POST EXERCISE BLOOD PRESSURE RESPONSE TO EXERCISE WITH BLOOD FLOW RESTRICTION

By

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B.S. Southern Illinois University, 2010

A Research Paper

Submitted in Partial Fulfillment of the requirements for the

Master of Science in Education degree

Department of Kinesiology

In the Graduate School

Southern Illinois University Carbondale

May 2012

RESEARCH APROVAL

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Fulfillment of the Requirements

For the Degree of

Master of Science in Education

In the Field of

Exercise Science

Approved by:

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AN ABSTRACT OF THE RESEARCH APPROVAL OF

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TITLE: POST EXERCISE BLOOD PRESSURE RESPONSE TO EXERCISE WITH BLOOD FLOW RESTRICTION

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The restriction of muscle blood flow with short term low-intensity exercise has been shown to enhance muscle size and strength. Post exercise hypotension is consistently elicited following 30-60min bouts of moderate intensity (50-60% peak aerobic capacity) exercise. Following an acute bout of exercise, systemic resistance does not completely recover, resulting in post exercise hypotension. **Purpose:** To determine if exercise with blood flow restriction in healthy individuals is as effective as traditional exercise in eliciting post exercise hypotension. **Methods:** Ten healthy (age =23±2y; VO_2max=38.4±10ml*kg^{-1}*min^{-1}; bodyfat =18±5%) college-aged individuals volunteered to participate in this within subject's design. Participants were randomly assigned to one of two exercise trials: one with blood flow restriction and one without. The normal exercise (NE) trial consisted of level walking at 60% of heart rate max for a total of 60 minutes. Exercise with blood flow restriction (EBR) consisted of level walking at 53.6 m/min (2.0mph) for 20 minutes (two bouts of 10 min). In order to create blood flow restriction, large blood pressure cuffs were placed around the most proximal portion of both legs. Prior to exercise, the pressure in each cuff was set at 100mmHg and increased by 20mmHg while holding for 30s at each pressure and releasing for 10 seconds between increments until the final pressure of 160mmHg was reached. In both exercise trials, heart rate (HR), systolic blood pressure (SBP) and diastolic blood pressure (DBP) were assessed every 5 minutes. Post exercise HR, SBP, and DBP were assessed every 5 minutes for a total of 60 minutes. **Results:**

SBP was significantly lower post NE at minutes 30(111±4 vs. 115±5 mmHg), 35(109±3 vs. 114±5 mmHg), 40(110±2 vs. 115.4±5 mmHg), and 50(111±4 vs.113±4 mmHg) compared to EBR. DBP was significantly lower in the first 5 minutes post exercise (76±7 vs.83±4 mmHg) in the NE vs. the EBR trial. Post exercise HR was significantly higher in the EBR group at 50 minutes (70 ±10 vs.66±10 bpm). **Conclusion:** Exercise with blood flow restriction utilizing a lower duration and intensity of exercise does not appear to yield the same post exercise hypotension as traditional moderate intensity exercise.

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CHAPTER 1

INTRODUCTION

The typical age-related decline in cardiovascular fitness has been attributed to changes in body composition, especially a loss of skeletal muscle (SM) mass referred to as senile sarcopenia. A loss of SM mass leads to an increased risk for development of insulin resistance and type-2 diabetes, as well as reduced levels of daily activity and physical function. This loss of functional ability can contribute to the drop in VO2peak level that is common with advancing age and this VO2peak decline is considered to be a prominent risk factor for both cardiovascular and all-cause mortality in middle-aged and aging adult populations (Abe, et al, 2010). High intensity resistance training is traditionally recommended as the primary method for increasing muscle mass and strength, but this type of training carries with it a higher risk of injury, particularly in an older population (Baechle & Earle, 2008).

