulse induced by high-intensity resistance exercise. To the best of our knowledge, this study is the first to demonstrate the relationship between classical music and exercise-induced changes in central hemodynamics.

Central blood pressure is an independent predictor of cardiovascular morbidity and mortality (Vlachopoulos et al. 2010). It has been shown that a single bout of high-intensity resistance exercise increases central pressure (DeVan et al. 2005). Furthermore, habitual high-intensity resistance exercise induces an elevation of central pressure (Bertovic et al. 1999; Kawano et al. 2008). Hence, it is possible that regular high-intensity resistance exercise-induced increases in central pressure are due to the chronic effects of repeated single bouts high-intensity resistance exercise. However, a strategy for improving increasing central pressure caused by high-intensity resistance exercise has not been identified. Current study showed high-intensity resistance exercise elicits a widened central PP. This result was in good accordance with previous report (DeVan et al. 2005). We found that classical music significantly alleviated high-intensity resistance exercise-induced widened central PP. This result suggests that music suppresses the central pressure following high-intensity resistance exercise. Our results are beneficial for finding safer strategies to perform high-intensity resistance exercise.

It is proposed that the return of the reflected pressure wave is a contributor to changes in aortic blood pressure (Nichols et al. 2011). However, in exercise, augmentation of aortic blood pressure occurs almost exclusively by major increases in forward propagating waves. A single bout of exercise increases pulsatile pressure with an increased forward wave, but it does not change wave reflection (Schultz et al. 2013). Hence, it has been suggested that the forward wave determines an elevation in aortic pressure induced by exercise independent of wave reflection. In the current study, a single bout of high-intensity resistance exercise increased aortic PP and incident pressure wave height, and resistance exercise-induced widening of the aortic PP was associated with change in incident pressure wave height but not change in aortic AP, which is attributed to the reflected wave. These findings are in good accordance with logic circuit information by Schultz et al. (2013). In addition, classical music significantly attenuated the increased aortic pulsatile pressure and incident pressure wave height after high-intensity resistance exercise, there was a strong correlation between these changes. Thus, a regression in increased forward pressure wave induced by classical music may play a key role in determining aortic pulsatile pressure.

Cardiac work would explain the relationship between music and increased forward pressure wave following resistance exercise. Music is a powerful stimulus for modulating not only emotions but also moods (Baumgartner e t al. 2006), and slightly modulates regional cardiac work (Koelsch et al. 2007). Moreover, changed emotion with music tranquilizes regional cardiac work and cardiac autonomic nervous system via reduced neural activity in the hippocampal formation (Koelsch et al. 2007). Previous study has shown evidence that classical music attenuates the increases in rate of perceived exertion and double product (i.e., worsened emotion and increased cardiac work) during exercise (Szmedra and Bacharach 1998). Therefore, it is considered that a brain-heart relationship regulates the beneficial effect of music on excessive increase in forward pressure wave following resistance exercise. However, the present study did not measure rate of perceived exertion. Further studies are necessary to elucidate the role of emotion on the relationship between music and forward pressure wave after resistance exercise.

In contrast to aortic PP, classical music did not attenuate increased brachial PP with resistance exercise. This could be attributed to vascular endothelial function. Intriguingly, the previous studies have shown that a single bout of resistance exercise worsens vascular endothelial function in the brachial region (Choi et al. 2016), but not central region (Heffernan et al. 2017). Moreover, music (except joyful music) under resting conditions does not change vascular endothelial function (Miller et al. 2010). It is considered that effect of resistance exercise on vascular endothelial function is the difference between brachial and central, and classical music did not suppress increased brachial PP following resistance exercise because it may not improve vascular endothelial function.

Although guidelines of the ACSM and AHA recommend performing resistance exercise (Garber et al. 2011; Williams et al. 2007), a single-bout of high-intensity resistance exercise increases central pressure (DeVan et al. 2005). Our data suggest that classical music can significantly attenuate increasing central pressure induced by high-intensity resistance exercise. We propose that it is desirable to combine high-intensity resistance exercise with classical music to prevent cardiovascular disease. Future intervention studies are necessary to elucidate these chronic effects.

