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ACUTE CARDIOVASCULAR RESPONSES TO NOVEL COMBINATIONS OF RESISTANCE AND AEROBIC EXERCISE

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ACUTE CARDIOVASCULAR RESPONSES TO NOVEL COMBINATIONS OF
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Table of Contents

List of figures

List of tables

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List of abbreviations

aDAP   aortic diastolic arterial pressure

AIx   aortic augmentation index

AIx@75   aortic augmentation index normalized to 75 beats/min

aMAP   aortic mean arterial pressure

aPP   aortic pulse pressure

aSAP   aortic systolic arterial pressure

BMI   body mass index

DAP   diastolic arterial pressure

HR   heart rate

MAP   mean arterial pressure

PL   pulsatile load

PP   pulse pressure

PWA   pulse wave analysis

PWV   pulse wave velocity

SAP   systolic arterial pressure

Abstract

Cardiovascular disease (CVD) is the leading cause of death globally. One of the most effective forms of prevention and treatment is physical activity. However, recent studies have suggested that resistance exercise can increase arterial stiffness. Maintaining adequate strength is critical for performing activities of daily living, occupational-related tasks, and sport movements. The purpose of this project was to determine if novel combinations of resistance and aerobic exercise could offer musculoskeletal benefits without adverse cardiovascular consequences. In **Study 1**, we examined the effect of order (i.e. aerobic before resistance, or resistance before aerobic) on arterial stiffness when combining these exercise modes in a single training session. In **Study 2**, we compared the effects of acute eccentric and concentric arm cycling on central and peripheral arterial stiffness. Eccentric arm cycling is a unique combination of resistance and aerobic exercise. We hypothesized that these novel combinations of resistance and aerobic exercise would not cause arterial stiffening as observed in resistance exercise alone. In **Study 1**, we concluded performing resistance before aerobic to be the more beneficial exercise order in terms of arterial stiffness. In **Study 2**, we found that eccentric arm cycling reduces arterial stiffness in the arm, but not centrally. Collectively, our results suggest that the key to reducing the negative effects of resistance exercise on arterial function is to combine it with aerobic exercise, either first within a single session or simultaneously.

1 Literature Review

The literature review of this thesis will provide a general framework to better understand the effects of combined resistance and aerobic exercise on arterial function. First, an overview of cardiovascular health will provide context to the burden of cardiovascular disease and the importance of preventative behaviors. Then, the utility of arterial stiffness an indicator of cardiovascular health will be defined. Additionally, specific measurement techniques used to assess arterial stiffness will be explained. The cardiovascular responses, with an emphasis on arterial stiffness, to different exercise modalities (aerobic, resistance, eccentric, and concentric) will be discussed. Finally, the current literature will be summarized in relation to the two presented research studies.

1.1 Cardiovascular Health

Cardiovascular disease (CVD) one of the largest health and economic burdens around the world (Mozaffarian et al., 2015). There are a variety of risk factors that influence the prevalence of CVD, such as: physical inactivity, hypertension, obesity, high blood lipids, diabetes mellitus, and family history (Mozaffarian et al., 2015). Although many agencies are working to reduce the prevalence of CVD, it only reduced modestly between 1999 and 2012 (Booth et al., 2017).

Increased physical activity is one behavioral modification that can be used to prevent CVD. Physical activity is associated with reducing the risk of CVD and all-cause mortality by nearly a third (Nocon et al., 2008). Physical activity and exercise can improve body composition and reduce other risk factors, such as blood pressure. This may be attributed to positive adaptations within the cardiovascular system, specifically changes to the

vasculature. Improvements in endothelium function and vascular remodeling have been observed following exercise training (Green, Maiorana, O'Driscoll, & Taylor, 2004), which can reduce stiffening of arteries.

1.2 Arterial Stiffness

Arterial stiffness occurs when arteries lose their ability to expand and recoil during the cardiac cycle. Degradation of the elastic fibers occurs naturally through aging, but other factors can either slow or quicken the process. Although there are genetic factors, lifestyle and pathologies (i.e. hypertension, diabetes mellitus, etc.) often contribute to arterial stiffness (Zieman, Melenovsky, & Kass, 2005). This can cause reflected pressure waveforms from bifurcations in the vasculature to return to the heart early, which then augments aortic blood pressure and potentially induces damage.

1.2.1 Measurement Techniques

Arterial stiffness can be assessed noninvasively through applanation tonometry in clinical and research settings. This technique involves placing a small pressure transducer onto a pulse site. The blood vessel is flattened against hard underlying tissue and the pressure waveform at the site is recorded. Pulse wave analysis (PWA) and pulse wave velocities (PWV) can be measured using this technique.

The process of PWA includes estimating aortic pulse pressures based on the measured pressure waveform characteristics and a validated transfer function (Chen et al., 1997). Augmentation index (AIx) can also be calculated by determining the percentage of aortic pulse pressure that is caused by a reflected waveform returning to the heart. AIx has

been shown to be directly related to arterial stiffness (Laurent et al., 2006). Heart rate can influence the value of AIx, therefore, it is best practice to normalize for the heart rate of 75 beats per minute (AIx@75). Higher values of AIx@75 indicate increased systemic arterial stiffness.

Arterial stiffness can also be assessed regionally using PWV. The process includes measuring two different pulse sites along region of interest (e.g. carotid and radial to assess the arm) and measuring their transit time by gating them to the R-wave of an electrocardiogram. Higher values of pulse wave velocity indicate increased arterial stiffness within that region.

Although AIx and PWV are valuable measures of arterial stiffness, they are not interchangeable. One can be affected independently of the other (Kelly, Millasseau, Ritter, & Chowienczyk, 2001). AIx is influenced by integrity of smaller vasculature, whereas PWV is primarily a result of the elasticity of large arteries (Kelly et al., 2001). Measures of AIx and PWV can be taken at rest or pre and post interventions (e.g. exercise) to determine changes in arterial function.

1.3 Cardiovascular Responses to Exercise

The cardiovascular system serves a key role in maintaining homeostasis within the human body. Physical activity is one of the most common everyday stressors that stimulate the system to respond. In order to meet the increased metabolic demand to sustain activity, heart rate and blood pressure throughout the vasculature become augmented in order to deliver required oxygen and nutrients to the active tissue.

The changes within the cardiovascular system are partially regulated by the nervous system. During moderately intense exercise, sympathetic neural activity is increased and parasympathetic neural activity is inhibited. The increase in sympathetic activity, increases cardiac output. In addition, vasoconstriction occurs within the active muscle mass to promote blood flow. Systolic blood pressure increases linearly with dynamic exercise intensity and diastolic tends to decrease (Laughlin, 1999). In contrast, resistance exercise typically causes larger increases in pulse pressure that are oscillatory and dependent on the phase of the exercise (Laughlin, 1999).

Although the changes induced by exercise are well understood, different types of exercise elicit different responses. Therefore, measuring and understanding these physiological differences is important when prescribing exercise, especially in clinical populations.

1.3.1 Aerobic Training

Aerobic training involves physical activity activities such as walking, running, cycling, and swimming. It is activity that can be sustained for extended periods of time while consuming oxygen to meet the energy demands. A recent meta-analysis concluded that *chronic* aerobic exercise training improved both AIx and PWV significantly (Ashor, Lara, Siervo, Celis-Morales, & Mathers, 2014). Moreover, another meta-analysis found that aerobic exercise had very little *acute* effects on arterial stiffness (Pierce, Doma, & Leicht, 2018). However, the results of this meta-analysis did note significant diversity within the aerobic exercise studies. Studies that have examined direct differences between aerobic and resistance exercise suggest that aerobic exercise provides a more beneficial

stimulus to the cardiovascular system. (Collier et al., 2010; Heffernan, Collier, Kelly, Jae, & Fernhall, 2007).

1.3.2 Resistance Training

In contrast to aerobic training, the effects of resistance exercise on arterial stiffness have been debated. One meta-analysis of 42 randomized, controlled studies found that resistance training had no effect on arterial stiffness (Ashor et al., 2014). Likewise, another review of 17 randomized controlled studies reported that resistance exercise did not augment arterial stiffness (Li, Hanssen, et al., 2015). In contrast, an earlier meta-analysis of eight randomized controlled clinical trials found that resistance training actually increased arterial stiffness (Miyachi, 2013).

Although there have been contrasting findings from studies on the effects of chronic resistance exercise, a recent meta-analysis of 45 acute exercise studies concluded that both carotid-femoral PWV and AIx increases following resistance exercise (Pierce et al., 2018).

1.3.3 Eccentric v. Concentric Training

Few studies have examined at the different muscle actions of resistance exercises: concentric (i.e. muscle shortening) and eccentric (i.e. active muscle lengthening). One controlled training study assessed the brachial-ankle pulse wave velocity after 8 weeks of either concentric resistance training, eccentric resistance training, or remaining sedentary (Okamoto, Masuhara, & Ikuta, 2006b). All three groups had similar pre-training values. However, after training, only the concentric resistance training participants increased their arterial stiffness. Likewise, one of our recent training studies reported no change in radial-

carotid or carotid-femoral pulse wave velocity after dynamic eccentric arm exercise (Elmer et al., 2017). This suggested that eccentric exercise may be a safe form of resistance exercise in terms of cardiovascular health.

1.4 Summary and Hypothesis

Exercise is one the leading methods to prevent and treat CVD (Patnode, Evans, Senger, Redmond, & Lin, 2017). However, some modalities of exercise can negatively impact the cardiovascular system by eliciting stiffening of the elastic arteries. Although there is some debate, it appears that concentric resistance exercise can have harmful acute cardiovascular consequences (Pierce et al., 2018). However, the negative effects of resistance may be able to be negated by combining aerobic exercise or isolating eccentric muscle contractions within the resistance exercise.

Study 1 examines the effect of order (i.e. aerobic before resistance (AR) or resistance before aerobic (RA)) on arterial stiffness when combining these exercise modes in a single training session. Study 2 compares the effects of acute eccentric and concentric arm cycling on central and peripheral arterial stiffness. We hypothesized that these novel combinations of resistance and aerobic exercise would not cause arterial stiffening as observed in resistance exercise alone.

2 Study 1: The Influence of Resistance and Aerobic Exercise Order on Acute Arterial Stiffness Responses

2.1 Introduction

Both aerobic and resistance exercise are frequently used to improve health. Although individuals may focus primarily on one mode or the other, combining both methods has been cited as one of the most effective way to manage body composition and improve overall fitness (Donnelly et al., 2009). Furthermore, in the interest of time and convenience, it is common for individuals to mix these training methods into the same exercise session.

Both aerobic and resistance exercise have been shown to influence arterial stiffness. Chronically, aerobic exercise training is thought to reduce arterial stiffness, while resistance exercise is thought to increase it (Miyachi et al., 2004). Aerobic exercise has been observed to reduce arterial stiffness acutely (Collier et al., 2010; Heffernan, Collier, et al., 2007), while resistance exercise may acutely increase stiffness (DeVan et al., 2005). A single acute session of aerobic exercise is reported to decrease arterial stiffness for up to 60 minutes post-exercise (Heffernan, Collier, et al., 2007).

Although the acute and chronic effects of independent aerobic and resistance exercise on arterial stiffness are known, the acute effects of performing both modes in a single session remain unclear. One study reports that arterial stiffness is reduced after eight-weeks of resistance then aerobic training, but not after aerobic then resistance training (Okamoto, Masuhara, & Ikuta, 2007). However, it is unknown whether the order in which these exercise modes are performed within a session has an effect on post-exercise arterial stiffness. Therefore, we hypothesized that arterial stiffness would be lower following resistance then aerobic (RA), but not after aerobic then resistance (AR) exercise.

2.2 Methods

2.2.1 Subjects

Seventeen (12 male, 5 female) healthy, recreationally active individuals participated in the study as shown in Table 1. All participants reported to not smoke, take any heart/blood pressure medications, or have a pacemaker. All participants attended an orientation session before providing written informed consent. A physical activity readiness questionnaire was also completed with each participant before testing. This study was reviewed and approved by the Michigan Technological University Institutional Review Board.

Table 1: Participant demographics, anthropometrics, and resting seated cardiovascular values.

Age (year)	Height (cm)	Weight (kg)	BMI (kg/m^2)	SAP (mmHg)	DAP (mmHg)	MAP (mmHg)	HR (bpm)
24 ± 2	174 ± 2	78 ± 3	25 ± 1	118 ± 3	65 ± 3	83 ± 2	59 ± 2

Values are reported as mean $\pm$ standard error. Body mass index (BMI), systolic arterial pressure (SAP), diastolic arterial pressure (DAP), mean arterial pressure (MAP), and heart rate (HR).

2.2.2 Experimental Design

Two testing sessions were performed, one in which participants performed a bout of RA exercise, and one where the opposite order was performed (i.e. AR). Each mode of exercise was performed for 30 minutes, so that the total exercise duration per session was 60 minutes. All participants completed both testing sessions approximately one week apart in a randomized balanced crossover design. Prior to each testing session, participants abstained from alcohol, caffeine, and exercise for a minimum of 12 hours, and fasted for at least 3 hours before.
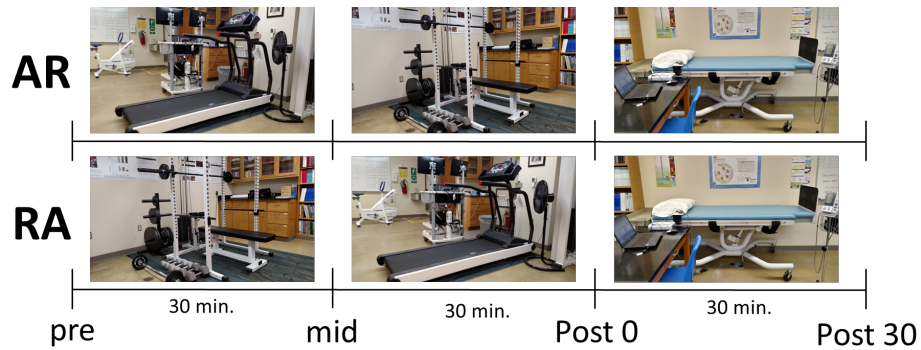
Figure 1: Conceptual diagram describing the protocol for each testing session.

2.2.3 Resistance Training

Resistance exercise training consisted of three sets of ten repetitions for six exercises, with each separated by one minute of rest. The exercises were performed in the following order: barbell squat, barbell bench press, seated lat pull down, triceps pushdown, biceps curls, and single leg lunge. The load for the each exercise was set at each participant's ten-repetition max, which was measured during the orientation session. The same load was used for both RA and AR exercise sessions. Resistance training duration averaged 30 minutes, with a range of 28 to 32 minutes.

2.2.4 Aerobic Training

Aerobic exercise training was conducted using a treadmill. Participants were able to self-select the speed and grade in order to maintain approximately 70% of their age-predicted maximum heart rate for 30 minutes to match the intensity and time of the resistance training. The same speed and grade was used for the RA and AR exercise sessions.