Blood flow restriction exercise or "KAATSU" is an exercise training method in which the restriction of muscle blood flow concurrent with short term low-intensity exercise has been shown to induce positive changes in muscle size and strength (Takarada, Sato, & Ishii, 2002). Resistance training at relatively low levels of force (20-50% 1 RM), combined with blood flow restriction, has resulted in gains in strength and hypertrophy that can compare to traditional high-load resistance training (Burgomaster et al, 2003). It is suggested that through the restriction of muscular blood flow during low-intensity aerobic training, certain strength gains can be realized while keeping injury risk low (Takarada, Sato, & Ishii, 2002). A study completed in young men found significant improvements in muscle hypertrophy and greater knee joint strength after blood flow restricted slow treadmill walk training (Abe, Kearns, & Sato, 2006). Elderly subjects have also experienced improvements with blood flow restriction training, with increases in muscular fitness and cardiovascular function, as well as muscular size, strength, and functional ability over a six week time period (Sakamaki, Fujita, Sato, Bemben, & Abe, 2008). Exercise with blood flow restriction training may be a potentially useful method for improving muscle function for a wide range of populations, including those in the rehabilitation phase and frail elderly populations.

Studies in humans have demonstrated that immediately after a single bout of exercise, there are profound changes in the factors that regulate and determine arterial blood pressure. These changes can result in post-exercise hypotension which can last nearly 2 hours in healthy individuals and may last beyond 12 hours in hypertensive patients (Kenny & Seals, 1993). A bout of aerobic exercise has been shown to reduce blood pressure acutely and is often prescribed for people with mild hypertension. In most individuals, the occurrence of post-exercise hypotension is due to a persistent drop in peripheral vascular resistance that is not completely offset by increases in cardiac output (Halliwill, Minson, & Joyner, 2000). Post-exercise hypotension is consistently elicited after 30-60 min bouts of moderate intensity (50-60% peak aerobic capacity) exercise (various modes can trigger the response), whereas shorter or less vigorous exercise elicits inconsistent changes in arterial pressure in normotensive subjects (Halliwill, 2001).

Previous research has indicated that low-intensity dynamic resistance exercise, when combined with blood flow restriction will slightly increase total peripheral resistance (TPR) (Sakamaki, Fujita, Sato, Bemben, & Abe, 2008), which could lead to increased blood pressure. A decrease in TPR (e.g., during exercise) will result in an increased flow to tissues and an increased venous flow back to the heart. An increased TPR will decrease flow to tissues and decrease venous flow back to the heart, causing an increase in systolic blood pressure. Blood flow restriction exercise partially restricts the venous blood flow back to the heart. This causes more blood to be pumped to the area of restriction, which then causes diastole to last almost twice as long as systole.

Williams, Pricher, and Halliwill (2005) investigated aerobic exercise and post exercise blood flow in the leg and found that underlying the post exercise hypotension observed was an elevated leg blood flow through 90 min post exercise. Sakamaki and colleagues (2008) looked specifically at blood pressure response to slow walking combined with blood flow restriction in the elderly. They found significantly higher blood pressures for the blood flow restriction training group compared to the control group, but these blood pressure readings were only taken during the exercise session. There were no reported values for post-exercise blood pressure response.

Statement of Purpose

As stated earlier, most individuals believe the best way to improve their health and become physically fit is by doing vigorous intensive exercise. It is possible that through the restriction of muscular blood flow during low-intensity aerobic training, certain strength gains can be attained while maintaining a lower risk of injury; however, the impact of this technique on the appearance of lower post-exercise blood pressures is unknown. The purpose of the current investigation was to determine if exercise with blood flow restriction in healthy individuals is as effective as traditional exercise in eliciting post-exercise hypotension.

Hypotheses

Traditional exercise would yield greater post-exercise hypotension than exercise with blood flow restriction because of the increased TPR associated with exercise with blood flow restriction.

Assumptions

While conducting this study there were a few assumptions that were made to create a workable research question. It was assumed that the participants participated at a maximal level according to their abilities. It was assumed that participants were able and comfortable using a treadmill.

Delimitations

The participants in the pool were Caucasian, ages 19-26; therefore we cannot generalize our findings to other races or age ranges. We felt that post-exercise blood pressure responses to exercise with blood flow restriction should be determined in young people before testing an older population.

CHAPTER 2

METHODS

Participants

Ten apparently healthy, 19-27 year old (5 male, 5 female) participants were assessed. All participants completed a medical history form, and were screened for a body mass index <29kg/m, normotensive blood pressure (<140/90), overt cardiovascular diseases, cardiovascular medications, and use of tobacco products. All participants signed an informed consent approved by the Southern Illinois University Carbondale Human Subjects Committee.