This study has multiple strengths and greater depth than other studies. First, this trial was a randomized, single-blinded, sham-controlled, crossover designed study. Second, an improvement strategy to attenuate increases in central pressure following resistance exercise has yet to be identified. Our findings suggest that classical music, a non-pharmacological approach, protects central hemodynamics from the effects of resistance exercise. Third, all subjects were healthy young men, who have no effects related to advancing age, disease, or estrogen. Investigating the effect of classical music on these excluded factors would help to understand the precise effect of classical music on changes in central pressure induced by resistance exercise.

In summary, our present study indicates that classical music did not change aortic PP. However, classical music reduced the widening of aortic PP following resistance exercise in young men. This demonstrates the benefits of classical music while performing high-intensity resistance exercise. Therefore, listening to classical music should be encouraged during high-intensity resistance exercise.

Author contributions

KT, YN, and SM contributed to the conception and design of the study. KT, AY, and TS performed the whole experiment and the acquisition and analysis of data. KT drafted the manuscript. YN, AY, TS, and SM revised the manuscript. All authors approved the final version of the manuscript.

Acknowledgments

We would like to thank Naoya Okabe for the technical assistance.

Grant

None.

Declaration of interest statement

None.

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Figure legends

Figure 1. Brachial (left) and aortic (right) PPs for four conditions determined using 3-way ANOVA. Three-way ANOVA revealed a significant interaction for both PPs. Data are presented as mean ± SE. **P* < 0.05 vs baseline (time effect at each condition); $^{\$}P < 0.05$ vs IA (recovery effect at each condition); $^{\#}P < 0.05$ vs C condition (exercise or music effect compared to sham control); $^{¶}P < 0.05$ vs M condition (combined effect [exercise and music] compared to music condition); $^{\dagger}P < 0.05$ vs RE condition (combined effect [exercise and music] compared to exercise condition).

Abbreviation: IA, immediately after; C, control; M, music; RE, resistance exercise; RE + M, resistance exercise with music; PP, pulse pressure.

Figure 2. The associations between changes in incident pressure wave height and aortic PP from baseline to immediately (left) and 30 min (right) after resistance exercise with music condition. The line in the scatter plots indicates a significant correlation determined using Pearson's correlation analysis.

Abbreviations: PP, pulse pressure.

Figure S1. All experimental time-course of each condition.

Table 1. Characteristics of selected subject

Variables	
Number of subjects	18
Age, years	25 ± 3
Height, cm	172 ± 7
Body mass, kg	70.6 ± 11.2
Body mass index, $kg \cdot m^{-2}$	23.7 ± 3.3
Body fat, %	17.0 ± 5.7
Lean body mass, kg	58.4 ± 8.4
1RM biceps curls, kg	23 ± 3

Note: Values are means ± SDs. 1RM indicates one repetition maximum.

Table 2. Hemodynamic variables for sham control, music, resistance exercise, and resistance exercise with music conditions

Variables	Condition	Baseline	IA	30 min	Three-way ANOVA			
					Time	Exercise	Music	Interaction
bSBP, mmHg	C	112 ± 7	115 ± 9	113 ± 10	*F* = 28.72	*F* = 31.37	*F* = 0.04	*F* = 2.40
	M	114 ± 7	116 ± 7	113 ± 8	*P* < 0.05	*P* < 0.05	*P* = 0.84	*P* = 0.11
	RE	115 ± 8	121 ± 10	116 ± 8				
	RE + M	113 ± 6	119 ± 8	117 ± 7				
bDBP, mmHg	C	64 ± 6	66 ± 8	65 ± 8	*F* = 0.42	*F* = 9.46	*F* = 0.50	*F* = 1.62
	M	65 ± 7	66 ± 7	66 ± 7	*P* = 0.66	*P* < 0.05	*P* = 0.49	*P* = 0.21
	RE	66 ± 8	64 ± 8	64 ± 6				
	RE + M	64 ± 6	62 ± 6	63 ± 6				
HR, bpm	C	55 ± 9	52 ± 10	53 ± 10	*F* = 9.71	*F* = 10.61	*F* = 0.02	*F* = 0.58