9

2.2.5 Measurements

During each testing session, measurements were taken at pre-exercise, mid-exercise (in between the two modes of exercise), directly after the exercise session, and 30 minutes post-exercise. The pre-exercise brachial blood pressures were taken in triplicate after at least 10 minutes of supine rest with an automated cuff (Omron HEM-907XL, Omron Health Care, Vernon Hills, IL) with one minute between each recording. A single supine blood pressure was taken at mid, post, and 30 minutes post-exercise.

The brachial blood pressures were used to calibrate the SphygmoCor CPVH system (AtCor Medical, West Ryde, Australia) for pulse wave analysis (PWA) measurements. A small pressure transducer (Milar Instruments, Houston, TX) was placed at the radial pulse site to record ten consecutive waveforms to estimate the aortic augmentation index and aortic blood pressure. These PWA measurements were performed in duplicate at each of the time points outlined above.

Peripheral pulse wave velocity (pPWV) was measured from waveforms at the radial and carotid pulses to observe arm arterial stiffness. Central pulse wave velocity (cPWV) was measured from waveforms at the carotid and femoral pulses to observe trunk arterial stiffness. The waveforms were gated to the R-wave of a three-lead electrocardiogram recording, which was also used to obtain heart rate (HR). Distances between the suprasternal notch, carotid pulse, radial pulse, and femoral pulse sites were measured as straight lines with a tape measure. Recordings were completed in duplicate following recommendations from the American Heart Association (Townsend et al., 2015). Aortic pulsatile load was calculated by multiplying aortic pulse pressure by the heart rate derived from the SphygmoCor system.

2.2.6 Statistical Analysis

Paired t-tests were used to test for differences in resting physiological values between to the two trials. A 2 (exercise order) x 4 (time) repeated measures analysis of variance (ANOVA) was used to assess difference in heart rate, mean arterial pressure, aortic pulsatile load, and pulse wave velocities (pPWV and cPWV). Post-hoc paired t-tests were performed when a significant time effect or condition (i.e. exercise order) by time interaction were observed after the ANOVA procedures. Data are presented as mean ± standard error and the *a priori* alpha was set to 0.05.

2.3 Results

Heart rate, mean arterial pressure, pPWV, and cPWV values were similar at rest before both exercise order conditions as shown in Table 2. Aortic pulsatile load was slightly higher preceding the AR than the RA condition.

Table 2: Baseline values between two testing sessions.

Variable	RA Session	AR Session	P value
Heart Rate (bpm)	57 ± 2	57 ± 3	0.54
MAP (mmHg)	81 ± 2	81 ± 2	0.97
Peripheral PWV (m/s)	7.3 ± 0.3	7.3 ± 0.3	1.00
Central PWV (m/s)	5.8 ± 0.3	5.6 ± 0.2	0.48

Values are reported as mean ± standard error. Mean arterial pressure (MAP), pulse wave velocity (PWV).

Heart rate increases were similar (time effect: $P < 0.05$) for RA and AR. Heart rate increased during exercise and remained elevated afterwards in both conditions. (57 ± 2 vs. 57 ± 2, 89 ± 5 vs. 92 ± 3, 97 ± 3 vs. 100 ± 4, and 74 ± 3 vs. 79 ± 4, time effect: $P = 0.00$). Mean arterial pressure increased significantly during exercise, but returned to baseline 30

minutes post-exercise during the RA session (81 ± 2 vs. 79 ± 2 mmHg, $P = 0.38$) and was reduced after the AR session (81 ± 2 vs. 74 ± 2 mmHg, $P < 0.05$). Aortic pulsatile load increased during exercise and remained elevated post-exercise after both sessions ($P < 0.05$ for both) as depicted in Figure 1.

Arm arterial stiffness (i.e., pPWV) tended to decrease 30 minutes after both RA and AR sessions (7.4 ± 0.3 vs. 6.9 ± 0.3; 7.2 ± 0.3 vs. 6.9 ± 0.3 m/s, time effect: $P = 0.086$). Aortic arterial stiffness (i.e. cPWV) decreased similarly 30 minutes after both RA and AR sessions (5.8 ± 0.3 vs. 5.5 ± 0.2; 5.6 ± 0.2 vs. 5.5 ± 0.2 m/s, time effect: $P < 0.05$). When normalized to aortic mean arterial pressure, cPWV values were increased following the AR session (0.072 ± 0.002 vs. 0.078 ± 0.003 m/s/mmHg, $P < 0.05$).
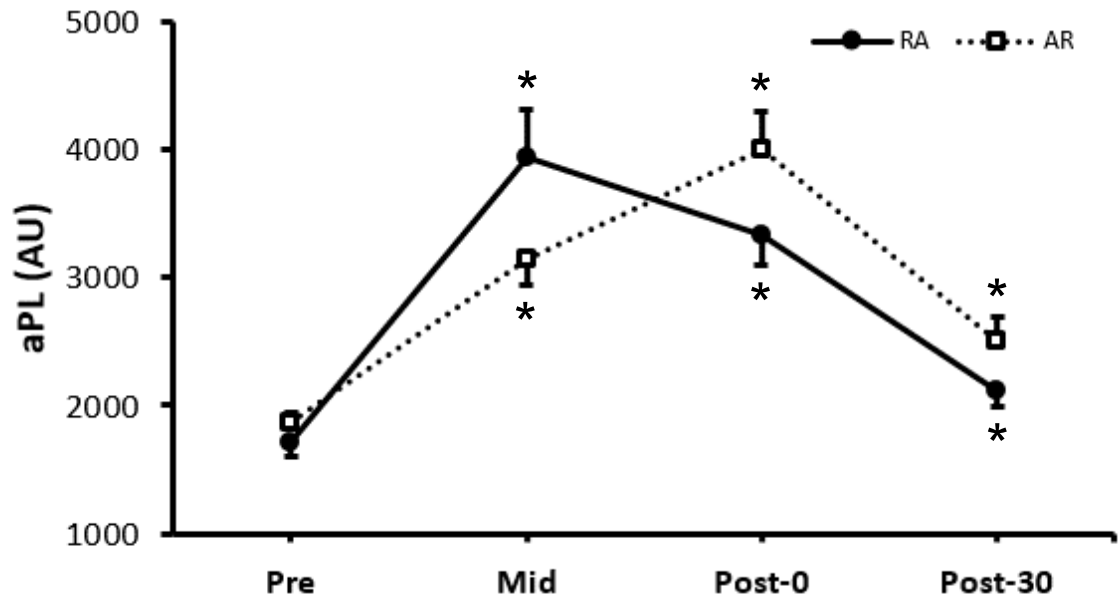
z
Figure 2: Aortic pulsatile load (aPL) before, between, and after exercise. Time effect: $P < 0.05$

12
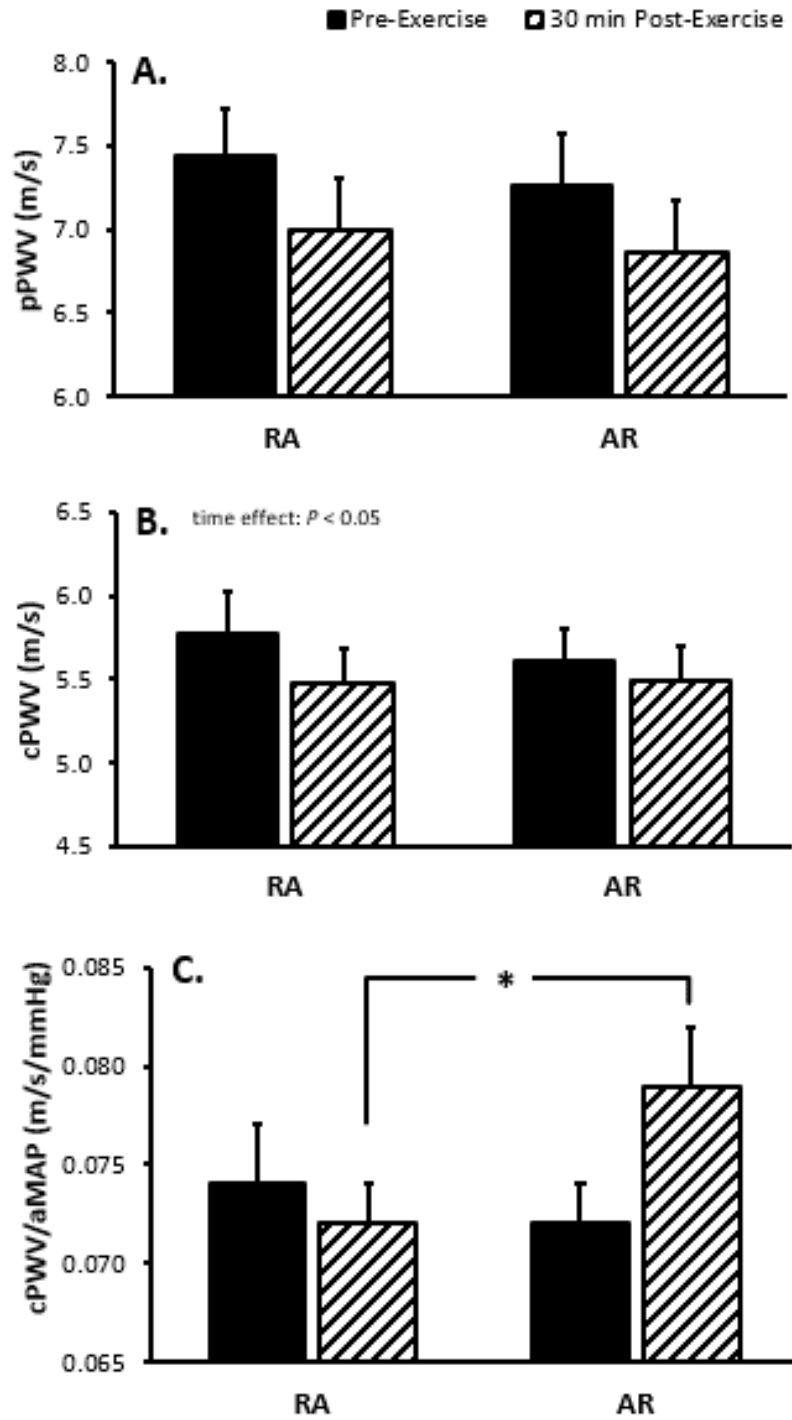
Figure 3: Peripheral (Panel A), central (Panel B), and normalized central (Panel C) pulse wave velocity responses 30 min post-exercise. * *P* < 0.05 vs. order

2.4 Discussion

This is the first study to report the effect of the order of aerobic and resistance exercise on acute cardiovascular responses. Heart rate changed and recovered similarly for each exercise order (i.e. RA and AR). Likewise, aortic pulsatile load increased and remained elevated after each session similarly. After both RA and AR, pPWV tended to be reduced 30 minutes post. There was a similar reduction in cPWV after each order. However, when normalized to mean aortic blood pressure, cPWV appears to be elevated following AR.

Prolonged elevated aortic pulse pressure and / or heart rate can increase pulsatility to pressure sensitive end organs, such as the brain and the kidney (Augustine, Yoon, Choo, Heffernan, & Jae, 2016). In the present study, aortic pulsatile load remained elevated 30 minutes post-exercise for both the RA and AR conditions. Although this elevation is not likely to cause long-term damage, it is important to consider in future chronic training studies and clinical populations. It would be interesting to determine if pulsatile load is reduced to baseline conditions more rapidly following RA or AR.

Peripheral and central arteries are structurally and functionally different, and therefore may respond to exercise differently. The peripheral vasculature can vasodilate in active tissue and vasoconstrict in other areas during resistance exercise, whereas aerobic exercise typically induces whole body vasodilation (Sardeli, Gaspari, & Chacon-Mikahil, 2015). Vasodilation during exercise can increase shear stress and nitric oxide bioavailability, which in turn can decrease regional arterial stiffness (Beck, Casey, Martin, Emerson, & Braith, 2013; C. Goto et al., 2003). Arterial stiffness in the arms, as measured by pPWV in our study, tended to decrease after each session. The tendency for reductions

in pPWV may have been due to vasoactive substances, such as nitric oxide, similar to previous work by Beck, Martin, Casey, and Braith (2013). Moreover, this reduction in pPWV is likely associated with our study protocol, which included four upper-body resistance exercises (Fahs, Heffernan, & Fernhall, 2009).

Although cPWV is considered the gold standard for measuring arterial stiffness (Laurent et al., 2006), cPWV is a pressure-dependent measure. Therefore, normalizing cPWV to aortic mean pressure, can be useful when interpreting results from an exercise intervention (Sacre, Jennings, & Kingwell, 2014). Our acute normalized cPWV results suggest that RA may be a better option for combined exercise compared to AR. Results from an 8-week combined training study reported that performing resistance then aerobic exercise can reduce arterial stiffness (Okamoto et al., 2007). Importantly, the above benefits were lost with four weeks of detraining (Okamoto et al., 2007), signifying the importance of consistence acute bouts of combined exercise. Furthermore, early studies noted improved growth hormone (K. Goto, Higashiyama, Ishii, & Takamatsu, 2005) and greater lipolysis (K. Goto, Ishii, Sugihara, Yoshioka, & Takamatsu, 2007) when resistance exercise is performed before aerobic exercise. More recently, this order of combined training has also been shown to be beneficial in diabetics by improving glycemic stability (Yardley et al., 2012) and increasing growth hormone secretion (Yardley, Sigal, Riddell, Perkins, & Kenny, 2014) throughout the exercise session.

One limitation to this study is that the sample size did not allow us to adequately examine potential sex differences. Our sample had a larger percentage of male participants (12 male, 5 female). It has been previously reported that there can be differences in arterial stiffness at rest and after acute bouts of exercise between males and females (Doonan,

Mutter, Egiziano, Gomez, & Daskalopoulou, 2013). Understanding these potential differences is important for future exercise prescription recommendations.

In conclusion, although there is much debate of the effects of resistance exercise on arterial stiffness, and a recent meta-analysis concluded that acute resistance exercise is likely to have adverse effects on arterial stiffness (Pierce et al., 2018). Conversely, aerobic exercise was reported to reduce pulse wave velocity (Pierce et al., 2018). However, it has been demonstrated in a cross-sectional study that simultaneous resistance and aerobic exercise (i.e. rowing) can be used to reduce stiffening (Cook et al., 2006). Our results in the present study also suggest that by combining both forms of exercise within a single exercise session can also reduce stiffening independent of exercise order. However, our results regarding cPWV normalized to aMAP, in conjunction with previous work on arterial stiffness (Okamoto et al., 2007) and metabolic function (K. Goto et al., 2005; K. Goto et al., 2007; Yardley et al., 2012; Yardley et al., 2014), may suggest that RA would be the most beneficial combined exercise order.

