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Sex Differences in Measures of Wave Reflection and Aortic Arterial Stiffness in Response to Weight Machine Resistance Exercise

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ABSTRACT

International Journal of Exercise Science 15(2): 1190-1201, 2022. While it has been demonstrated that acute resistance exercise (RE) alters measures of wave reflection and aortic arterial stiffness in young, healthy individuals, limited research has evaluated sex differences. Accordingly, we recruited moderately active, resistance-trained men (Age: 22 ± 3yrs, n=12) and women (23 ± 3yrs, n=10) to perform two randomized conditions consisting of an acute bout of weight machine RE or a quiet control (CON). Measures of aortic wave reflection and aortic stiffness were taken at baseline and 15 minutes following the RE (Recovery). At baseline, women had significantly higher heart rate ($p = 0.05$) and lower brachial systolic blood pressure ($p = 0.009$) compared to men. There were no significant three-way interactions for any variable. Significant condition by time interactions were noted for heart rate (Baseline: 65 ± 10bpm, Recovery: 87 ± 13bpm, $p = 0.001$), brachial systolic blood pressure (Baseline: 116 ± 9mmHg, Recovery: 123 ± 10mmHg, $p = 0.014$), and the augmentation index (AIx) normalized at 75bpm (Baseline: 7.7 ± 12.8%, Recovery: 15.5 ± 9.5%, $p = 0.002$) such that Recovery was augmented compared to Baseline following RE but not CON. There was also a significant main effect of time for augmentation pressure (Baseline: 4.1 ± 4.0mmHg, Recovery: 4.0 ± 3.6mmHg, $p = 0.04$) such that it decreased from Baseline to Recovery following RE but not the CON. There were no significant effects of sex, condition, or time on aortic arterial stiffness. Men and women have similar responses in measures of aortic wave reflection and aortic arterial stiffness following acute RE using weight machines.

KEY WORDS: Subendocardial viability index, pulse wave velocity, wasted left ventricular energy

INTRODUCTION

Increased aortic arterial stiffness has been shown to be an indicator of cardiovascular disease (CVD) (8). Increases in aortic arterial stiffness impairs the ability of the aorta to buffer pressure and thus contributes to increases in systolic blood pressure (SBP) as well as left ventricular hypertrophy (10). Aortic arterial stiffness can be measured non-invasively using carotid-femoral pulse wave velocity (cf-PWV) in which the transit time of the pressure wave is measured at the carotid and the femoral artery using a tonometer (27).

Measures of wave reflection including the augmentation index (AIx), the AIx at 75bpm (AIx@75), augmentation pressure (AP), and subendocardial viability ratio (SEVR) are measures that can be used to predict cardiovascular events and are superior to brachial blood pressure (BP) (22, 28). Collectively, alterations in these measures of wave reflection are risk factors for the development of CVD (22, 28). Measures of wave reflection such as the AIx and AP are a result of increases in arterial reservoir pressure, contraction and relaxation of the heart, and forward traveling waves in the aorta (3-5) while SEVR is an indirect measure of myocardial perfusion and left ventricular workload (2). Cardiovascular incidences increase in relation to increases in the AIx due to increases in left ventricular afterload and wasted left ventricular energy (ΔEw) (7, 8). Therefore, measurements of wave reflection can be used to noninvasively examine how the cardiovascular system may be impacted by an acute stressor.