	M	54 ± 8	55 ± 11	52 ± 8	$P < 0.05$	$P < 0.05$	$P = 0.90$	$P = 0.56$
	RE	55 ± 7	60 ± 10	58 ± 8				
	RE + M	54 ± 8	61 ± 10	58 ± 10				
aSBP, mmHg	C	106 ± 11	107 ± 10	106 ± 10	$F = 10.51$	$F = 11.66$	$F = 2.09$	$F = 1.51$
	M	106 ± 10	108 ± 11	108 ± 11	$P < 0.05$	$P < 0.05$	$P = 0.17$	$P = 0.24$
	RE	106 ± 11	118 ± 11	114 ± 12				
	RE + M	106 ± 9	111 ± 13	110 ± 10				
AP, mmHg	C	-4 ± 7	-2 ± 6*	-2 ± 5	$F = 0.13$	$F = 1.59$	$F = 0.92$	$F = 4.78$
	M	-3 ± 6	-3 ± 7	-2 ± 7	$P = 0.88$	$P = 0.23$	$P = 0.35$	$P < 0.05$
	RE	-3 ± 6	-4 ± 7	-4 ± 7				
	RE + M	-4 ± 6	-3 ± 5	-3 ± 7				

AIx, %	C	-7 ± 14	-4 ± 14	-4 ± 12	F = 0.19	F = 2.25	F = 0.48	F = 3.93
	M	-4 ± 12	-4 ± 12	-3 ± 13	P = 0.83	P = 0.16	P = 0.50	P < 0.05
	RE	-4 ± 13#	-6 ± 12	-6 ± 12				
	RE + M	-8 ± 12†	-6 ± 10	-6 ± 12				
IWH, mmHg	C	40 ± 12	37 ± 11	39 ± 9	F = 11.85	F = 30.97	F = 2.90	F = 5.24
	M	38 ± 12	39 ± 13	39 ± 13	P < 0.05	P < 0.05	P = 0.11	P < 0.05
	RE	37 ± 12	52 ± 12*#	48 ± 12*#				
	RE + M	40 ± 12	46 ± 12*¶†	44 ± 12†				
aPWV, m/sec	C	7.1 ± 0.9	7.3 ± 1.1	7.1 ± 0.9	F = 8.95	F = 9.87	F = 0.19	F = 0.73
	M	7.2 ± 0.8	7.3 ± 0.8	7.1 ± 0.8	P < 0.05	P < 0.05	P =	P = 0.49

				0.67
RE	7.3 ± 1.1	7.8 ± 1.1	7.5 ± 0.8	
RE + M	7.2 ± 0.7	7.7 ± 1.2	7.5 ± 0.9	

Note: Values are means ± SDs. C, sham control; M, music; RE, resistance exercise; RE + M, resistance exercise with music; b, brachial; a, aortic; IA, immediately after; SBP, systolic blood pressure; DBP, diastolic blood pressure; HR, heart rate; AP, augmented pressure adjusted for heart rate; AIx, augmentation index adjusted for heart rate; IWH, incident pressure wave height (P_{1h}); PWV, pulse wave velocity. **P* < 0.05 vs baseline; #*P* < 0.05 vs control condition; ¶*P* < 0.05 vs music condition; †*P* < 0.05 vs resistance exercise condition.