3 Study 2: Post-Exercise Arterial Stiffness Responses Are Similar After Acute Eccentric and Concentric Arm Cycling

3.1 Introduction

Many activities of daily living, work-related manual labor, and locomotor tasks such as wheelchair propulsion rely on arm, shoulder, and trunk musculature. Adequate upper-body strength is critical for maintaining health, functioning independently, and preventing lifestyle related diseases (P. LaStayo, Marcus, Dibble, Frajacomo, & Lindstedt, 2014). However, both acute (Pierce et al., 2018) and chronic (Miyachi et al., 2004) resistance exercise can increase arterial stiffness. Additionally, upper-body resistance exercise has been observed to increase arterial stiffness both acutely (Li, Bopp, et al., 2015) and chronically (Okamoto, Masuhara, & Ikuta, 2009) to a greater extent than lower-body resistance exercise. Increased stiffness (inability to expand and recoil during the cardiac cycle) of arteries contributes to hypertension (Carthy, 2014), and increases the risk for cardiovascular disease (Vlachopoulos, Aznaouridis, & Stefanadis, 2010). In contrast to upper-body resistance exercise, upper-body aerobic exercise provides cardiorespiratory benefits and can acutely decrease regional (i.e. arm) arterial stiffness (Ranadive et al., 2012).

Resistance exercise typically includes both concentric (active muscle shortening) and eccentric (active muscle lengthening) phases. Forces produced during eccentric muscle actions can be substantially greater than those produced during concentric muscle actions (P. C. LaStayo, Pierotti, Pifer, Hoppeler, & Lindstedt, 2000). In addition to this increased capacity for force production, eccentric exercise is performed with a lower metabolic cost

and thus lower perceived exertion (Elmer, Danvind, & Holmberg, 2013; Elmer & LaStayo, 2014; Elmer, Marshall, McGinnis, Van Haitsma, & LaStayo, 2013). To date, it is well established that eccentric exercise is more effective than traditional concentric-based exercise at improving neuromuscular function (Elmer et al., 2017), balance, and mobility in populations ranging from cardiopulmonary patients to competitive athletes (Isner-Horobeti et al., 2013; P. LaStayo et al., 2014).

During eccentric exercise sympathetic activation and blood pressure are lower compared to similarly matched concentric exercise (Carrasco, Delp, & Ray, 1999). These attributes would possibly favor lower post-exercise arterial stiffness outcomes. In related work, Okamoto and colleagues reported that eight weeks of eccentric elbow flexor actions increased strength without changing arterial stiffness, whereas concentric elbow flexor actions increased strength and arterial stiffness (Okamoto, Masuhara, & Ikuta, 2006a). These results are promising and imply that attenuated circulatory adjustments to eccentric muscle action might help to offset the effects of arterial stiffening associated with resistance exercise. With this in mind, we sought to determine whether a novel form of upper-body resistance cycling exercise could be performed without compromising arterial function.

We recently developed a novel eccentric arm cycle ergometer in which the user resists the reverse moving motor-driven handles (Figure 3). This modality can be used to safely perform repetitive, high-force, multi-joint eccentric actions with the upper-body while minimizing metabolic and cardiorespiratory strain. Assessment of arterial stiffness following acute eccentric and concentric arm cycling performed at the same heart rate would offer a model for evaluating the impact of aerobically-based upper-body resistance

exercise on arterial function. Accordingly, the purpose of this study was to compare the effects of acute eccentric and concentric arm cycling on central and peripheral arterial stiffness. We anticipated that power output during eccentric arm cycling would be ~2x greater than that during concentric arm cycling (Elmer, Danvind, et al., 2013). Previous work has shown that regional arterial stiffness is reduced after acute arm and leg cycle ergometry, but that central arterial stiffness remains unchanged (Ranadive et al., 2012). Therefore, we hypothesized that peripheral arterial stiffness would be reduced following both eccentric and concentric arm cycling, but that that central arterial stiffness would remain unchanged.

3.2 Methods

3.2.1 Participants

Twenty-two healthy individuals volunteered to participate in this study. Seventeen of these participants were part of a previously published training study (Elmer et al., 2017). Participants were recreationally active, but did not regularly participate in upper-body aerobic or resistance exercise. Experimental procedures used in this investigation were reviewed and approved by the Michigan Technological University Institutional Review Board. The protocol and procedures were explained verbally and all participants provided written informed consent prior to testing. Participants were clustered together in such a way as to create two exercise groups of 11 participants with similar body composition, upper-body cardiorespiratory capacity, and maximum upper-body muscular power as shown in Table 1.

Table 3: Participant demographic, anthropometric, and physiological characteristics.

Variable	Eccentric (n = 11)	Concentric (n = 11)	P value
Age (yr)	23 ± 1	24 ± 1	0.53
Height (m)	1.74 ± 0.03	1.77 ± 0.03	0.60
Body mass (kg)	74 ± 4	79 ± 5	0.40
BMI (kg·m^{-2})	24 ± 1	25 ± 1	0.58
Body Fat (%)	22 ± 4	25 ± 4	0.62
Systolic Arterial Pressure (mmHg)	110 ± 4	111 ± 3	0.86
Diastolic Arterial Pressure (mmHg)	60 ± 3	61 ± 2	0.86
Resting Heart Rate (b·min^{-1})	64 ± 3	60 ± 3	0.33
$\dot{V}O_{2peak}$ (L·min^{-1})	2.2 ± 0.2	2.3 ± 0.2	0.74
$\dot{V}O_{2peak}$ (ml·kg^{-1}·min^{-1})	29 ± 3	29 ± 2	0.82
HR_{peak} (b·min^{-1})	185 ± 3	181 ± 3	0.37
W_{peak} (W)	134 ± 12	134 ± 12	1.00
P_{max} (W)	599 ± 59	591 ± 60	0.94

Values are reported as Mean ± SE. Body mass index (BMI), peak oxygen consumption (VO_{2peak}), peak heart rate (HR_{peak}), peak power reached at the end of VO_{2peak} test (W_{peak}), and maximal upper-body concentric power (P_{max}).

3.2.2 Pre-Experimental Assessments

Body composition was assessed using dual energy x-ray absorptiometry (DEXA; Lunar Prodigy, General Electric Company, Fairfield, CT, USA). Upper-body cardiorespiratory capacity was evaluated during an incremental concentric arm cycling test ($15 + 15$ W·min^{-1}) using an expired air analysis system (ParvoMedics TrueOne 2400, Salt Lake City, UT, USA) for determination of peak oxygen consumption ($\dot{V}O_{2peak}$), peak heart rate (HR_{peak}), and peak power output reached (W_{max}). Maximum upper-body power was determined during maximal concentric arm cycling trials (3 s, 120 rpm). Exercise groups were then assigned to one of the following exercise conditions: 1) eccentric arm cycling, or 2) concentric arm cycling.

3.2.3 Habituation Period

During the weeks preceding the experimental visit, participants in the eccentric group performed several habituation trials of eccentric arm cycling in order become familiar with the cycle ergometer, acquire the specific coordination required for eccentric arm cycling, and minimize the occurrence of muscle soreness that can be associated with unaccustomed eccentric exercise (P. C. LaStayo et al., 2000). Participants in the concentric group also performed similar habituation sessions of concentric arm cycling. Muscle soreness associated with eccentric arm cycling or concentric arm cycling was monitored using a visual analog scale (0-10 cm; 10 cm representing the most soreness possible (Elmer, Marshall, et al., 2013; P. C. LaStayo et al., 2000)). Specifically, 24 to 48 hours after each habituation trial, participants performed a standardized bilateral elbow extension movement (''bench dip'') during which they indicated the level of perceived muscle

soreness in their arms by placing a mark on the visual analog scale. Perceived muscle soreness was quantified by measuring the distance to the mark on the line to the nearest 0.1 cm. Both groups tolerated the habituation sessions well as muscle soreness was minimal (< 1.0 cm), and thus were reasonably trained with their respective modality.

3.2.4 Experimental Protocol

For the experimental visit, participants were instructed to avoid exercise and caffeine for 12 h preceding the experiment which was performed at least 3 h post-prandial. Baseline measures of heart rate, blood pressure, and pulse wave velocity were recorded before exercise (described below). Subsequently, participants performed either eccentric arm cycling or concentric arm cycling on an isokinetic arm cycle ergometer (described below) at ~70% of HR_{peak} for 20 min at a pedaling rate of ~60 rpm. Arm cycling power output and heart rate (Polar Electro OY, Kempele, Finland) were recorded and averaged over the 20 min exercise trial. Overall rating of perceived exertion (RPE_{body}), as well as arm specific RPE (RPE_{arm}), were assessed during the final min of exercise using a Borg 6-20 scale (Borg, 1982). Heart rate, blood pressure, and pulse wave velocity were reassessed at 10 min and 30 post exercise. These time points were selected because previous studies have shown that arterial stiffness can be altered from 10 to 30 min post-exercise (Heffernan, Jae, Echols, Lepine, & Fernhall, 2007; Ranadive et al., 2012).

3.2.5 Cardiovascular Parameters

All measurements were completed following the guidelines from the American Heart Association for standardizing vascular research (Townsend et al., 2015). At baseline,

brachial blood pressures were taken in triplicate after at least 10 minutes of supine rest with an automated cuff (Omron HEM-907XL, Omron Health Care, Vernon Hills, IL) with one minute between each recording. Average systolic arterial pressure (SAP) and diastolic arterial pressure (DAP) were used to calibrate the SphygmoCor CPVH system (AtCor Medical, West Ryde, Australia) for pulse wave analysis measurements. A single supine blood pressure was taken to calibrate directly before recordings at 10 and 30 min post exercise.

A small pressure transducer (Millar Instruments, Houston, TX) was placed at the radial pulse site to record consecutive waveforms during pulse wave analysis. The SphygmoCor system was used to estimate aortic blood pressures and aortic augmentation index (AIx) from the radial site. Recordings were completed in duplicate with an operator index of ≥ 80 for all readings as recommended by the manufacturer. Values are reported as an average of the two recordings. Aortic pulsatile load was calculated by multiplying the average aortic pulse pressure by the heart rate from the SphygmoCor system.

Peripheral pulse wave velocity (pPWV) was measured from waveforms at the radial and carotid pulses to indicate arm arterial stiffness. Central pulse wave velocity (cPWV) was measured from waveforms at the carotid and femoral pulses to indicate aortic arterial stiffness. The pressure waveforms were gated to the R-waves of a three-lead electrocardiogram recording, which was also used to obtain heart rate (HR). Distances between the suprasternal notch to the carotid, radial, and femoral pulse sites were measured as straight lines with a tape measure. Pulse wave velocity recordings were taken in duplicate with $\leq 10\%$ standard error and a HR difference of ≤ 5 b·min^{-1} between the consecutive measurements sites. Values are reported as an average of the two recordings.

3.2.6 Arm Cycle Ergometer

The isokinetic arm cycle ergometer (Figure 1) used in this investigation has been previously described in detail (Elmer, Marshall, et al., 2013). Briefly, the flywheel of the ergometer was driven in reverse for eccentric arm cycling group by a 560 W three-phase electric motor (Leeson, C4T17PT2C; Santa Fe Springs, CA, USA) via pulleys and a belt, or driven forward by the participants in the concentric arm cycling group. The motor was controlled by a variable frequency drive equipped with regenerative braking capability (Leeson, SM2 Series, Sante Fe Springs, CA, USA). Power delivered to the ergometer crank was quantified using a power meter (Schoberer Rad Messtechnik, SRM, Jülich, Germany), which serves as an accurate method to quantify cycling power (Abbiss, Quod, Levin, Martin, & Laursen, 2009). Pedaling rate was set to ~60 rpm and the SRM power meter (sampled at 2 Hz) displayed the power that the participant was absorbing (eccentric arm cycling trials) or producing (concentric arm cycling trials). The SRM power meter was calibrated using static calibration procedures (Elmer, Danvind, et al., 2013) and a zero offset ($f_{unloaded}$) was obtained before all arm cycling trials. The cranks (170 mm) were positioned in the asynchronous fashion and custom made wider surface area handles were used to allow for a comfortable pronated hand position. Ergometer seat position was carefully standardized such that the: 1) crank axle was set just below the level of the heart, 2) elbow was positioned at a comfortable angle when the cranks were horizontal (~20° ulnar notch to humeral head), and 3) legs were positioned to help stabilize the torso (~90° lateral malleolus to greater trochanter). Finally, for the eccentric arm cycling trials, participants were instructed to "resist" the motor-driven handles of the ergometer at the

specified target heart rate whereas for the concentric arm cycling trials, participants were instructed to propel the handles of the ergometer at the specified target heart rate.
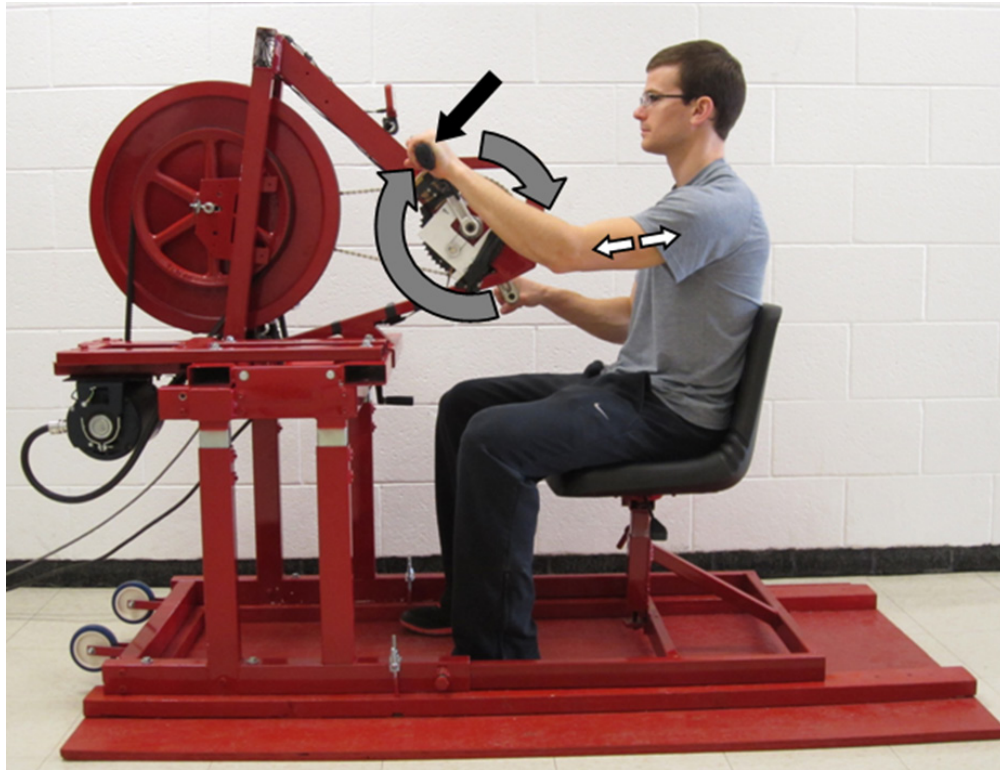
Figure 4: Motor-driven ergometer for eccentric arm cycling. The handles are driven in a backwards rotation as indicated by the grey arrows, and the participant resists the turning of the handles as indicated by the black arrow.