Acute resistance exercise increases measures of wave reflection and aortic arterial stiffness in young, healthy individuals (11-13, 20, 30). These studies have demonstrated increases in AIx, AIx@75, SEVR, ΔEw, and cf-PWV for 10 min to 30 min post exercise, following acute resistance exercise using both free-weights and weight machines; the observed changes in pulse wave reflection and aortic stiffness were similar between exercise modalities. However, the majority of these particular studies were in men, with women included, but did not have sufficient power to evaluate sex differences. It has been suggested that young, healthy women have higher resting AIx than men (14-16) as well as augmented AIx@75 and ΔEw (10) with significantly reduced SEVR (18). The differences in wave reflection between the sexes may stem from estrogen as well as the shorter arterial tree in women. The short arterial tree may result in a faster HR, such that the reflected wave would return during, or closer to, diastole (14). In addition, work by Doonan et al. (2013) demonstrated that young, healthy women have reduced aortic arterial stiffness compared to men but this finding is not universal (6). However, to date, no studies have evaluated sex differences on measures of wave reflection and aortic arterial stiffness in response to acute resistance exercise using weight machines. Therefore, the purpose of this study was to examine sex-specific differences in measures of wave reflection and aortic arterial stiffness in response to acute resistance exercise using weight machines. It was hypothesized that at baseline women would have increased HR, brachial SBP, AIx, AIx@75, and ΔEw coupled with a decreased SEVR and aortic arterial stiffness compared to men. It was hypothesized that during recovery from acute resistance exercise both sexes would have increased AIx, AIx@75, ΔEw, and aortic arterial stiffness with reductions in SEVR compared to baseline and a non-exercise control (CON), with the men having elevated values for each variable compared to the women.

METHODS

Participants

Twenty-one young moderately active, resistance-trained individuals (11 men, 10 women) between the ages of 18-30 yrs volunteered to participate in the study and signed an informed consent prior to participating in the study. All individuals completed the Lipids Research Questionnaire and met the requirements of 'moderately active' using a four-point scoring system (1). Additionally, participants reported engaging in resistance training for at least 6 months. Exclusion criteria included any known cardiovascular, pulmonary or metabolic disease, obesity, hypertension (baseline blood pressure > 130/80 mmHg), medication use (sans birth control), recent infections, or orthopedic problems based on a Health History Questionnaire. All women were tested during the early to mid-follicular phase of their menstrual cycle based on the participant's last period (days 1-5). Apriori power calculations using previously published data on wave reflection and resistance exercise determined a range of Cohen's d from 1.19 - 2.01. With a power of 0.80, and an alpha of 0.05, this determined 8-10 participants per group were needed. This study was approved by the Kent State University IRB. This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (17).

Protocol

The present study was a randomized within-subjects cross-over design. Participants reported to the Cardiovascular Dynamics Laboratory a total of four times. During the first day participants were assessed for anthropometrics and maximal strength using the 1-repetition maximum (1RM). The second day was verification of the participants' 1RM. The third and fourth test days had the participants arrive at the laboratory between the hours of 7am and 10am to control for the circadian rhythm. All testing was completed by noon. Participants arrived at the laboratory having abstained from food for three hours, as well as caffeine, alcohol, and strenuous exercise for 24 hrs. Upon arriving at the laboratory, participants rested in the supine position for 10 min in a climate-controlled room. Following assessment of baseline BP, measures of wave reflection were completed. Participants then underwent an acute bout of resistance exercise using weight machines or a supine, time-matched control (CON). Recovery measurements were taken at 15 min following the acute resistance exercise or the CON. All measurements were made at the same time of day (±1 hr) for each participant. Each day was separated by a minimum of 72 hours. All participants were able to complete the study design.

Anthropometrics: Participant's height and weight were determined within 1cm and 0.1lb using a stadiometer and balance beam scale (HM210D, Charder, Taichung City, Taiwan). The weight was then converted to kg, and body mass index (BMI) was calculated (kg/m2).

One-repetition maximum: The 1RM was determined on the leg press, chest press, leg extension, lat pulldown, and leg curl. Participants completed a 5-min warmup on the cycle ergometer (Schwinn Air Dyne; Boulder, Colorado). The initial load for each resistance exercise machine was 50% of the participant's body weight. Participants were given 5 sets to determine the maximal load (1RM) applying 5% increases in load for the upper-body, and 10% increases for the lower-body. Proper breathing, and technique, were reinforced by certified professionals. Three minutes of rest was given between sets and exercises. The intraclass-correlations (ICC) in our laboratory quantifying the 1RM on two separate occasions on the chest press and leg extension were 0.97 and 0.98, respectively.

Brachial Artery Blood Pressure Assessment: Baseline and recovery measures of brachial BP were made using an automated oscillometric device (AtCor Medical, SphygmoCor EXCEL Technology, Sydney, Australia). At both time points BP was collected twice, with no difference >5mmHg between readings. If the reading was >5mmHg, a third one was taken. The BPs were then averaged.