Figure 1

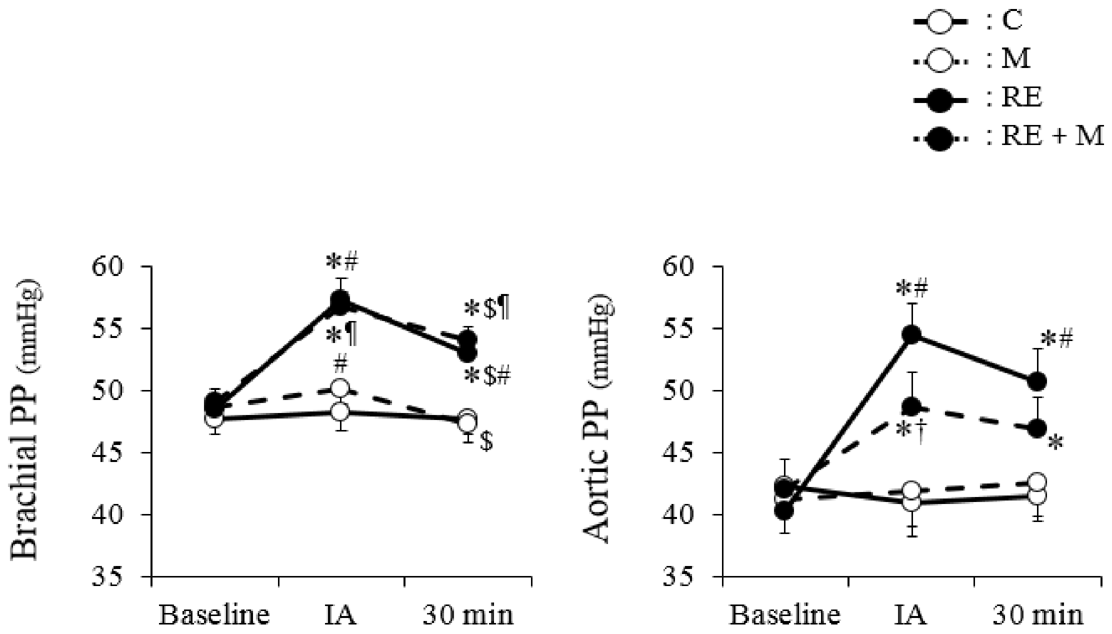

: C
: M
: RE
: RE + M
Brachial PP (mmHg)
60
55
50
45
40
35
Baseline
IA
30 min
*#
*$¶
*¶
#
*$#
$
Aortic PP (mmHg)
*#
*#
*†
*