Design

Participants reported to the laboratory on three separate occasions. The first meeting assessed anthropometric data and established the participant's fitness level (VO_2max testing). During the second meeting, participants were randomly assigned to one of two exercise conditions, normal exercise or blood flow restricted exercise. On the third visit, participants completed the exercise protocol that was not randomly selected for the second meeting. Prior to data collection, all participants were informed of the risks and benefits of this study verbally as well as in writing. All participants were also asked to refrain from engaging in any exercise, alcohol and caffeine consumption for 12 hours and food intake 2 hours before all testing sessions. A total of 48 hours elapsed between each visit to the lab.

Screening Visit

Upon arrival, body mass (kg), height (cm), and body fat percentage, were measured with a balance scale, stadiometer, and skinfold calipers, respectively. Maximal oxygen uptake was assessed using indirect calorimetry (Medgraphics) while undergoing incremental treadmill exercise. Using the Bruce protocol, the participant walked on the treadmill at a very slow speed initially (1.7 mph) at 0% elevation. Every 3 minutes, the speed was increased (0.8 mph) as well as the grade (5% initially, 2% after the first 2 stages) after each stage the changes in heart rate, RPE, and VO_2 were recorded. The test was stopped if signs/symptoms suggested the test should be terminated, if a maximal rate of perceived exertion (RPE) was reached, heart rate reached its max, a VO_2 plateau occurred, or when the participant requested to do so. Since the test was conducted on young, normotensive individuals, a physician was not required to be present.

Blood Flow Restriction Exercise Trial (BFR)

In the blood flow restriction exercise trial, resting blood pressure and heart rate were measured pre-exercise in the supine, sitting, and standing positions. The participant wore a Polar heart rate monitor™ which determined the heart rate both at rest and during exercise. The participant was then asked to sit in a chair while extra-large blood pressure cuffs were placed on the most proximal portion of both legs and taped lightly to secure. The cuffs were slowly inflated to 100mmHg in the sitting position. The participant was then asked to stand and move onto the treadmill. Prior to exercise, the pressure in each cuff was set at 100mmHg and increased by 20mmHg while holding for 30s at each pressure and releasing for 10 seconds between increments until the final pressure of 160mmHg was reached. Blood pressure and heart rate were taken in this position. The technician then started the treadmill and the participant began the exercise protocol which consisted of level walking at 67 m/min (2.5mph) for two 10 minute bouts of exercise (Abe, Sakamaki, Fujita, Ozaki, Sato, & Nakajima, 2010). Arterial pressure (upper arm) and heart rate were measured every 5 min during the exercise bout. After the 20 minute bout of exercise, the treadmill was stopped and the thigh cuff pressure was released immediately. Heart rate and arterial pressure were taken immediately after the release of pressure. The participant then sat down in a chair for post exercise measurements of heart rate and arterial pressure, which were completed every 5 minutes for a total of 60 minutes.

Normal Exercise Trial (NE)

Pre-exercise measurements were identical to the blood restriction condition. The exercise protocol for this trial is level walking at 60% of heart rate max for a total of 60 minutes (Senitko, Charkoudian, & Halliwill, 2002). Arterial pressure (upper arm) and heart rate were measured every 5 min during the exercise bout. After completion of the 60 minute exercise trial, the participant was asked to immediately get off the treadmill and sit in a chair for post exercise measurements of heart rate and arterial pressure which were completed every 5 minutes for a total of 60 minutes.

Statistics

This was a within-participant research design. Data were analyzed using a paired t-test between the two exercise trials for each 5 minute period post exercise. Significance level was set at $p<.05$ and data are presented as means ± standard error of the mean.

CHAPTER 3

RESULTS

Participant characteristics are summarized in Table 1. Post-exercise systolic blood pressure was significantly lower following normal exercise when compared to the blood flow restriction exercise trial at minute 30 (111±4 vs. 115±5 mmHg), 35 (109±3 vs. 114±5 mmHg), 40 (110±2 vs. 115±5 mmHg), and 50 (111±4 vs.113±4 mmHg) (Figure 1, $p < 0.05$). Diastolic blood pressure was significantly lower post-normal exercise when compared to the blood flow restriction exercise trial in minute 5 (76±7 vs.83±4 mmHg) (Figure 2, $p < 0.05$). Post-exercise heart rate responses tended to be higher (non-significant) in the blood flow restriction trial at minute 10 (72±12 vs. 69±8 mmHg), 20 (70±12 vs. 68 ± 10 mmHg) and was significantly higher at minute 50 (69 ± 11 vs. 67 ± 10 mmHg) (p<.05; Figure 3).