Wave Reflection: Measures of wave reflection were assessed using a brachial cuff equipped with a strain gauge (SphygmoCor). From the brachial pressure waveform a generalized transfer function was used to generate a central pressure waveform (21). This waveform has been validated and has been shown to have a high reproducibility. The AIx was determined as the ratio of the amplitude of the pressure wave in relation to the systolic shoulder adjusted to pulse pressure (PP) (23, 24). AIx is expressed as a percentage and is directly related to the aortic pressure wave-reflection intensity. Since AIx is directly affected by HR (29), the AIx was normalized to a HR of 75pm (AIx@75). All measurements were assessed in duplicate and averaged for subsequent analysis. In our laboratory, the ICC measured at baseline for the AIx and AIx@75 on two separate days was 0.96 and 0.95, respectively.

In addition to the AIx and AIx@75, other variables were also derived from the aortic waveform. These include aortic systolic BP (ASBP), aortic diastolic BP (ADBP), travel time of the reflected wave (Tr), SEVR, and ΔEw. The Tr is derived from the speed of the reflected wave back to the original wave point. SEVR is indicative of myocardial oxygen supply and is derived from the systolic pressure time index (SPTI) and the diastolic time pressure index (DPTI). The ΔEw is indicative of myocardial work and can be calculated using 1.333 x AP [ventricular ejection duration – Tr] x π/4, such that 1.333 allows for the conversion of mmHg/s to dynes s/cm^2 (4).

Aortic Arterial Stiffness: Aortic arterial stiffness was determined using cf-PWV following the guidelines of the Clinical Application of Arterial Stiffness, Task Force III (27). A high-fidelity tonometer was used to applanate the right common carotid artery pressure waveform, with a blood pressure cuff on the right thigh to capture the femoral waveform (SyphgmoCor). The distance between the common carotid and femoral artery was determined using the subtraction method. This method requires a straight-line measurement from the carotid artery to the suprasternal notch, and from the suprasternal notch to the bifurcation of the femoral artery. The formula for determining cf-PWV was derived from the distances between measurements and the time delay between the proximal and distal pressure waveforms. All measurements were collected in duplicate, with no more than 0.1m/sec between measurements. The ICC for this variable based on two separate days was 0.98.

Acute Resistance Exercise: Following a 5-min warmup on a cycle ergometer participants completed three sets of 10 repetitions at 75% 1RM on the leg press, chest press, leg extension, lat pulldown, leg curl (Cybex, Medway MA, USA). Two minutes was allotted between sets and exercises. Proper technique and breathing was emphasized by certified professionals. Total volume was determined by sets x repetitions x load.

Statistical Analysis
Sex comparisons were made for all baseline data using independent sample t-tests. Prior to any analysis, a Kolmogorov-Smirnoff test of normality was used to assess normal distribution of all variables. Since all variables were normally distributed, a 2 x 2 x 3 repeated-measures analysis of variance (ANOVA) was used to determine the effects of sex (men and women) with the repeated factors of condition (acute resistance exercise and CON) and time (Baseline, 15 min during recovery). Post hoc analysis utilized a bonferonni correction. Partial eta squared ($\eta 2$) was used to determine effect size. Confidence intervals (CI) are presented for pairwise comparisons where appropriate. Significance was set apriori at $p \leq 0.05$. All statistical analyses were completed using IBM SPSS (Version 27, Armonk, NY, USA).

RESULTS

Baseline descriptive data of the participants are presented in Table 1. The sexes were similar for age (p = 0.84) but were significantly different for height (p = 0.001, CI: -0.23, -0.11) , weight (p = 0.001, CI: -32.1, -12.9), and BMI (p = 0.01, CI: -4.31, -0.56). The men were significantly (p = 0.001) stronger on all 1RMs and had a significantly (p = 0.001, CI: -7354.7, -4207.8) greater total volume compared to the women.