3.2.7 Data Analysis

Independent t-tests were used to test for differences in participant demographic data, power output, heart rate, and RPE values between eccentric arm cycling and concentric arm cycling. A 2 (exercise group) x 3 (time) repeated measures analysis of variance (ANOVA) was used to assess differences in heart rate, brachial blood pressures, aortic blood pressures, aortic augmentation index normalized to 75 b·min^{-1} (AIx@75), and pulse wave velocity (cPWV, pPWV). If any of the ANOVA procedures revealed a significant time effect, and/or group x time interaction, then subsequent post-hoc tests were

performed to determine where those differences occurred. Data are presented as mean ±
standard error and the *a priori* alpha was set to 0.05.

3.3 Results

3.3.1 Responses during exercise

Mechanical, cardiorespiratory, and perceptual responses to the 20 min exercise trial
are reported in Figure 4. Power absorbed during eccentric arm cycling was ~2x that
produced during concentric arm cycling (125 ± 13 vs. 67 ± 7 W, p < 0.01). These powers
corresponded to 94 ± 5 and $50 \pm 2\%$ of the peak power reached during the concentric arm
cycling VO_{2peak} test (W_{peak}) and to 22 ± 2 and $12 \pm 1\%$ of maximal concentric arm cycling
power (P_{max}), respectively. Mean absolute and relative heart rates during eccentric arm
cycling (122 ± 4 b·min^{-1}, $66 \pm 2\%$ of HR_{peak}) and concentric arm cycling (122 ± 2 b·min^{-1},
$67 \pm 1\%$ of HR_{peak}) did not differ (p = 0.87 and p = 0.68, respectively) and were close to
the prescribed target of target of 70% of HR_{peak}. Rating of perceived exertion for the whole-
body during eccentric and concentric arm cycling was between a "light" and "somewhat
hard" effort and did not differ between groups (12.6 ± 0.4 vs. 11.8 ± 0.5, p = 0.20). Rating
of perceived exertion for the arms during eccentric and concentric arm cycling was between
a "somewhat hard" and "hard" effort and did not differ between groups (14.0 ± 0.3 vs. 13.4
± 0.6, p = 0.38).
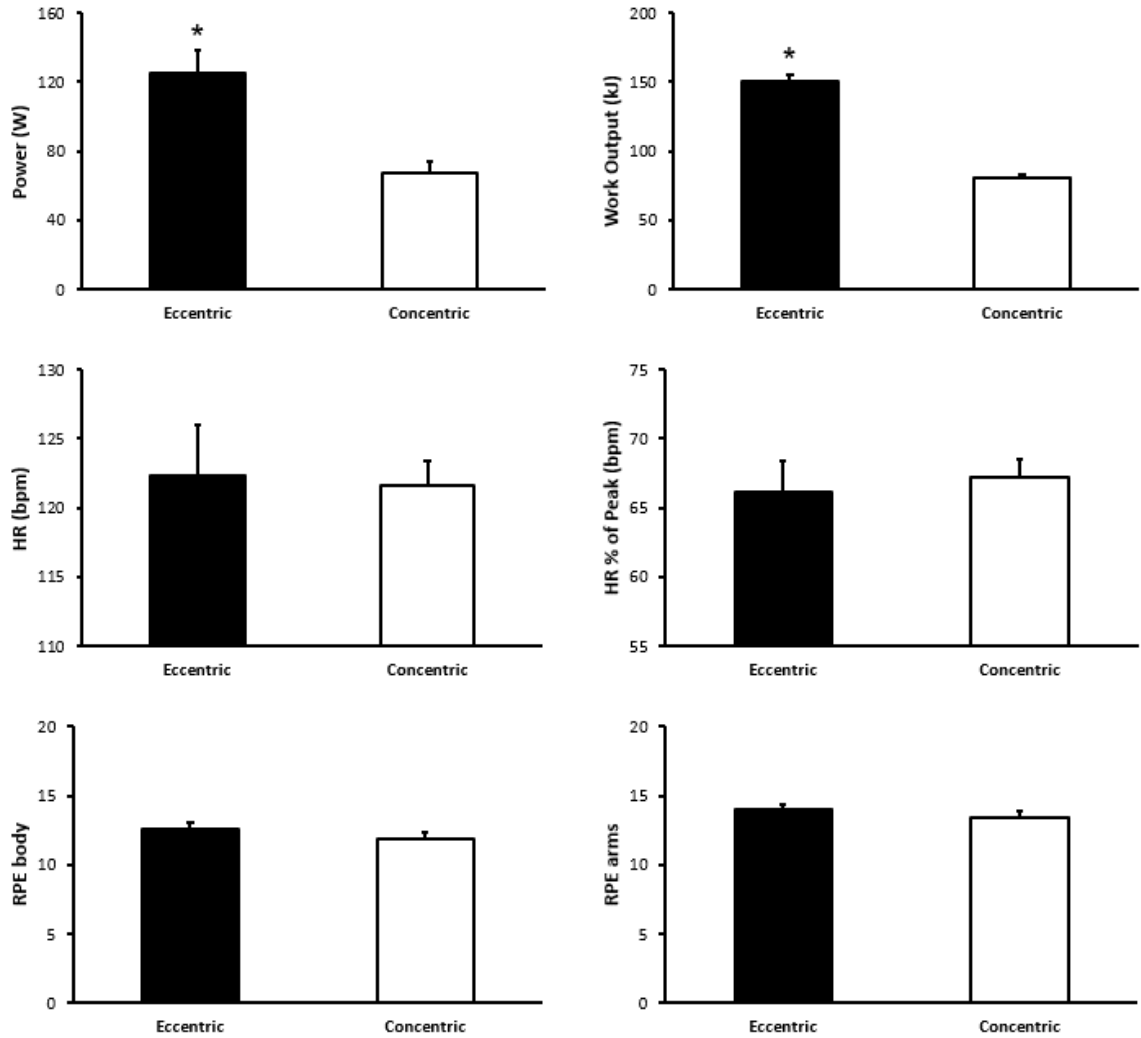
Figure 5: Eccentric arm cycling results in significantly greater production of work and power at a predetermined heart rate (HR) as an absolute value or percentage of the participant's age-predicted maximal value. Ratings of perceived exertion (RPE) were similar. * $p < 0.05$ between groups

3.3.2 Responses after exercise

Heart rate tended to be elevated at 10 min post ECC_{arm} ($p = 0.08$) and was elevated at 10 min post CON_{arm} ($p < 0.01$), but returned to baseline levels at 30 min post-exercise in both groups. Mean arterial pressure was not significantly changed from baseline at 10 or 30 min post-exercise in either group. Aortic pulsatile load remained elevated 10 and 30 min post exercise in both groups ($p < 0.01$ for both). AIx@75 was elevated in both groups

at 10 min post-exercise (p<0.03 for both), but returned to baseline values at 30 min post (see Table 4). As shown in Figure 5, pPWV was decreased at 10 min post-exercise for both ECC_{arm} and CON_{arm} (p<0.05), while both groups returned to baseline values by 30 min post. cPWV did not change in either group.
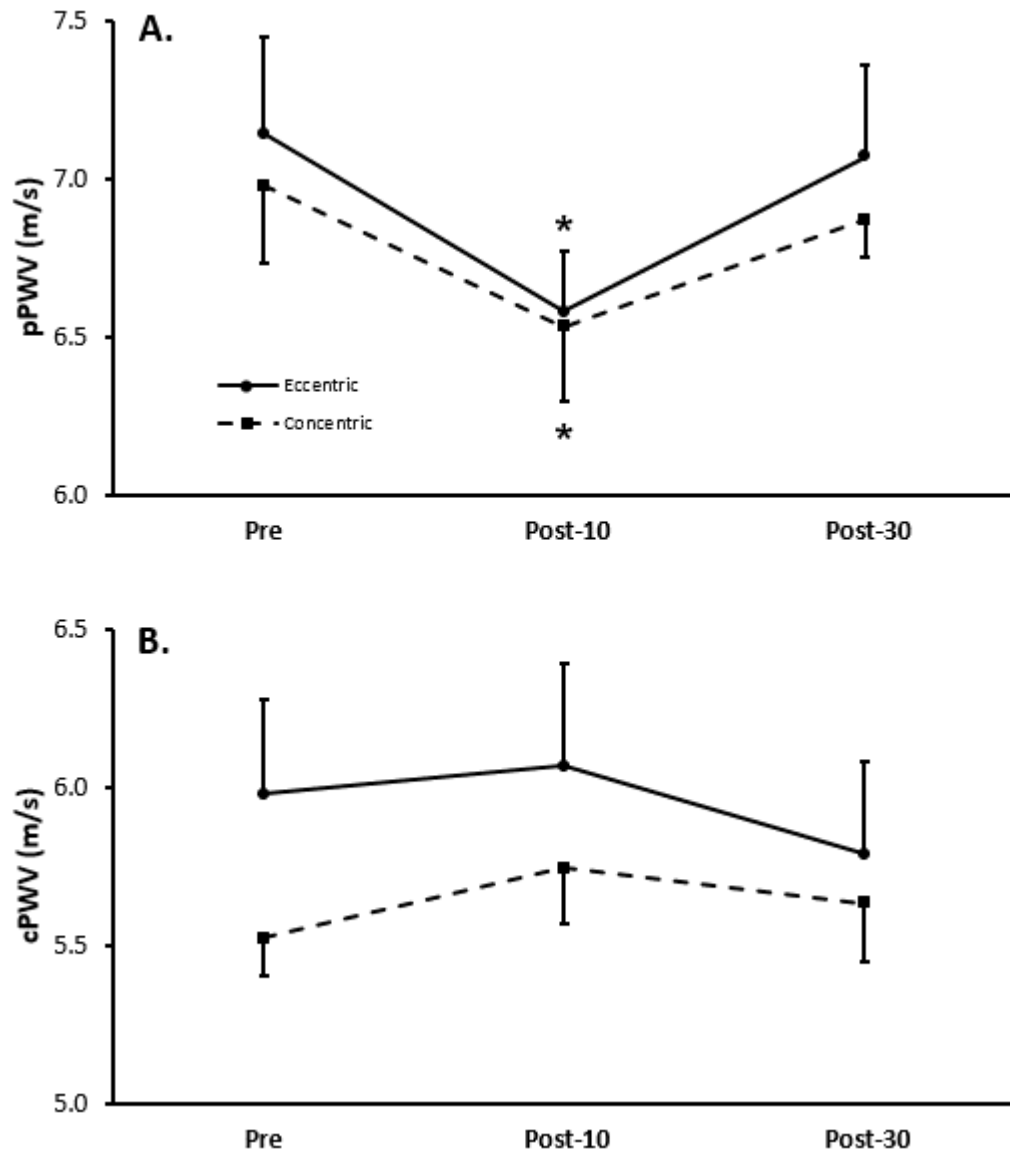
Figure 6: Peripheral (i.e. arm) pulse wave velocity (pPWV) was significantly decreased at 10 min post-exercise in both groups, but returned to baseline at 30 min post (Panel A). Central (i.e. aortic) pulse wave velocity (cPWV) was not changed from baseline at 10 or 30 min post-exercise for either group (Panel B). * p<0.05 vs. pre-exercise baseline.

Table 4: Cardiovascular responses to acute exercise session.

Variable	Eccentric (n=11)			Concentric (n=11)		
	Pre-Exercise	10 min Post-Exercise	30 min Post-Exercise	Pre-Exercise	10 min Post-Exercise	30 min Post-Exercise
HR (bpm)	64 ± 3	68 ± 3	61 ± 2	60 ± 3	71 ± 4*	66 ± 3
bMAP (mmHg)	76 ± 3	79 ± 2	75 ± 2	77 ± 2	72 ± 2	74 ± 2
AIx@75	-9 ± 3	0 ± 3*	-4 ± 3	-14 ± 4	-4 ± 3*	-12 ± 3
aSAP (mmHg)	91 ± 3	96 ± 2	93 ± 2	92 ± 2	89 ± 2	87 ± 3
aDAP (mmHg)	61 ± 3	59 ± 2	59 ± 2	63 ± 2	52 ± 2	54 ± 2
aMAP (mmHg)	74 ± 3	76 ± 2	74 ± 2	74 ± 2	69 ± 2	69 ± 2
aPP (mmHg)	31 ± 1	38 ± 1*	35 ± 1	31 ± 2	37 ± 2*	35 ± 2
aPL (aU)	1907 ± 136	2607 ± 184*	2074 ± 130*	1800 ± 107	2440 ± 121*	2179 ± 172*

Values are reported as Mean ± SE. Heart rate (HR), brachial mean atrial pressure (bMAP), aortic augmentation index normalized to 75 beats per minute (Aix@75), aortic systolic blood pressure (aSAP), aortic diastolic blood pressure (aDAP), aortic mean blood pressure (aMAP), aortic pulse pressure (aPP), aortic pulsatile load (aPL). * $p < 0.05$ vs. pre-exercise baseline

3.4 Discussion

This study compared arterial stiffness responses to acute steady-state eccentric and concentric upper body cycling. The main finding of our study was that both eccentric and concentric upper body cycling elicit similar acute arterial stiffness responses. This is supported by three novel findings. First, pPWV measured in the arm was reduced at 10 min post-exercise after both eccentric and concentric arm ergometry, but returned to pre-exercise values by 30 min post-exercise. Second, cPWV was similar to pre-exercise baseline values at 10 and 30 min post-eccentric and post-concentric arm ergometry. Third, AIx@75 was elevated at 10 min post-exercise, but returned to baseline values at 30 min post-exercise in both groups.

Our pPWV results (top panel of Figure 5) are in agreement with findings from Ranadive et al. (2012), who reported that maximal concentric upper body cycling can acutely decrease arterial stiffness in the arm. Acute decreases in pPWV are thought to be largely due to increases in nitric oxide which can contribute to vasodilation (C. Goto et al., 2003). Additionally, our observation that cPWV did not change through concentric arm cycling agrees with previous findings from Ranadive et al. (2012). However, it was not previously known if eccentric arm cycling would elicit similar responses.

Arm cycling recruits a smaller muscle mass compared to many other forms of aerobic exercise, such as running or biking. Therefore, arm blood flow is higher during arm cycling compared to whole body exercise (Volianitis & Secher, 2002). Hence, it is plausible that the vasculature in the arms would be primarily effected during our protocol and not the descending aorta. Furthermore, changes in the stiffness of muscular peripheral arteries are

due to changes in endothelial function, whereas the central arteries change more so due to structural changes associated with aging (Choi et al., 2010).