N	10
Age, yr	22± 2.0
Height, in	68 ± 3
Body mass, kg	72 ± 15
Body fat, %	17 ± 4
VO2 max, ml/kg/min	38 ± 10
Supine Systolic BP, mmHg	111 ± 4
Supine Diastolic BP, mmHg	69 ± 7
Supine Heart rate, beats/min	64 ± 12
Sitting Systolic BP, mmHg	114 ± 4
Sitting Diastolic BP, mmHg	72 ± 7
Sitting Heart rate, beats/min	69 ± 14
Standing Systolic BP, mmHg	115 ± 6
Standing Diastolic BP, mmHg	75 ± 8
Standing Heart rate, beats/min	74 ± 15

Table 1 – Participant Characteristics

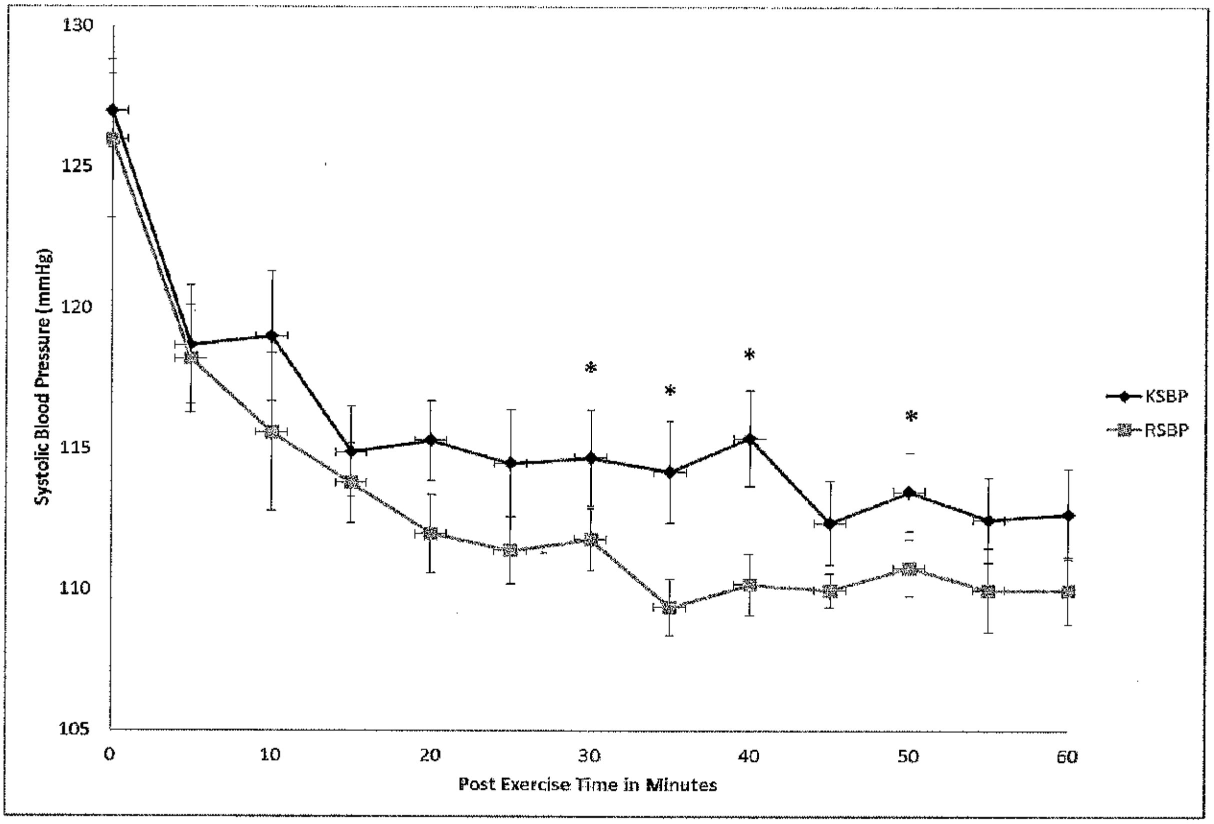

Figure 1 – Post Exercise Systolic Blood Pressure

KSBP = Blood Flow Restriction Post Exercise Trial (Systolic)