Table 1. Participant characteristics (n=21)

	Men (n=10)	Women (n=11)
Age, yrs	22 ± 3	23 ± 3
Height, m	1.79 ± 0.07	1.61 ± 0.07*
Weight, kg	83.0 ± 13.0	60.5 ± 7.0*
BMI, kg/m^2	25.5 ± 2.5	23.1 ± 1.4*
Leg Press 1RM, a.u.	385 ± 73	234 ± 38*
Chest Press 1RM, a.u.	260 ± 52	143 ± 44*
Leg Curl 1RM, a.u.	206 ± 34	105 ± 23*
Lat Pulldown 1RM, a.u.	317 ± 33	173 ± 28*
Leg Extension 1RM, a.u.	254 ± 63	158 ± 48*
Total Workload, a.u.	13813 ± 2146	8032 ± 1126*

1RM, one-repetition maximum; a.u., arbitrary units, BMI, body mass index. Data presented are mean ± SD. *p≤0.05, significantly different than men

Hemodynamics are presented in Table 2, and measures of wave reflection are presented in Table 3. There were no significant three-way interactions for hemodynamic or measures of wave reflection. At baseline the women had significantly higher HR (p = 0.05, CI: -1.46, 14.79) and a significantly lower brachial SBP (p = 0.009, CI: -16.83, -1.77). Significant condition by time interactions were noted for HR ($F_{1,19}$ = 21.7, p = 0.001, $\eta 2$ = 0.53), AP ($F1_{1,19}$ = 4.8, p = 0.04, $\eta 2$=0.20), AIx@75 ($F_{1,19}$ = 13.9, p = 0.002, $\eta 2$ = 0.44), ΔEw ($F_{1,19}$ = 6.8, p = 0.017, $\eta 2$ = 0.26), and SEVR ($F_{1,19}$ = 23.0, p = 0.001, $\eta 2$ = 0.55). HR, AIx@75, and SEVR significantly increased from Baseline to Recovery, following acute resistance exercise but not the CON. Augmentation pressure and ΔEw decreased during Recovery from the CON and was reduced compared to Baseline as well as was significantly lower than Recovery from the acute resistance exercise. There was also a main effect of time for brachial SBP ($F_{1,19}$ = 5.2, p = 0.034, $\eta 2$ = 0.27) such that it was not altered with the CON but increased from Baseline to Recovery following acute resistance exercise. There were no significant ($p > 0.05$) interactions or main effects for brachial DBP, ASBP, ADBP, or AIx.

Table 2. Heart rate and blood pressures after an acute bout of resistance exercise using weight machines between resistance-trained men (n=10) and women (n=11)

	Control		Acute Resistance Exercise	
	Baseline	**Recovery**	**Baseline**	**Recovery**
Heart Rate, bpm				
Men	59 ± 12	56 ± 13	61 ± 12	89 ± 15†¥
Women	63 ± 9*	72 ± 18	68 ± 7*	86 ± 11†¥
Brachial Systolic Blood Pressure, mmHg				
Men	125 ± 6	124±5	122 ± 8	127 ± 9†¥
Women	114 ± 6*	115±8	111 ± 7*	118 ± 9†¥
Brachial Diastolic Blood Pressure, mmHg				
Men	68 ± 6	68 ± 4	68 ± 6	64 ± 6
Women	70 ± 5	71 ± 6	69 ± 5	69 ± 6
Aortic Systolic Blood Pressure, mmHg				
Men	108 ± 6	107 ± 3	106 ± 7	109 ± 7
Women	102 ± 6	102 ± 7	99 ± 7	103 ± 7
Aortic Diastolic Blood Pressure, mmHg				
Men	69 ± 6	69 ± 5	69 ± 6	66 ± 6
Women	71 ± 5	72 ± 6	70 ± 5	71 ± 6
Augmentation Pressure, mmHg				
Men	3.8 ± 4.0	2.0 ± 2.8†	3.4 ± 3.1	5.1 ± 4.2¥
Women	3.9 ± 2.9	2.1 ± 3.1†	4.7 ± 4.7	3.0 ± 2.5¥

Data presented are mean ± SD. *≤0.05, significantly different between sexes, †p≤0.05, significantly different than Baseline, ¥p≤0.05, different than Control

Aortic arterial stiffness is presented in Table 3. There was no significant three-way interaction ($p > 0.05$) for arterial stiffness. There were also no significant condition by time interactions ($F_{1,19} = 4.0$, $p = 0.06$, $\eta 2 = 0.48$) or main effects.