AIx has been demonstrated to be influenced independently from pulse wave velocity and is affected by heart rate to a greater extent (Kelly et al., 2001). Heart rate returned to baseline values by 30 min post-eccentric arm cycling, but was still elevated at 30 min post-concentric arm cycling. This may partially explain the disparity between AIx and PWV responses. Increases in aortic pulse pressure were similar at 30 min post-exercise for the eccentric and concentric groups (~4 mmHg). Elevated aortic pulse pressure, and / or heart rate, can increase the pulsatility to end organs such as the brain and kidney and lead to long-term damage (Augustine et al., 2016). Increased aortic pulsatility is also noted to increase the risk for coronary heart disease (Nishijima et al., 2001). Aortic pulsatile load increased after exercise and remained elevated 30 minutes after in each group.

It would be beneficial to include more female participants in future studies to allow for potential sex differences to be examined. Measurements of PWV were taken at 10 and 30 minutes to measure acute changes following exercise and after a brief recovery. However, it would be beneficial to add additional time points, as the cardiovascular system can rapidly change following exercise.

Our findings have potential implications for clinicians who prescribe exercise to improve upper body strength to patient populations, especially those with cardiovascular impairments. Specifically, our results demonstrate that eccentric arm cycling can be used to provide significant mechanical stress at moderate levels of perceived exertion while not increasing arterial stiffness. This exercise modality could also be useful in athletic

31

populations to increase performance in which upper-body strength and endurance is important, such as rowing or cross-country skiing.

These acute findings, in conjunction with our recent longitudinal training study that indicated no change in pPWV or cPWV (Elmer et al., 2017), demonstrate that eccentric arm cycling does not appear to negatively influence arterial stiffness. These results are promising, considering that participants increased their upper body strength and power in our longitudinal eccentric exercise study (Elmer et al., 2017), whereas traditional longitudinal upper body resistance training has been reported to increase pulse wave velocity (Okamoto et al., 2009). These findings indicate that eccentric arm cycling appears to be safe for healthy individuals in regard to arterial function. It is currently unknown if these findings will extend to those with pre-clinical, or clinical, conditions such as hypertension or coronary artery disease.

4 Summary, Limitations, and Future Directions

4.1 Summary

Our results suggest that a key to reducing the negative effects of resistance exercise on arterial function is to combine it with aerobic exercise, either within a single session or simultaneously. Eccentric arm cycling is a novel form of resistance exercise at aerobic capacities that prevents adverse arterial responses.

4.2 Limitations

Both studies have a pool of young, healthy individuals. Although this is an important first step to determine the effects of combined resistance and aerobic exercise, it limits our ability to prescribe exercise to clinical populations. Additionally, our sample is not large enough to adequately examine potential sex differences – something that continues to be absent in much of the literature.

Peripheral stiffness measurements were focused only in the arm (carotid-radial). Recently, there has been a focus on differential response in the upper and lower arterial segments (Mutter, Cooke, Saleh, Gomez, & Daskalopoulou, 2017). Additional recordings of femoral-pedal pulse wave velocities could further our understanding of cardiovascular responses to combined resistance and aerobic exercise.

4.3 Future Directions

Future studies could use more invasive measures to determine the mechanisms that are responsible for the observed cardiovascular responses. This might include measurements of nitric oxide, endothelin-1, and other vasoactive substances. Another

regulatory mechanism that could be further studied is muscle sympathetic nerve activity, which is associated with arterial stiffness (Swierblewska et al., 2010). Ultrasonography and the flow-mediated dilation technique could also offer further insight into the changes in arterial diameter and stiffness after eccentric exercise.

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Appendix A. Raw Data for Study 1

A.1   Demographic Information

SUBECT #	SEX	AGE (year)	HEIGHT (cm)	WEIGHT (kg)	BMI (kg/m²)	SAP (mmHg)	DAP (mmHg)	MAP (mmHg)	HR (bpm)
1	M	33	181	95.6	29.2	137	79	98	59
2	F	22	170	61.8	21.4	93	58	70	45
3	F	20	168	59.8	21.2	107	57	74	56
4	M	41	173	96.0	32.1	115	62	80	56
5	M	21	180	84.0	25.9	128	70	89	66
6	M	19	184	81.4	24.0	125	44	71	52
7	M	21	176	72.2	23.3	120	73	89	61
8	F	32	165	56.9	20.9	118	77	91	50
9	M	29	186	101.4	29.3	142	83	103	72
10	M.	21	173	80.2	26.8	125	76	92	66
11	M	21	166	85.5	31.0	117	61	80	67
12	M	21	179	80.8	25.2	110	53	72	61
13	M	19	170	73.3	25.4	123	67	86	77
14	M	19	166	61.9	22.5	115	66	82	56
15	M	19	178	81.5	25.7	101	50	67	50
16	F	19	178	81.0	25.6	114	61	79	57
17	F	36	173	70.9	23.7	108	71	83	50

A.2 Target Heart Rate and 10 RM Strength Test

Subject #	Target HR (bpm)	Barbell Squat (lbs)	Barbell Bench Press (lbs)	Seated Lat Pull Down (lbs)	Triceps Pushdown (lbs)	Biceps Curl (lbs)	Single Leg Lunge (lbs)
1	149	185	165	130	60	55	65
2	152	115	95	60	40	40	65
3	157	115	55	60	30	30	65
4	142	80	155	90	60	55	30
5	159	155	115	70	40	50	25
6	156	225	105	100	50	50	95
7	158	135	145	110	50	55	55
8	146	85	75	60	30	30	15
9	155	135	115	100	50	45	45
10	159	95	155	100	60	70	25
11	159	175	125	70	50	65	75
12	158	205	155	90	40	45	110
13	164	155	125	70	40	50	25
14	157	205	125	60	40	35	105
15	156	155	105	90	40	45	0
16	158	155	75	80	40	45	50
17	143	65	60	50	30	30	25

A.3   Brachial Hemodynamics: RA Pre-Exercise

Subject #	SAP	DAP	MAP	HR
1	144	65	91	96
2	112	54	73	62
3	145	63	90	99
4	145	78	100	77
5	135	60	85	97
6	135	47	76	57
7	140	66	91	106
8	123	67	86	67
9	182	63	103	117
10	115	53	74	101
11	149	49	82	51
12	148	47	81	111
13	133	75	94	109
14	137	59	85	121
15	109	40	63	99
16	120.0	57	78	64
17	120.0	68	85	80

A.4   Brachial Hemodynamics: AR Pre-Exercise

Subject #	SAP	DAP	MAP	HR
1	119	68	85	53
2	103	58	73	45
3	104	52	69	52
4	115	62	80	56
5	127	67	87	66
6	113	52	72	54
7	119	70	86	70
8	118	77	91	50
9	141	72	95	71
10	120	68	85	78
11	111	56	74	48
12	115	64	81	52
13	120	64	83	72
14	121	68	86	51
15	103	52	69	54
16	116	59	78	55
17	110	66	81	48

A.5   Brachial Hemodynamics: RA Mid-Exercise

Subject #	SAP	DAP	MAP	HR
1	144	65	91	96
2	112	54	73	62
3	145	63	90	99
4	145	78	100	77
5	135	60	85	97
6	135	47	76	57
7	140	66	91	106
8	123	67	86	67
9	182	63	103	117
10	115	53	74	101
11	149	49	82	51
12	148	47	81	111
13	133	75	94	109
14	137	59	85	121
15	109	40	63	99
16	120	57	78	64
17	120	68	85	80

A.6   Brachial Hemodynamics: AR Mid-Exercise

Subject #	SAP	DAP	MAP	HR
1	137	66	90	122
2	137	67	90	86
3	127	66	86	99
4	137	58	84	106
5	140	62	88	119
6	134	56	82	69
7	114	70	85	112
8	120	72	88	65
9	151	53	86	105
10	125	62	83	107
11	133	50	78	97
12	125	38	67	106
13	136	61	86	108
14	143	64	90	118
15	137	52	80	100
16	123	67	86	83
17	141	72	95	100

A.7　Brachial Hemodynamics: RA 0 Minutes Post-Exercise

Subject #	SAP	DAP	MAP	HR
1	147	73	98	94
2	121	67	85	76
3	122	73	89	98
4	121	87	98	88
5	133	71	92	102
6	138	60	86	80
7	143	79	100	114
8	143	73	96	87
9	160	79	106	106
10	111	57	75	102
11	132	55	81	103
12	125	67	86	85
13	132	56	81	109
14	132	51	78	114
15	143	58	86	103
16	129	72	91	99
17	121	73	89	89

A.8　Brachial Hemodynamics: AR 0 Minutes Post-Exercise

Subject #	SAP	DAP	MAP	HR
1	137	66	90	122
2	137	67	90	86
3	127	66	86	99
4	137	58	84	106
5	140	62	88	119
6	134	56	82	69
7	114	70	85	112
8	120	72	88	65
9	151	53	86	105
10	125	62	83	107
11	133	50	78	97
12	125	38	67	106
13	136	61	86	108
14	143	64	90	118
15	137	52	80	100
16	123	67	86	83
17	141	72	95	100

A.9 Brachial Hemodynamics: RA 30 Minutes Post-Exercise

Subject #	SAP	DAP	MAP	HR
1	122	69	87	60
2	106	72	83	59
3	104	60	75	70
4	120	72	88	77
5	121	68	86	75
6	112	50	71	55
7	110	67	81	85
8	113	71	85	66
9	126	74	91	82
10	106	48	67	95
11	116	53	74	82
12	110	54	73	66
13	124	81	95	87
14	111	48	69	84
15	97	49	65	85
16	110	59	76	67
17	109	71	84	55

A.10 Brachial Hemodynamics: AR 30 Minutes Post-Exercise

Subject #	SAP	DAP	MAP	HR
1	117	57	77	79
2	107	61	76	57
3	107	55	72	69
4	120	69	86	81
5	115	56	76	95
6	120	52	75	53
7	101	56	71	90
8	116	73	87	58
9	114	54	74	75
10	122	64	83	89
11	102	44	63	79
12	110	44	66	87
13	110	53	72	98
14	120	35	63	117
15	99	39	59	78
16	115	58	77	69
17	110	68	82	64

A.11   Pulse Wave Analysis Trial 1: RA Pre-Exercise

Subject #	aSAP	aDAP	aMAP	aPP
1	104	77	89	27
2	87	60	72	27
3	90	57	73	33
4	100	69	82	31
5	104	76	89	28
6	86	51	64	35
7	90	62	75	28
8	102	73	86	29
9	123	84	102	39
10	86	61	73	25
11	92	57	74	35
12	91	58	71	33
13	102	70	84	32
14	95	68	80	27
15	79	50	62	29
16	83	57	67	26
17	99	71	82	28

A.12   Pulse Wave Analysis Trial 2: RA Pre-Exercise

Subject #	aSAP	aDAP	aMAP	aPP
1	104	77	88	27
2	87	61	73	26
3	89	57	72	32
4	100	69	83	31
5	104	76	90	28
6	86	51	63	35
7	90	62	74	28
8	104	73	87	31
9	124	84	102	40
10	85	61	72	24
11	92	57	73	35
12	94	59	72	35
13	101	70	84	31
14	92	67	79	25
15	78	50	61	28
16	83	57	68	26
17	98	71	81	27

A.13   Pulse Wave Analysis Trial 1: AR Pre-Exercise

Subject #	aSAP	aDAP	aMAP	aPP
1	99	69	81	30
2	84	58	68	26
3	87	53	70	34
4	95	62	76	33
5	101	67	79	34
6	88	52	66	36
7	98	71	83	27
8	111	77	93	34
9	113	73	91	40
10	101	69	85	32
11	91	57	71	34
12	97	64	78	33
13	96	65	78	31
14	104	69	85	35
15	82	52	65	30
16	97	60	77	37
17	96	66	78	30

A.14   Pulse Wave Analysis Trial 2: AR Pre-Exercise

Subject #	aSAP	aDAP	aMAP	aPP
1	100	68	80	32
2	84	58	70	26
3	86	53	69	33
4	96	63	77	33
5	101	67	79	34
6	88	52	66	36
7	98	71	85	27
8	111	77	92	34
9	112	73	91	39
10	98	69	82	29
11	91	57	71	35
12	97	65	78	32
13	96	64	78	32
14	104	69	85	35
15	83	52	64	31
16	96	60	75	36
17	97	66	79	31

A.15 Pulse Wave Analysis Trial 1: RA Mid-Exercise

Subject #	aSAP	aDAP	aMAP	aPP
1	.	.	.	.
2	93	55	72	38
3	109	64	79	45
4	120	80	97	40
5	105	64	81	41
6	99	47	65	52
7	112	69	87	43
8	105	68	85	37
9	131	66	89	65
10	94	54	73	40
11	114	55	80	59
12	105	50	69	55
13	105	59	79	46
14	106	63	83	43
15	89	41	62	48
16	84	58	70	26
17	99	69	84	30

A.16 Pulse Wave Analysis Trial 2: RA Mid-Exercise

Subject #	aSAP	aDAP	aMAP	aPP
1	.	.	.	.
2	93	55	73	38
3	.	.	.	.
4	120	80	98	40
5	105	64	81	41
6	100	48	68	52
7	112	69	87	43
8	104	68	85	36
9	131	67	91	64
10	92	54	71	38
11	114	54	79	60
12	107	48	73	59
13	104	59	79	45
14	106	62	83	44
15	88	42	62	46
16	83	57	69	26
17	100	69	85	31

A.17   Pulse Wave Analysis Trial 1: AR Mid-Exercise

Subject #	aSAP	aDAP	aMAP	aPP
1	113	76	90	37
2	93	59	68	34
3	106	75	90	31
4	119	77	97	42
5	119	78	95	41
6	110	60	81	50
7	106	79	91	27
8	112	82	97	30
9	118	76	94	42
10	93	65	78	28
11	102	57	80	45
12	111	74	89	37
13	106	65	83	41
14	102	72	87	30
15	104	69	84	35
16	103	71	86	32
17	106	80	93	26

A.18   Pulse Wave Analysis Trial 2: AR Mid-Exercise

Subject #	aSAP	aDAP	aMAP	aPP
1	113	76	88	37
2	92	58	68	34
3	105	75	89	33
4	119	77	97	42
5	119	77	95	42
6	109	60	81	49
7	106	79	91	27
8	112	82	97	30
9	119	76	94	43
10	94	65	77	29
11	101	57	77	44
12	110	74	89	36
13	107	68	84	39
14	102	72	87	30
15	109	70	87	39
16	103	71	86	32
17	106	80	93	26

A.19   Pulse Wave Analysis Trial 1: RA 0 Minutes Post-Exercise

Subject #	aSAP	aDAP	aMAP	aPP
1	118	78	96	40
2	100	68	84	32
3	102	76	89	26
4	108	89	98	19
5	108	75	89	33
6	108	62	83	46
7	118	83	100	35
8	119	76	98	43
9	127	85	102	42
10	92	59	73	33
11	101	59	76	42
12	105	71	84	34
13	110	80	94	30
14	99	55	76	44
15	112	61	84	51
16	105	75	89	30
17	103	75	90	28