Figure 2

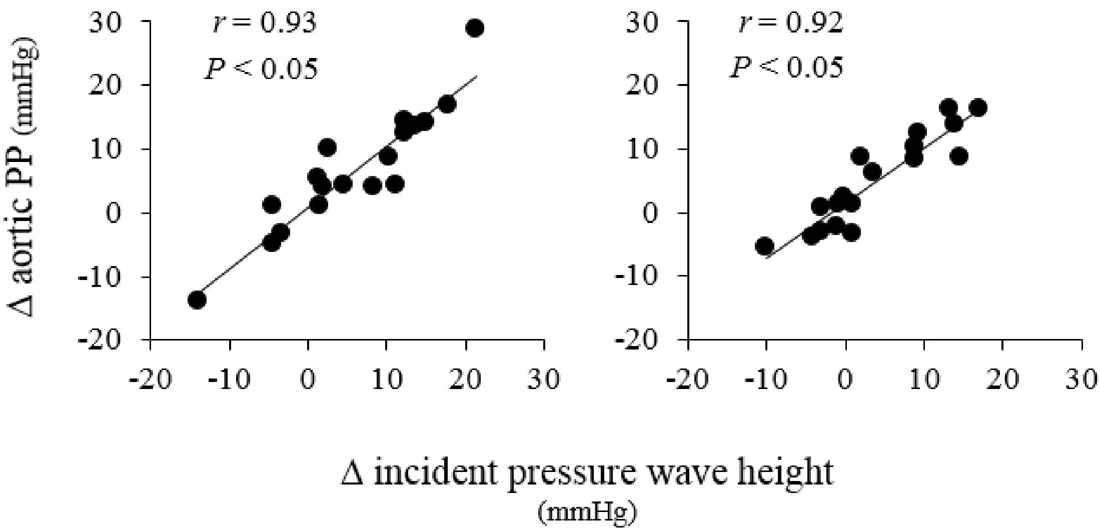
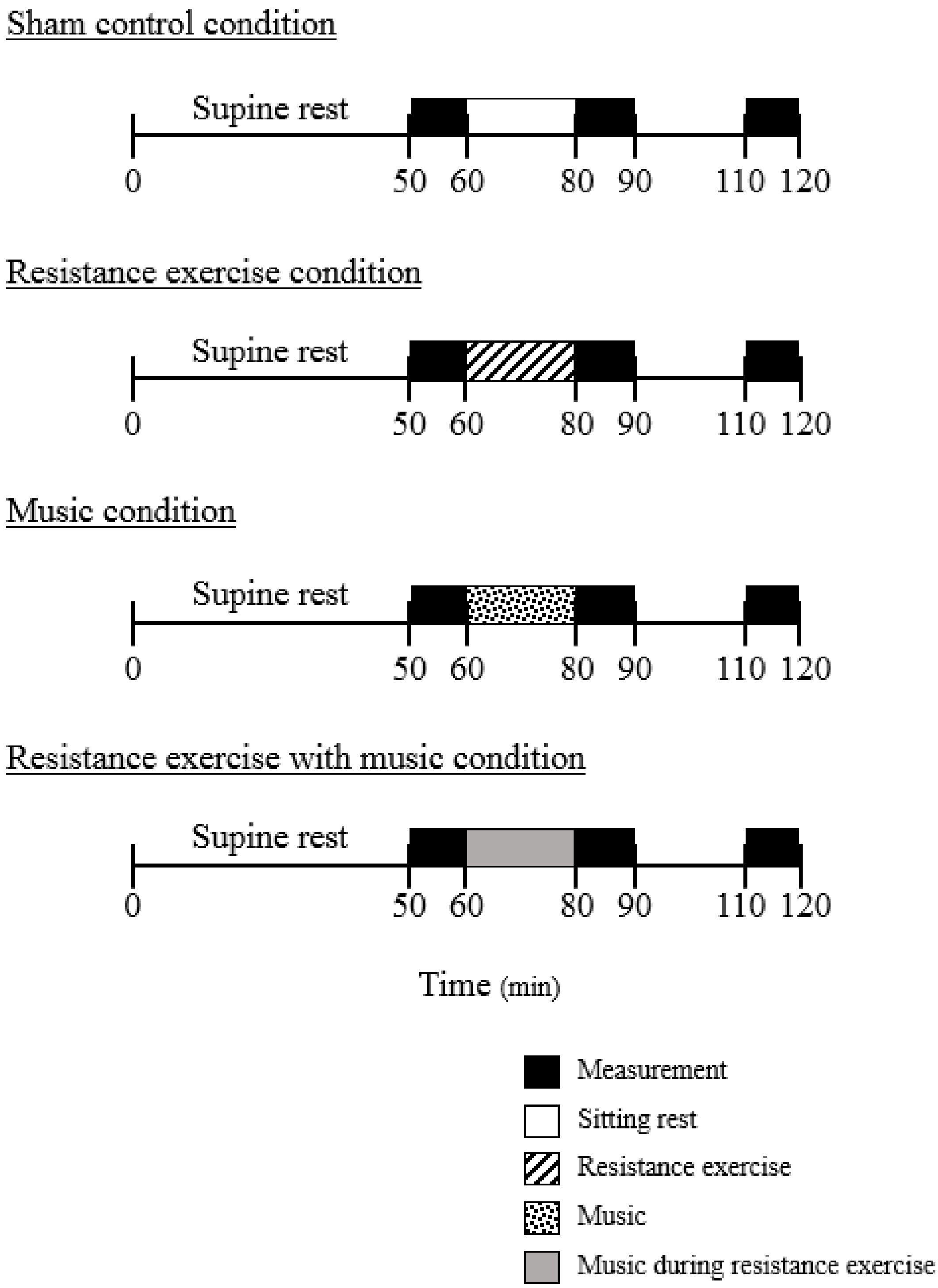

30
20
10
0
-10
-20
-20 -10 0 10 20 30
r = 0.93
P < 0.05
Δ aortic PP (mmHg)
r = 0.92
P < 0.05
Δ incident pressure wave height
(mmHg)

Figure S1


Sham control condition
Supine rest
0
50 60
80 90
110 120
Resistance exercise condition
Supine rest
0
50 60
80 90
110 120
Music condition
Supine rest
0
50 60
80 90
110 120
Resistance exercise with music condition
Supine rest
0
50 60
80 90
110 120
Time (min)
Measurement
Sitting rest
Resistance exercise
Music
Music during resistance exercise