DISCUSSION

The present study suggests that at baseline women have higher baseline HR and lower baseline brachial SBP with no sex-specific differences in baseline measures of wave reflection or aortic arterial stiffness. In addition, during recovery from acute resistance exercise using weight machines there are increases in hemodynamics such as heart rate and brachial systolic blood pressure, increases in measures of wave reflection as measured by AIx@75, decreases in myocardial perfusion, and no changes in aortic arterial stiffness, regardless of sex. These data demonstrate that the sexes were similar at baseline for many wave reflection variables, that both sexes responded the same to the acute resistance exercise, and that there are significant alterations during recovery from acute resistance exercise using weight machines that resulted in augmented stress on the left ventricle.

The data from the present study demonstrated differences in baseline HR and baseline brachial SBP between the sexes. Specifically, women had significantly higher baseline HR and significantly reduced baseline brachial SBP compared to men. However, the present study did not have significant differences between the sexes for measures of wave reflection. This is in contrast to some of the studies that have been published and our hypothesis (18, 19) but not all (25). Doonan et al. (2013) reported no differences in baseline HR between the sexes but did note significantly lower baseline brachial systolic and diastolic BP, ASBP, ADBP, AIx@75, with augmented SEVR and cf-PWV in young women compared to age-matched men (6). McEinery et al. (2005) demonstrated that women 20-29 yrs of age have lower brachial systolic BP, ASBP and Tr but had significantly augmented AP and HR compared to age-matched men (16). Both of these studies partially support the findings of the present study. While the sexes were similar for measures of wave reflection at baseline in the present study, it has been demonstrated that the shorter average height between men and women may explain why previous studies have reported differences in AIx and AIx@75, due to close proximity between the heart and wave reflection site. However, work by McEniery et al. (2005) determined that sex remained a strong independent predictor for AIx, even after correcting AIx for height (16). In contrast, this similar adjustment for height often removes the significant finding (18, 26).

Table 3. Measures of wave reflection and arterial stiffness after an acute bout of resistance exercise using weight machines between resistance-trained men (n=10) and women (n=11)

	Control		Acute Resistance Exercise	
Augmentation Index, %				
Men	114.9 ± 6.1	110.4 ± 5.0	113.5 ± 6.0	114.6 ± 5.9
Women	117.2 ± 7.0	113.1 ± 7.4	119.4 ± 9.8	113.9 ± 5.6
Augmentation Index@75bpm, %				
Men	4.7 ± 9.4	-2.1 ± 7.7	5.1 ± 8.6	18.9 ± 11.3†¥
Women	9.1 ± 11.8	6.4 ± 17.2	9.8 ± 15.5	12.7 ± 7.1†¥
SEVR, %				
Men	153.5 ± 35.2	165.2 ± 43.5	146.2 ± 26.8	85.9 ± 39.3†¥
Women	146.8 ± 12.7	131.2 ± 42.6	135.7 ± 12.7	91.2 ± 26.4†¥
Tr, ms				
Men	149.3 ± 6.5	151.7 ± 5.5	148.9 ± 6.8	150.0 ± 4.8
Women	147.0 ± 4.3	148.5 ± 6.4	145.2 ± 4.0	147.4 ± 5.2
ΔEw, dynes s/cm²				
Men	1068 ± 896	443 ± 636†	707 ± 636	1067 ± 912¥
Women	848 ± 578	354 ± 513†	964 ± 917	642 ± 606¥
Cf-PWV, m/s				
Men	5.6 ± 0.6	5.7 ± 0.6	5.7 ± 0.9	6.1 ± 0.8
Women	5.8 ± 0.9	5.8 ± 0.9	5.9 ± 0.7	6.3 ± 1.0

ΔEw, wasted left ventricular energy; Cf-PWV, carotid-femoral pulse wave velocity; SEVR, subendocardial viability ratio; Tr, time of the reflected wave. Data presented are mean ± SD. *≤0.05, significantly different between sexes, †p≤0.05, significantly different than Baseline, ¥p≤0.05, different than Control