A.20   Pulse Wave Analysis Trial 2: RA 0 Minutes Post-Exercise

Subject #	aSAP	aDAP	aMAP	aPP
1	120	76	94	44
2	104	69	87	35
3	102	76	88	26
4	108	89	98	19
5	108	75	90	33
6	109	62	83	47
7	118	83	98	35
8	120	75	98	45
9	126	83	100	43
10	92	59	74	33
11	101	59	76	42
12	104	72	84	32
13	110	80	94	30
14	99	55	76	44
15	107	59	80	48
16	106	74	90	32
17	104	75	90	29

A.21 Pulse Wave Analysis Trial 1: AR 0 Minutes Post-Exercise

Subject #	aSAP	aDAP	aMAP	aPP
1	109	73	85	36
2	107	68	86	39
3	106	68	85	38
4	110	70	84	40
5	108	65	83	43
6	103	57	75	46
7	97	72	82	25
8	107	73	90	34
9	112	60	79	52
10	103	62	80	41
11	101	56	76	45
12	89	41	60	48
13	103	51	75	52
14	110	68	89	42
15	111	56	77	55
16	100	68	83	32
17	115	75	93	40

A.22 Pulse Wave Analysis Trial 2: AR 0 Minutes Post-Exercise

Subject #	aSAP	aDAP	aMAP	aPP
1	109	72	85	37
2	107	68	83	39
3	104	68	84	36
4	108	67	82	41
5	108	64	82	44
6	104	57	76	47
7	97	72	82	25
8	105	73	88	32
9	114	58	79	56
10	104	64	81	40
11	103	58	76	45
12	91	40	61	51
13	102	51	74	51
14	110	68	89	42
15	112	54	77	58
16	102	69	85	33
17	114	74	94	40

A.23 Pulse Wave Analysis Trial 1: RA 30 Minutes Post-Exercise

Subject #	aSAP	aDAP	aMAP	aPP
1	100	70	83	30
2	93	72	81	21
3	.	.	.	.
4	102	74	86	28
5	99	69	81	30
6	86	50	65	36
7	94	69	80	25
8	98	72	85	26
9	103	75	87	28
10	87	53	66	34
11	91	55	72	36
12	87	55	69	32
13	105	82	92	23
14	87	49	65	38
15	82	55	64	27
16	92	60	74	32
17	96	72	83	24

A.24 Pulse Wave Analysis Trial 2: RA 30 Minutes Post-Exercise

Subject #	aSAP	aDAP	aMAP	aPP
1	100	70	83	30
2	93	73	82	20
3	.	.	.	.
4	102	73	86	29
5	99	69	82	30
6	86	50	61	36
7	92	68	77	24
8	100	72	86	28
9	103	75	87	28
10	86	52	65	34
11	90	55	71	35
12	88	55	70	33
13	105	83	93	22
14	86	50	67	36
15	81	54	63	27
16	91	60	74	31
17	97	72	83	25

A.25   Pulse Wave Analysis Trial 1: AR 30 Minutes Post-Exercise

Subject #	aSAP	aDAP	aMAP	aPP
1	92	61	73	31
2	87	61	73	26
3	85	56	67	29
4	101	71	84	30
5	92	61	73	31
6	91	53	67	38
7	85	60	69	25
8	102	74	87	28
9	89	54	66	35
10	99	66	79	33
11	79	46	61	33
12	88	52	66	36
13	89	60	70	29
14	85	41	59	44
15	77	44	55	33
16	91	59	74	32
17	95	69	82	26

A.26   Pulse Wave Analysis Trial 2: AR 30 Minutes Post-Exercise

Subject #	aSAP	aDAP	aMAP	aPP
1	91	59	71	32
2	87	62	73	25
3	86	56	72	30
4	101	71	84	30
5	93	64	75	29
6	91	52	65	39
7	85	62	70	23
8	102	74	88	28
9	90	55	68	35
10	99	67	80	32
11	78	45	59	33
12	88	52	66	36
13	88	59	71	29
14	87	41	60	46
15	74	41	53	33
16	91	58	73	33
17	94	69	81	25

A.27 Pulse Wave Velocity: RA Pre-Exercise

| | Peripheral PWV (m/s) | | | | Central PWV (m/s) | | | |
| | Trial 1 | | Trial 2 | | Trial 1 | | Trial 2 | |
Subject #	Value	SD	Value	SD	Value	SD	Value	SD
1	8.6	0.2	9.9	0.5	8.5	0.4	6.5	0.3
2	4.1	0.2	6.9	0.3	5.3	0.2	6.2	0.4
3	7.7	0.7	6.2	0.5	5.0	0.3	.	.
4	8.2	0.6	7.2	0.5	6.1	0.3	6.5	0.6
5	7.2	4.4	7.9	0.4	5.8	0.3	5.4	0.3
6	5.6	0.3	6.3	0.5	4.7	0.4	5.3	0.3
7	8.2	0.8	6.9	0.4	8.5	0.8	7.8	0.5
8	8.5	0.8	8.0	0.6	5.8	0.4	5.3	0.4
9	7.8	0.4	7.9	0.5	7.1	0.6	7.2	0.6
10	7.1	0.6	6.2	0.4	5.3	0.5	4.8	0.3
11	6.6	0.6	7.1	0.6	5.4	0.5	6.4	0.3
12	7.7	0.7	7.1	0.6	4.1	0.2	5.0	0.4
13	6.1	0.4	6.8	0.5	5.0	0.2	5.6	0.3
14	7.6	0.8	11.3	1.2	4.8	0.3	5.8	0.4
15	6.3	0.4	7.0	0.5	4.3	0.2	4.8	0.2
16	5.5	0.6	5.1	0.3	4.8	0.4	4.7	0.3
17	8.9	0.5	8.2	0.7	6.5	0.2	6.0	0.3

A.28 Pulse Wave Velocity: AR Pre-Exercise

| | Peripheral PWV (m/s) | | | | Central PWV (m/s) | | | |
| | Trial 1 | | Trial 2 | | Trial 1 | | Trial 2 | |
Subject #	Value	SD	Value	SD	Value	SD	Value	SD
1	6.6	0.6	9.6	0.6	5.9	0.3	6.0	0.4
2	7.3	0.7	9.1	0.4	4.8	0.3	5.6	0.5
3	6.0	0.4	7.2	0.4	5.0	0.4	4.4	0.2
4	8.9	0.7	7.4	0.5	7.6	0.6	6.0	0.3
5	7.6	0.5	7.0	0.5	6.2	0.3	6.5	0.5
6	6.5	0.4	6.8	0.3	4.7	0.2	6.0	0.4
7	7.3	0.7	7.3	0.4	5.7	0.4	5.7	0.5
8	8.4	0.8	8.5	0.7	7.3	0.7	6.5	0.5
9	7.1	0.5	7.4	0.5	6.4	0.6	6.9	0.5
10	5.3	0.2	4.8	0.2	5.4	0.3	5.6	0.3
11	6.5	0.4	6.2	0.6	6.0	0.5	5.7	0.5
12	6.1	0.3	7.0	0.5	4.4	0.2	5.2	0.5
13	6.9	0.5	7.1	0.4	5.9	0.5	5.2	0.5
14	8.9	0.8	8.0	0.5	5.3	0.4	5.5	0.3
15	6.1	0.5	7.0	0.6	3.8	0.2	3.9	0.2
16	5.8	0.5	5.9	0.5	4.6	0.3	5.3	0.5
17	11.3	0.9	9.2	0.6	5.5	0.3	5.4	0.2

A.29 Pulse Wave Velocity: RA Mid-Exercise

	Peripheral PWV (m/s)				Central PWV (m/s)			
	Trial 1		Trial 2		Trial 1		Trial 2	
Subject #	Value	SD	Value	SD	Value	SD	Value	SD
1	10.6	0.6	7.9	0.4	7.4	0.4	7.2	10.6
2	7.2	0.6	7.5	0.4	6.9	0.4	6.3	7.2
3	5.7	0.2	6.3	0.3	5.0	0.2	5.1	5.7
4	7.5	0.4	7.4	0.5	7.1	0.4	7.3	7.5
5	6.9	0.2	6.4	0.2	6.9	0.5	6.6	6.9
6	6.2	0.4	7.0	0.3	5.1	0.3	5.4	6.2
7	5.3	0.3	5.7	0.5	7.0	0.4	6.8	5.3
8	9.3	0.8	7.0	0.3	5.6	0.3	6.0	9.3
9	7.6	0.4	7.5	0.3	6.1	0.3	8.2	7.6
10	5.4	0.2	4.9	0.2	5.1	0.2	5.2	5.4
11	6.4	0.3	5.8	0.3	7.6	0.4	5.9	6.4
12	6.3	0.3	6.4	0.3	4.8	0.2	4.4	6.3
13	7.6	0.4	6.7	0.4	5.2	0.2	6.0	7.6
14	6.3	0.3	6.7	0.3	5.8	0.4	5.4	6.3
15	4.5	0.2	5.1	0.3	4.6	0.3	4.0	4.5
16	5.5	0.2	5.8	0.3	5.6	0.6	5.6	5.5
17	8.3	0.3	7.9	0.3	5.9	0.3	5.8	8.3

A.30 Pulse Wave Velocity: AR Mid-Exercise

Subject #	Peripheral PWV (m/s)				Central PWV (m/s)			
	Trial 1		Trial 2		Trial 1		Trial 2	
	Value	SD	Value	SD	Value	SD	Value	SD
1	10.6	1.0	9.5	0.5	7.3	0.5	6.2	0.3
2	6.8	0.4	6.7	0.4	4.4	0.3	4.5	0.3
3	8.0	0.5	5.8	0.3	5.2	0.2	4.8	0.3
4	8.7	0.6	8.5	0.6	7.7	0.4	8.7	0.4
5	5.3	0.1	6.1	0.2	6.0	0.2	6.6	0.3
6	6.4	0.5	6.3	0.3	4.5	0.2	6.0	0.5
7	8.1	0.4	6.5	0.3	6.2	0.3	6.0	0.4
8	7.8	0.5	8.9	0.7	6.1	0.5	6.9	0.6
9	9	0.7	7.7	0.5	6.0	0.4	7.8	0.7
10	7.2	0.2	6.2	0.2	5.5	0.1	5.9	0.2
11	6.0	0.3	6.3	0.2	5.9	0.3	6.6	0.4
12	8.0	0.4	7.4	0.4	5.1	0.2	.	.
13	6.1	0.3	6.1	0.3	4.8	0.2	5.3	0.3
14	9.1	0.6	7.5	0.7	4.8	0.3	6.0	0.4
15	7.1	0.4	6.0	0.5	4.3	0.2	4.1	0.2
16	7.7	0.5	7.1	0.6	5.3	0.5	5.8	0.6
17	10.4	0.9	8.0	0.5	5.5	0.1	5.9	0.2

A.31 Pulse Wave Velocity: RA 0 Min Post-Exercise

	Peripheral PWV (m/s)				Central PWV (m/s)			
	Trial 1		Trial 2		Trial 1		Trial 2	
Subject #	Value	SD	Value	SD	Value	SD	Value	SD
1	9.9	0.7	10.5	0.6	7.7	0.5	6.6	0.4
2	6.9	0.3	7.8	0.3	6.1	0.5	6.6	0.3
3	6.7	0.5	6.6	0.2	4.3	0.2	4.6	0.2
4	7.8	0.3	8.5	0.3	6.9	0.4	7.3	0.4
5	6.8	0.3	8.0	0.5	5.9	0.3	5.1	0.3
6	6.4	0.4	6.0	0.3	5.8	0.4	5.7	0.4
7	6.1	0.2	7.4	0.4	5.5	0.3	5.1	0.4
8	9.1	0.6	7.8	0.4	4.7	0.2	5.7	0.4
9	9.5	0.5	8.1	0.7	7.7	0.6	8.2	0.7
10	6.0	0.2	6.8	0.2	4.7	0.2	4.8	0.2
11	6.4	0.2	7.1	0.2	7.0	0.3	8.8	0.5
12	6.9	0.4	7.0	0.3	5.3	0.3	4.6	0.3
13	7.2	0.5	6.4	0.3	5.9	0.3	5.0	0.2
14	7.1	0.4	6.7	0.4	5.1	0.3	5.4	0.2
15	5.0	0.2	5.3	0.3	3.8	0.1	4.0	0.2
16	6.7	0.4	5.8	0.4	5.0	0.4	5.3	0.5
17	9.9	0.8	8.9	0.6	5.4	0.2	5.6	0.3

A.32 Pulse Wave Velocity: AR 0 Min Post-Exercise

	Peripheral PWV (m/s)				Central PWV (m/s)			
	Trial 1		Trial 2		Trial 1		Trial 2	
Subject #	Value	SD	Value	SD	Value	SD	Value	SD
1	7.8	0.4	7.8	0.3	7.6	0.5	7.7	0.5
2	6.7	0.4	6.0	0.2	4.9	0.3	5.1	0.2
3	6.5	0.3	6.0	0.4	5.7	0.3	5.8	0.2
4	7.5	0.4	7.9	0.5	6.8	0.4	8.7	0.5
5	6.5	0.3	5.3	0.2	7.3	0.5	6.0	0.2
6	7.0	0.7	6.3	0.4	5.1	0.2	4.6	0.2
7	5.8	0.2	6.3	0.3	5.5	0.4	5.4	0.3
8	7.7	0.4	8.4	0.3	6.9	0.5	7.5	0.4
9	7.0	0.3	6.1	0.2	6.4	0.4	6.9	0.5
10	5.3	0.2	5.1	0.3	5.8	0.4	6.2	0.3
11	6.1	0.3	5.5	0.1	6.7	0.5	6.9	0.3
12	5.7	0.2	5.3	0.3	4.7	0.3	4.4	0.2
13	7.0	0.3	6.7	0.4	4.8	0.2	5.1	0.2
14	6.3	0.4	7.1	0.4	5.0	0.3	5.9	0.3
15	5.1	0.2	5.3	0.3	4.2	0.2	4.0	0.2
16	7.9	0.6	7.5	0.8	5.6	0.4	5.7	0.5
17	7.5	0.4	8.1	0.4	5.9	0.3	6.6	0.4

A.33 Pulse Wave Velocity: RA 30 Min Post-Exercise

Subject #	Peripheral PWV (m/s)				Central PWV (m/s)			
	Trial 1		Trial 2		Trial 1		Trial 2	
	Value	SD	Value	SD	Value	SD	Value	SD
1	8.8	0.3	9.1	0.4	6.3	0.3	7.5	0.6
2	7.4	0.5	.	.	6.3	0.5	7.0	0.6
3	6.6	0.4	7.7	0.4	4.4	0.1	4.4	0.3
4	7.3	0.8	8.3	0.5	5.8	0.4	6.1	0.4
5	6.6	0.2	5.9	0.3	5.2	0.2	6.6	0.3
6	6.5	0.5	5.7	0.4	4.9	0.3	4.3	0.2
7	8.2	0.6	8.4	0.5	6.4	0.5	5.6	0.5
8	9.8	1.0	9.2	0.7	5.8	0.4	5.5	0.2
9	7.6	0.5	7.4	0.3	6.6	0.3	6.1	0.3
10	5.7	0.2	5.7	0.2	5.0	0.3	4.6	0.2
11	5.7	0.3	6.1	0.5	6.2	0.6	5.4	0.4
12	7.3	0.3	6.4	0.2	4.4	0.2	4.6	0.3
13	6.6	0.3	7.2	0.6	4.9	0.3	6.2	0.3
14	5.4	0.2	6.6	0.4	4.7	0.3	4.4	0.4
15	4.6	0.2	5.5	0.5	4.2	0.2	4.5	0.3
16	5.8	0.4	5.6	0.3	4.3	0.3	4.9	0.3
17	8.0	0.5	7.7	0.5	6.7	0.4	5.7	0.4

A.34 Pulse Wave Velocity: AR 30 Min Post-Exercise

| | Peripheral PWV (m/s) | | | | Central PWV (m/s) | | | |
| | Trial 1 | | Trial 2 | | Trial 1 | | Trial 2 | |
Subject #	Value	SD	Value	SD	Value	SD	Value	SD
1	10.5	0.9	10.1	0.7	6.3	0.4	5.9	0.3
2	.	.	.	.	4.5	0.3	6.0	0.3
3	6.1	0.2	6.1	0.4	3.9	0.1	4.2	0.2
4	7.8	0.4	7.7	0.4	5.6	0.2	6.3	0.3
5	4.8	0.2	6.6	0.3	5.4	0.2	5.2	0.2
6	6.7	0.2	6.4	0.4	5.7	0.5	5.3	0.4
7	6.7	0.5	6.6	0.4	5.5	0.3	6.3	0.4
8	7.0	0.4	6.2	0.5	6.2	0.5	7.1	0.4
9	7.1	0.5	7.1	0.4	7.5	0.5	6.9	0.4
10	6.2	0.3	5.2	0.2	4.8	0.2	5.8	0.3
11	6.4	0.3	6.2	0.2	5.1	0.2	4.9	0.4
12	6.9	0.4	5.6	0.1	5.0	0.2	5.1	0.2
13	6.5	0.3	6.6	0.3	4.9	0.2	5.4	0.2
14	7.1	0.5	6.2	0.3	6.0	0.4	5.0	0.2
15	4.8	0.2	5.1	0.4	3.6	0.2	3.4	0.1
16	7.2	0.6	8.2	0.9	6.0	0.4	5.5	0.4
17	8.0	0.4	9.2	4.0	6.0	0.3	5.5	0.3

Appendix B. Summary Statistics for Study 1

B.1   Aortic Pulsatile Load

<u>**Repeated Measures ANOVA**</u>

Within Subjects Effect	Mauchy's W	Approx. Chi-Squate	df	Sig.	Greenhouse-Geisser
Condition	1.000	0.000	0	.	1.000
Time	0.607	6.346	5	0.275	0.760
Condition * Time	0.151	24.086	5	0.000	0.617

Source		Type III Sum of Squares	df	Mean Square	F	Sig
Time	Sphericity Assumed	77125740.90	3	25708580.30	54.080	0.000
	Greenhouse-Geisser	77125740.90	2.279	33847235.59	54.080	0.000
Time x Condition	Sphericity Assumed	9093383.067	3	3031127.689	6.914	0.001
	Greenhouse-Geisser	9093383.067	1.850	4916622.719	6.914	0.005

<u>**Paired T-Tests**</u>

		95% Confidence Interval				
	Mean	Lower	Upper	T	df	Sig. (2-tailed)
Pre-RA – Mid-RA	-2229.188	-2883.141	-1575.234	-7.266	15	0.000
Pre-RA – P10-RA	-1605.941	-2065.932	-1145.950	-7.401	16	0.000
Pre-RA – P30-RA	-426.375	-714.553	-138.197	-3.154	15	0.007
Pre-AR – Mid-AR	-1286.118	-1581.767	-990.468	-9.222	16	0.000
Pre-AR – P10-AR	-2086.824	-2599.207	-1574.440	-8.634	16	0.000
Pre-AR – P30-AR	-632.765	-963.091	-302.439	-4.061	16	0.001

B.2   Peripheral Pulse Wave Velocity

Repeated Measures ANOVA

Within Subjects Effect	Mauchy's W	Approx. Chi-Squate	df	Sig.	Greenhouse-Geisser
Condition	1.000	0.000	0	.	1.000
Time	0.288	17.076	5	0.004	0.550
Condition * Time	0.819	2.735	5	0.741	0.898

Source		Type III Sum of Squares	df	Mean Square	F	Sig
Time	Sphericity Assumed	3.426	3	1.142	2.609	0.063
	Greenhouse-Geisser	3.426	1.649	2.077	2.609	0.102
Time x Condition	Sphericity Assumed	9.244	3	3.081	7.134	0.001
	Greenhouse-Geisser	9.244	2.694	3.432	7.134	0.001

Paired T-Tests

	95% Confidence Interval					
	Mean	Lower	Upper	T	df	Sig. (2-tailed)
Pre-RA – Pre-AR	0.000	-0.547	0.457	0.000	16	1.000
Mid-RA – Mid-AR	-0.694	-1.196	-0.192	-2.932	16	0.010
P10-RA – P10-AR	0.741	0.242	1.240	3.148	16	0.006
P30-RA – P30-AR	0.125	0.289	0.740	0.433	15	0.671

B.3   Central Pulse Wave Velocity

Repeated Measures ANOVA

Within Subjects Effect	Mauchy's W	Approx. Chi-Squate	df	Sig.	Greenhouse-Geisser
Condition	1.00	0.000	0	.	1.000
Time	0.292	18.114	5	0.003	0.619
Condition * Time	0.543	8.985	5	0.110	0.765

Source		Type III Sum of Squares	df	Mean Square	F	Sig
Time	Sphericity Assumed	3.700	3	1.233	4.975	0.061
	Greenhouse-Geisser	3.700	1.858	1.991	4.975	0.061
Time x Condition	Sphericity Assumed	0.757	3	0.252	1.123	0.237
	Greenhouse-Geisser	0.757	2.294	0.330	1.123	0.237

B.4 Normalized Central Pulse Wave Velocity

Repeated Measures ANOVA

Within Subjects Effect	Mauchy's W	Approx. Chi-Squate	df	Sig.	Greenhouse-Geisser
Condition	1.00	1.000	0	.	1.000
Time	0.292	0.450	5	0.072	0.714
Condition * Time	0.543	0.770	5	0.651	0.883

Source		Type III Sum of Squares	df	Mean Square	F	Sig
Time	Sphericity Assumed	0.001	3	0.000	2.617	0.063
	Greenhouse-Geisser	0.001	2.143	0.000	2.617	0.083
Time x Condition	Sphericity Assumed	0.001	3	0.000	7.424	0.000
	Greenhouse-Geisser	0.001	2.649	0.000	7.424	0.001

Paired T-Tests

	95% Confidence Interval					
	Mean	Lower	Upper	T	df	Sig. (2-tailed)
Pre-RA – Pre-AR	0.002	-0.005	0.009	0.688	16	0.502
Mid-RA – Mid-AR	0.009	0.004	0.014	4.099	15	0.001
P10-RA – P10-AR	-0.008	-0.014	-0.001	-2.616	15	0.019
P30-RA – P30-AR	-0.007	-0.013	-0.001	-2.322	15	0.035

Appendix C. Raw Data for Study 2

C.1 Demographic Information

Group	Subject #	Sex	Age	Height (cm)	Mass (kg)	BMI	Body Fat (%)
Eccentric	1	M	31	169	69.6	24.4	17.0
	2	M	22	174	76.8	25.4	15.6
	3	F	21	164	60.9	22.6	29.6
	4	F	21	159.5	73.2	28.8	48.4
	5	M	25	179.5	69.2	21.5	8.2
	6	F	22	165.1	60.3	22.1	33.2
	7	M	20	183	75.6	22.6	18.6
	8	M	20	182	106.9	32.3	37.6
	9	M	20	191.5	70.3	19.2	16.5
	10	M	26	177	79.8	25.5	8.9
	11	M	24	172.2	71.1	24.0	8.0
Concentric	12	F	23	158.5	49.3	19.6	20.5
	13	M	25	184	79.8	23.6	11.0
	14	M	22	186.5	92.1	26.5	19.0
	15	F	21	177	111.0	35.4	48.3
	16	M	21	173	75.9	25.4	32.9
	17	M	21	169.5	81.5	28.4	41.6
	18	M	27	186.5	81.6	23.5	28.9
	19	M	24	169	70.8	24.8	30.4
	20	M	23	197	93.6	24.1	11.0
	21	M	23	172.7	66.4	22.3	12.2
	22	M	32	169.0	71.0	24.9	17.0

C.2　Brachial Hemodynamics: Pre-Exercise

Group	Subject	SAP	DAP	MAP	HR
Eccentric	1	105	56	72	49
	2	125	57	80	81
	3	94	58	70	57
	4	.	.	.	.
	5	116	58	77	47
	6	98	53	68	65
	7	113	56	75	66
	8	121	75	90	72
	9	116	61	79	62
	10	106	62	77	79
	11	107	55	72	56
	12	131	78	96	54
	13	99	49	61	64
Concentric	14	99	54	69	56
	15	114	53	73	62
	16	128	67	87	42
	17	102	61	75	74
	18	97	55	69	53
	19	114	76	89	70
	20	120	60	80	64
	21	108	65	79	65
	22	118	51	73	59
	23	113.0	58.0	76	60
	24	111.0	67.0	82	56

C.3 Brachial Hemodynamics: 10 min Post-Exercise

Group	Subject	SAP	DAP	MAP	HR
Eccentric	1	118	62	81	56
	2	127	55	79	75
	3	99	52	68	68
	4	.	.	.	.
	5	117	49	72	62
	6	107	57	74	75
	7	116	54	75	75
	8	122	68	86	73
	9	114	50	71	59
	10	114	56	75	81
	11	107	53	71	59
	12	129	70	90	50
	13	107	49	68	77
Concentric	14	106	48	67	74
	15	108	43	65	79
	16	119	46	70	45
	17	116	62	80	79
	18	100	53	69	59
	19	114	62	79	74
	20	117	52	74	79
	21	119	58	78	89
	22	112	43	66	69
	23	115.0	49.0	71	67
	24	113.0	57.0	76	72

C.4 Brachial Hemodynamics: 30 min Post-Exercise

Group	Subject	SAP	DAP	MAP	HR
Eccentric	1	105	55	71	50
	2	126	53	77	69
	3	102	58	73	60
	4	.	.	.	.
	5	.	.	.	.
	6	109	61	77	63
	7	113	52	72	64
	8	121	71	88	69
	9	109	58	75	54
	10	109	57	74	68
	11	104	52	69	53
	12	129	66	87	51
	13	99	48	65	73
Concentric	14	102	52	64	69
	15	107	50	69	72
	16	123	52	76	45
	17	116	60	79	79
	18	98	63	75	57
	19	113	68	83	67
	20	123	53	76	71
	21	128	63	85	76
	22	116	40	65	65
	23	113.0	50.0	71	61
	24	111.0	56.0	74	65

C.5 Pulse Wave Analysis Trial 1: Pre-Exercise

		OI	HR	aSAP	aDAP	aMAP	aPP	AIx	AIx@75
	1	91	52	88	57	72	31	-3	-14
	2	99	79	97	58	74	39	-11	-9
	3	92	59	81	58	68	23	-1	-8
	4	.	.	.	.	.	.	.	.
Eccentric	5	85	49	90	58	70	32	-21	-33
	6	88	56	82	53	66	29	-5	-14
	7	82	59	93	56	71	37	11	3
	8	89	78	103	76	89	27	4	5
	9	99	64	96	61	76	35	-8	-13
	10	91	72	87	63	74	24	4	3
	11	98	58	86	55	69	31	-11	-19
	12	96	54	109	78	91	31	-11	-22
	13	90	61	79	49	61	30	-15	-22
	14	100	57	80	54	67	26	-3	-11
	15	94	60	90	54	66	36	-26	-33
	16	100	40	103	67	81	36	-12	-29
	17	96	72	85	61	70	24	-16	-18
	18	88	56	80	55	66	25	-5	-14
Concentric	19	82	70	99	77	87	22	6	4
	20	100	63	96	60	74	36	-26	-31
	21	87	70	94	66	80	28	10	8
	22	95	61	91	51	65	40	-11	-17
	23	100	54	93	59	75	34	2	-8
	24	88	56	95	68	82	27	7	-2

C.6   Pulse Wave Analysis Trial 1: 10 min Post-Exercise

		OI	HR	aSAP	aDAP	aMAP	aPP	AIx	AIx@75
Eccentric	1	97	65	101	63	81	38	11	6
	2	89	83	96	56	75	40	-4	0
	3	98	67	80	53	66	27	-2	-6
	4	.	.	.	.	.	.	.	.
	5	75	60	90	50	69	40	4	-4
	6	89	72	91	58	73	33	15	13
	7	77	72	98	56	76	42	7	6
	8	83	78	104	69	87	35	8	7
	9	93	60	92	50	68	42	-1	-8
	10	94	78	94	58	74	36	4	6
	11	92	61	88	53	69	35	6	-1
	12	100	53	106	71	86	35	-11	-21
	13	98	82	86	52	67	61	-4	-1
Concentric	14	91	71	81	48	63	33	-1	-3
	15	100	79	81	46	60	35	-9	-7
	16	97	48	89	46	63	43	-9	-22
	17	86	75	94	63	76	31	-1	-1
	18	84	65	80	53	64	27	-7	-12
	19	91	73	92	63	79	29	0	-1
	20	100	72	90	53	69	37	-19	-20
	21	100	66	94	58	75	36	1	-3
	22	78	72	89	45	62	44	-5	-7
	23	86	64	93	50	71	43	3	-3
	24	94	69	93	58	75	35	5	2

C.7   Pulse Wave Analysis Trial 1: 30 min Post-Exercise

		OI	HR	aSAP	aDAP	aMAP	aPP	AIx	AIx@75
	1	99	56	88	56	71	32	6	-3
	2	97	75	96	54	73	42	-7	-7
	3	86	56	84	58	70	26	-4	-13
	4	.	.	.	.	.	.	.	.
	5	.	.	.	.	.	.	.	.
Eccentric	6	95	60	92	61	75	31	14	7
	7	77	66	89	52	67	37	-4	-8
	8	92	71	103	72	87	31	8	6
	9	92	59	90	58	70	32	-8	-15
	10	89	71	92	58	73	34	8	6
	11	95	50	84	53	66	31	1	-11
	12	96	49	103	67	82	36	-11	-23
	13	98	77	80	50	62	30	-7	-6
	14	97	65	80	51	64	29	-5	-10
	15	86	67	81	43	58	38	-15	-18
	16	100	44	93	51	67	42	-10	-25
	17	97	83	92	62	76	30	-7	-2
Concentric	18	88	54	83	63	71	20	-9	-19
	19	83	59	93	68	80	25	-5	-12
	20	97	76	92	54	70	38	-13	-12
	21	85	72	105	64	83	41	11	9
	22	100	57	87	40	57	47	-11	-20
	23	95	54	89	51	69	38	-2	-12
	24	98	62	59	57	71	32	-5	-11