Collectively, the current study and work by Doonan et al. (2013) and McEniery et al. (2005) demonstrate that young women have increased HR and reduced brachial SBP compared to age-matched men at baseline (6, 16). The mixed results for the other measures of wave reflection and aortic arterial stiffness in the literature limit the understanding regarding differences between the sexes at baseline. The differences in the literature may be attributed to a number of factors, one of them being physical activity status. In the present study the participants met the criteria for moderately active. Other data using resistance-trained individuals have demonstrated no differences in baseline measures of wave reflection or aortic arterial stiffness between the sexes (25). It is clear that more data are needed to understand if sex differences exist in young, healthy men and women.

There were no differences in aortic arterial stiffness between the sexes at baseline which is in alignment with our hypothesis. McEniery et al. (2005) reported no differences in cf-PWV between the sexes at baseline in young, healthy men and women (16). Doonan et al. (2013) reported differences in cf-PWV in men and women after adjusting for BMI, but not without (6). Collectively, the data suggest that there are no sex differences in aortic arterial stiffness.

The present study demonstrated no change in AIx following acute resistance exercise, which was contrary to our hypothesis. However, the present study did demonstrate significant increases in AIx@75. This supports previous findings that increases in AIx may not be related to changes in HR, contrary to work from Wilkinson et al. (2000) (29). The increase in AIx@75 is supported by previous work using acute resistance exercise (20, 30). It has been postulated that the changes in AIx@75 are mediated by early return of the reflected wave. Similar to previously published data by Parks et al. (2020) that also collected data in the supine position, the present study reported a decrease in AP and ΔEw in the during Recovery from the CON with no change following the acute resistance exercise (20). An additional study also utilized a supine control reported no alterations in AP or ΔEw (14).

Reduced myocardial perfusion in response to acute resistance exercise has been reported previously and these changes were in agreement with our hypothesis. In the present study both sexes had reductions in SEVR following the acute resistance exercise; the men's SEVR was reduced by 41.2% while the women's SEVR was reduced by 32.8%. Parks et al. (2020) demonstrated that acute resistance exercise using weight machines significantly reduced myocardial perfusion quantified via SEVR by ~39% using both men and women, which is in alignment with the present study (20). In the present study and the work by Parks et al. (2020) there were increases in HR which resulted in a greater amount of time of the heart in systole compared to diastole (20). Myocardial perfusion occurs during diastole as systole increases compression of the vasculature and limits coronary blood flow (9). Based on the findings of the present and work by Parks et al. (2020) acute resistance exercise using weight machines results in a transient reduction in coronary blood flow (20). In turn, this may have implications for cardiovascular complications and may concomitantly increase the risk of experiencing a cardiovascular event, albeit acutely.

There were no changes in aortic arterial stiffness in response to acute resistance exercise using weight machines. This was contrary to our hypothesis and is not supported by the literature.