C.8 Pulse Wave Analysis Trial 2: Pre-Exercise

		OI	aSAP	aDAP	aMAP	aPP	aSAP	AIx	AIx@75
Eccentric	1	96	52	88	57	71	31	-4	-15
	2	99	76	97	58	76	39	-5	-5
	3	77	57	81	58	68	23	7	-1
	4	.	.	.	.	.	.	.	.
	5	82	48	91	58	72	33	-8	-21
	6	84	57	82	54	66	28	-3	-12
	7	93	60	94	57	72	37	14	7
	8	87	66	105	76	89	29	10	6
	9	99	62	94	61	74	33	-9	-15
	10	83	75	88	63	74	25	9	9
	11	83	54	86	56	69	30	-9	-19
	12	98	53	108	79	91	29	-5	-16
	13	92	65	80	49	62	31	-14	-19
Concentric	14	89	55	80	84	67	26	1	-9
	15	92	60	91	53	66	38	-25	-32
	16	92	44	102	67	80	35	-12	-26
	17	95	69	85	61	70	24	-14	-17
	18	88	57	80	55	67	25	-5	-13
	19	91	66	100	76	88	24	9	4
	20	100	63	95	61	73	34	-27	-33
	21	83	68	94	66	79	28	12	9
	22	92	59	92	51	67	41	-8	-15
	23	90	58	92	59	76	33	0	-9
	24	96	57	95	68	82	27	6	-2

C.9 Pulse Wave Analysis Trial 2: 10 min Post-Exercise

		OI	HR	aSAP	aDAP	aMAP	aPP	AIx	AIx@75
	1	91	63	101	63	82	38	11	6
	2	94	80	96	56	74	40	-4	-2
	3	78	69	80	52	67	28	-2	-5
	4	.	.	.	.	.	.	.	.
	5	76	53	94	50	70	44	12	2
Eccentric	6	85	69	90	58	73	32	15	12
	7	79	73	98	57	76	41	8	7
	8	87	73	103	69	87	34	10	9
	9	98	61	92	50	67	42	-5	-13
	10	86	77	94	57	73	37	-3	-2
	11	80	59	88	53	68	35	6	-2
	12	100	55	105	71	86	34	-8	-18
	13	95	78	87	51	67	36	-2	-1
	14	96	66	81	48	64	33	-1	-3
	15	89	73	81	44	59	37	-7	-8
	16	86	51	92	47	66	46	-5	-17
	17	97	83	92	62	76	30	-7	-2
Concentric	18	95	59	80	53	65	27	-4	-12
	19	77	72	92	63	79	29	-2	-3
	20	100	75	90	53	69	37	-9	-9
	21	99	69	93	59	74	34	-1	-4
	22	100	72	89	45	62	44	-3	-4
	23	96	64	94	50	70	44	2	-3
	24	89	69	93	58	75	35	6	4

C.10 Pulse Wave Analysis Trial 2: 30 min Post-Exercise

		OI	HR	aSAP	aDAP	aMAP	aPP	AIx	AIx@75
	1	89	59	87	56	70	31	4	-4
	2	88	70	96	54	71	42	-8	-10
	3	.	.	.	.	.	.	.	.
	4	.	.	.	.	.	.	.	.
	5	.	.	.	.	.	.	.	.
Eccentric	6	87	63	84	62	78	32	20	14
	7	90	61	90	52	67	38	-4	-11
	8	83	66	102	72	87	30	8	4
	9	94	58	90	58	70	32	-9	-17
	10	93	68	92	59	74	33	8	5
	11	86	59	84	52	65	32	-1	-9
	12	99	53	103	67	83	36	-8	-19
	13	88	72	82	49	64	33	-3	-4
	14	98	65	80	52	64	28	-9	-13
	15	99	67	81	43	58	38	-14	-18
	16	100	46	93	52	68	41	-10	-24
	17	90	76	92	60	73	32	-7	-7
Concentric	18	95	56	83	63	72	20	-8	-18
	19	84	62	94	68	80	26	-7	-14
	20	94	69	93	54	71	39	-10	-13
	21	.	.	.	.	.	.	.	.
	22	100	60	86	41	58	45	-9	-16
	23	98	62	88	51	70	37	-1	-7
	24	100	62	59	57	72	32	-2	-8

C.11 Pulse Wave Velocity: Pre-Exercise

	Peripheral PWV				Central PWV			
	Trial 1		Trial 2		Trial 1		Trial 2	
	Velocity	SD	Velocity	SD	Velocity	SD	Velocity	SD
1	6.3	0.3	5.7	0.4	5.3	0.2	5.5	0.3
2	7.6	0.6	8.2	0.6	8.1	0.6	7.7	0.6
3	7.6	0.5	7.2	0.7	5.6	0.2	5.1	0.3
4	.	.	.	.	.	.	.	.
5	.	.	5.8	0.6	4.9	0.5	5.4	0.6
6	8.4	1.2	9.7	1.4	5.7	0.6	5.0	0.3
7	4.9	0.4	5.9	0.3	5.1	0.3	5.8	0.4
8	7.4	0.6	7.7	0.8	5.6	0.3	5.9	0.4
9	6.7	0.5	6.5	0.6	5.9	0.5	5.3	0.4
10	6.4	0.4	7.3	0.4	6.3	0.6	6.1	0.3
11	7.5	0.2	7.2	0.3	6.9	0.3	5.8	0.2
12	7.5	0.5	8.1	0.3	6.8	0.3	6.8	0.6
13	6.1	0.6	6.8	0.6	4.7	0.5	5.2	0.5
14	8.0	0.7	6.5	0.4	5.0	0.3	5.1	0.4
15	6.0	0.3	5.5	0.3	5.5	0.6	4.9	0.1
16	5.9	0.4	7.2	0.2	5.3	0.3	5.0	0.4
17	6.9	0.3	5.6	0.2	6.3	0.5	.	.
18	7.4	0.4	7.9	0.8	5.1	0.4	5.8	0.5
19	8.5	0.9	7.3	0.7	5.4	0.4	5.4	0.3
20	6.8	0.4	6.1	0.2	5.5	0.3	5.7	0.3
21	8.3	0.4	8.2	0.7	7.1	0.5	7.3	0.7
22	5.8	0.3	6.2	0.5	6.1	0.5	5.0	0.5
23	6.8	0.3	7.1	0.3	4.8	0.2	5.7	0.3
24	7.70	0.70	7.00	0.40	5.40	0.4	5.9	0.4

Rows 1–13: Eccentric. Rows 14–24: Concentric.

C.12   Pulse Wave Velocity: 10 min Post-Exercise

		Peripheral PWV				Central PWV			
		Trial 1		Trial 2		Trial 1		Trial 2	
		Velocity	SD	Velocity	SD	Velocity	SD	Velocity	SD
Eccentric	1	5.8	0.3	6.7	0.5	4.9	0.2	5.8	0.4
	2	6.5	0.2	6.5	0.4	8.3	0.7	6.5	0.4
	3	8.2	0.3	7.4	0.4	.	.	.	.
	4	.	.	.	.	.	.	.	.
	5	4.5	0.2	6.4	0.6	.	.	.	.
	6	7.0	0.7	.	.	4.8	0.4	4.6	0.3
	7	5.4	0.3	5.9	0.4	7.5	0.6	.	.
	8	7.0	0.4	7.2	0.3	6.9	0.6	5.4	0.2
	9	6.6	0.3	6.6	0.5	5.1	0.4	4.8	0.3
	10	6.9	0.2	5.3	0.3	.	.	.	.
	11	7.1	0.4	7.3	0.3	5.9	0.2	6.5	0.3
	12	6.1	0.2	6.4	0.2	5.8	0.4	.	.
	13	5.6	0.3	6.0	0.3	6.5	0.4	6.3	0.4
Concentric	14	6.5	0.2	6.1	0.3	4.8	0.3	5.5	0.4
	15	5.4	0.2	5.3	0.1	5.4	0.3	5.8	0.3
	16	6.7	0.4	.	.	6.2	0.3	5.4	0.3
	17	6.3	0.4	6.6	0.2	6.7	0.3	6.3	0.7
	18	7.0	0.6	.	.	6.5	0.5	.	.
	19	7.8	0.5	7.3	0.4	5.9	0.3	5.4	0.3
	20	6.5	0.5	7.0	0.5	5.2	0.2	5.3	0.2
	21	8.2	0.3	7.4	0.4	.	.	.	.
	22	5.4	0.3	5.2	0.3	6.1	0.6	6.3	0.5
	23	6.2	0.4	6.8	0.4	5.5	0.2	4.8	0.3
	24	6.0	0.3	6.0	0.2	5.6	0.5	5.4	0.3

C.13   Pulse Wave Velocity: 30 min Post-Exercise

		Peripheral PWV				Central PWV			
		Trial 1		Trial 2		Trial 1		Trial 2	
		Velocity	SD	Velocity	SD	Velocity	SD	Velocity	SD
Eccentric	1	5.8	0.3	6.7	0.5	4.9	0.2	5.8	0.4
	2	6.5	0.2	6.5	0.4	8.3	0.7	6.5	0.4
	3	8.2	0.3	7.4	0.4	.	.	.	.
	4	.	.	.	.	.	.	.	.
	5	4.5	0.2	6.4	0.6	.	.	.	.
	6	7.0	0.7	.	.	4.8	0.4	4.6	0.3
	7	5.4	0.3	5.9	0.4	7.5	0.6	.	.
	8	7.0	0.4	7.2	0.3	6.9	0.6	5.4	0.2
	9	6.6	0.3	6.6	0.5	5.1	0.4	4.8	0.3
	10	6.9	0.2	5.3	0.3	.	.	.	.
	11	7.1	0.4	7.3	0.3	5.9	0.2	6.5	0.3
	12	6.1	0.2	6.4	0.2	5.8	0.4	.	.
	13	5.6	0.3	6.0	0.3	6.5	0.4	6.3	0.4
Concentric	14	6.5	0.2	6.1	0.3	4.8	0.3	5.5	0.4
	15	5.4	0.2	5.3	0.1	5.4	0.3	5.8	0.3
	16	6.7	0.4	.	.	6.2	0.3	5.4	0.3
	17	6.3	0.4	6.6	0.2	6.7	0.3	6.3	0.7
	18	7.0	0.6	.	.	6.5	0.5	.	.
	19	7.8	0.5	7.3	0.4	5.9	0.3	5.4	0.3
	20	6.5	0.5	7.0	0.5	5.2	0.2	5.3	0.2
	21	8.2	0.3	7.4	0.4	.	.	.	.
	22	5.4	0.3	5.2	0.3	6.1	0.6	6.3	0.5
	23	6.2	0.4	6.8	0.4	5.5	0.2	4.8	0.3
	24	6.0	0.3	6.0	0.2	5.6	0.5	5.4	0.3

Appendix D. Summary Statistics for Study 2

D.1   Aortic Pulsatile Load

Repeated Measures ANOVA

Within Subjects Effect	Mauchy's W	Approx. Chi-Squate	df	Sig.	Greenhouse-Geisser
Condition	1.000	0.000	0	.	1.000
Time	0.970	0.275	2	0.871	0.971
Condition * Time	0.809	1.912	2	0.384	0.839

Source		Type III Sum of Squares	df	Mean Square	F	Sig
Time	Sphericity Assumed	4992062.394	2	2496031.197	36.026	0.000
	Greenhouse-Geisser	4992062.394	1.942	2571221.759	36.026	0.000
Time x Condition	Sphericity Assumed	223981.121	2	111990.561	2.121	0.146
	Greenhouse-Geisser	223981.121	1.679	133423.595	2.121	0.156

Paired T-Tests

	Mean	95% Confidence Interval Lower	Upper	T	df	Sig. (2-tailed)
Pre-E – P10-E	-700.455	-1026.180	-374.730	-4.791	10	0.001
Pre-E – P30-E	-167.636	-314.030	-21.243	-2.551	10	0.029
P10-E – P30-E	532.818	275.906	789.731	4.621	10	0.001
Pre-C – P10-C	-639.273	-775.377	-503.169	-10.465	10	0.000
Pre-C – P30-C	-378.455	-618.576	-138.333	-3.512	10	0.006
P10-C – P30-C	260.819	14.095	507.541	2.355	10	0.040

D.2   Peripheral Pulse Wave Velocity

Repeated Measures ANOVA

Within Subjects Effect	Mauchy's W	Approx. Chi-Squate	df	Sig.	Greenhouse-Geisser
Condition	1.000	0.000	0	.	1.000
Time	0.895	0.995	2	0.608	0.905
Condition * Time	0.949	0.475	2	0.789	0951

Source		Type III Sum of Squares	df	Mean Square	F	Sig
Time	Sphericity Assumed	3.082	2	1.541	8.527	0.002
	Greenhouse-Geisser	3.082	1.810	1.702	8.527	0.003
Time x Condition	Sphericity Assumed	0.048	2	0.024	0.107	0.899
	Greenhouse-Geisser	0.048	1.902	0.025	0.107	0.890

Paired T-Tests

	95% Confidence Interval					
	Mean	Lower	Upper	T	df	Sig. (2-tailed)
Pre-E – P10-E	0.564	0.006	1.121	2.253	10	0.048
Pre-E – P30-E	0.118	-0.215	0.451	0.791	10	0.447
P10-E – P30-E	-0.446	-0.905	0.015	-2.158	10	0.056
Pre-C – P10-C	0.446	0.100	0.791	2.871	10	0.017
Pre-C – P30-C	0.109	-0.320	0.538	0.567	10	0.583
P10-C – P30-C	-0.336	-0.730	0.057	-1.906	10	0.086

D.3　Central Pulse Wave Velocity

Repeated Measures ANOVA

Within Subjects Effect	Mauchy's W	Approx. Chi-Squate	df	Sig.	Greenhouse-Geisser
Condition	1.000	0.000	0	.	1.000
Time	0.341	7.530	2	0.023	0.603
Condition * Time	0.810	1.475	2	0.478	0.840

Source		Type III Sum of Squares	df	Mean Square	F	Sig
Time	Sphericity Assumed	0.381	2	0.191	0.798	0.467
	Greenhouse-Geisser	0.381	1.206	0.316	0.798	0.417
Time x Condition	Sphericity Assumed	0.203	2	0.102	0.709	0.507
	Greenhouse-Geisser	0.203	1.681	0.121	0.709	0.486