	Doonan, et al. (2013)	Heffernan, et al. (2007)	Kingsley, et al. (2016)	Kingsley, et al. (2017)	Lieber, et al. (2010)	Parks, et al. (2020)	Seeland, et al. (2020)	McEniery, et al. (2005)	Shim, et al. (2011)	Yoon, et al. (2010)
Subject N										
Men	67	13	11	14	72	32	590	178	79	13
Women	55	--	5	12	51		400	101	79	
Subject Age, years										
Men	24.4±6.2	--	23±3	--	60±12	--	22-35; 60-82	20-29	58±10	20.8±2.2
Women	23.7±4.8	--		--	56±14		22-35; 60-82	20-29	58±10	
Heart Rate, bpm										
Men	n.s.	--	sig. aug‡	sig. aug‡	70±11	sig. aug.‡	--	68±12	67±11	sig. aug.‡
Women	n.s.	--		sig. aug‡	75±11*‡		--	73±13*‡	65±10	
Brachial Systolic Blood Pressure, mmHg										
Men	--	--	--	n.s.	157±26	--	--	123±9	129±16	n.s.
Women	--	--	--	n.s.	159±31	--	--	115±12*‡	130±18	
Brachial Diastolic Blood Pressure, mmHg										
Men	--	--	--	n.s.‡	95±15‡	--	--	75±8‡	78±10‡	n.s.‡
Women	--	--	--	n.s.‡	94±16‡	--	--	73±8‡	77±11‡	
Aortic Systolic Blood Pressure, mmHg										
Men	n.s.‡	--	--	n.s.‡	143±24	sig. aug.‡	--	105±8	119±16	n.s.‡
Women	n.s.‡	--	--	n.s.‡	148±30‡		--	101±9*	123±18‡	
Aortic Diastolic Blood Pressure, mmHg										
Men	sig. aug.	--	--	n.s.‡	--	--	--	--	79±11	n.s.‡
Women	sig. aug*	--	--	n.s.‡	--	--	--	--	78±11‡	
Augmentation Pressure, mmHg										
Men	--	--	--	sig. aug.	--	--	--	1±4	10.3±5.1	--
Women	--	--	--	sig. aug.	--	--	--	3±4*	16.5±7.9*	--
Augmentation Index, %										
Men	--	--	--	sig. aug.	21.5±13.0	--	sig. aug. with age	2±11‡	25.1±9.8	n.s.‡
Women	--	--	--	sig. aug.	28.3±15.9*	--	sig. aug. with age*	9±14*	34.7±10.0*	
Augmentation Index@75bpm, %										
Men	sig. aug.‡	--	--	sig. aug.‡	--	sig. aug.‡	--	--	21.3±8.7	sig. aug.‡
Women	sig. aug.*‡	--	--	sig. aug.‡	--		--	--	28.7±10.0*	
SEVR, %										
Men	sig. dec.‡	--	--	sig. dec.‡	--	sig. dec.‡	--	--	--	--
Women	sig. dec.*‡	--	--	sig. dec.‡	--		--	--	--	--
Tr, ms										
Men	--	--	--	--	--	--	--	151±21	--	--
Women	--	--	--	--	--	--	--	140±16*	--	--
ΔEw, dynes s/cm²										
Men	--	--	--	--	--	--	--	--	--	--
Women	--	--	--	--	--	--	--	--	--	--

Cf-PWV, m/s										
Men	sig. aug.	sig. aug.	sig. aug.	--	13.07±2.77	sig. aug.	sig. aug. with age	--	8.1±2.0	sig. aug.
Women	sig. aug.*	--		--	12.34±2.80		sig. aug. with age	--	8.0±2.0	

Table 4. Results of previous research discussed in comparison to results of the present study
n.s., not significantly different from baseline ($p > 0.05$); sig. aug., significantly augmented following exercise ($p \leq 0.05$); sig. dec., significantly decreased following exercise ($p \leq 0.05$); sig. aug. with age, significantly augmented with age ($p \leq 0.05$). Data presented are mean ± SD. *$p \leq 0.05$, significantly different than men. ‡ in support of the present study

Parks et al. (2020) demonstrated that acute resistance exercise using weight machines increases aortic arterial stiffness measured via cf-PWV (20). Using a mixture of weight machines and free weights an increase in cf-PWV was also reported by other researchers (11, 30). Similar to AIx, these changes in aortic arterial stiffness appear to be transient, with most data showing that it returns to baseline levels within an hour after acute resistance exercise (20, 30). All comparisons between the present study and past research discussed are presented in Table 4.

There are some limitations to the present study. While we controlled for the menstrual cycle, we did not quantify hormone levels. While the sample size of the present study appears to be small, the needs of our power equation were met. The present study did not inquire regarding specifics of the participants' physical activity modality. The present study can only speculate on how chronic resistance training may affect the vasculature.

In conclusion, the present study demonstrates that young, healthy women have higher baseline HRs coupled with decreased brachial SBP compared to age-matched men. Wave reflection data suggest that acute resistance exercise using weight machines lowers myocardial perfusion and increases aortic arterial stiffness for at least 15-20 min after the acute bout of resistance has finished, with the similar responses between the sexes. These data further demonstrate that acute resistance exercise has a profound effect on the heart and vasculature, and that more data are needed. More research is needed to further investigate the sex differences in response to acute resistance exercise as well as chronic alterations.

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