RSBP=Normal Post Exercise Trial (Systolic)

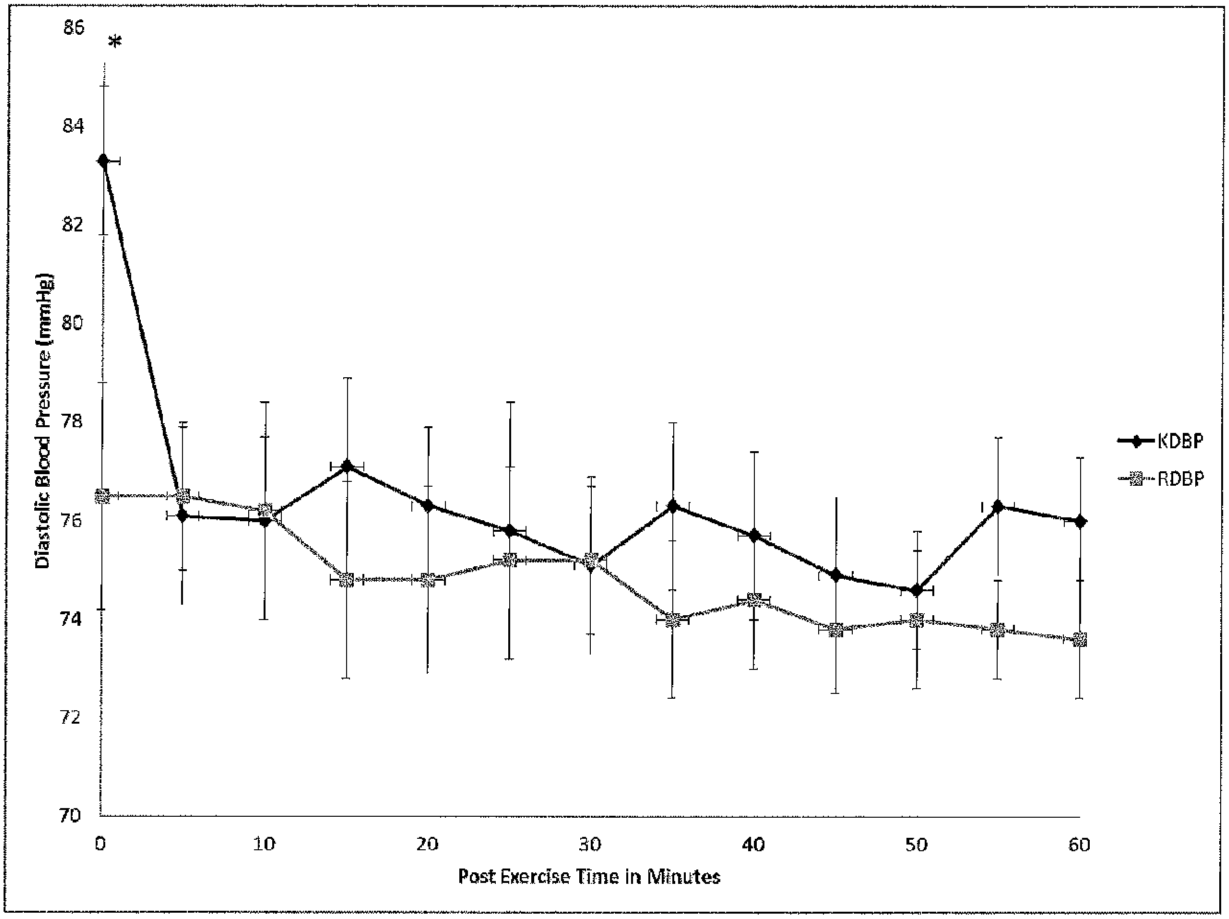

Figure 2 – Post Exercise Diastolic Blood Pressure

KDBP = Blood Flow Restriction Post Exercise Trial (Diastolic)

RDBP= Normal Post Exercise Trial (Diastolic)

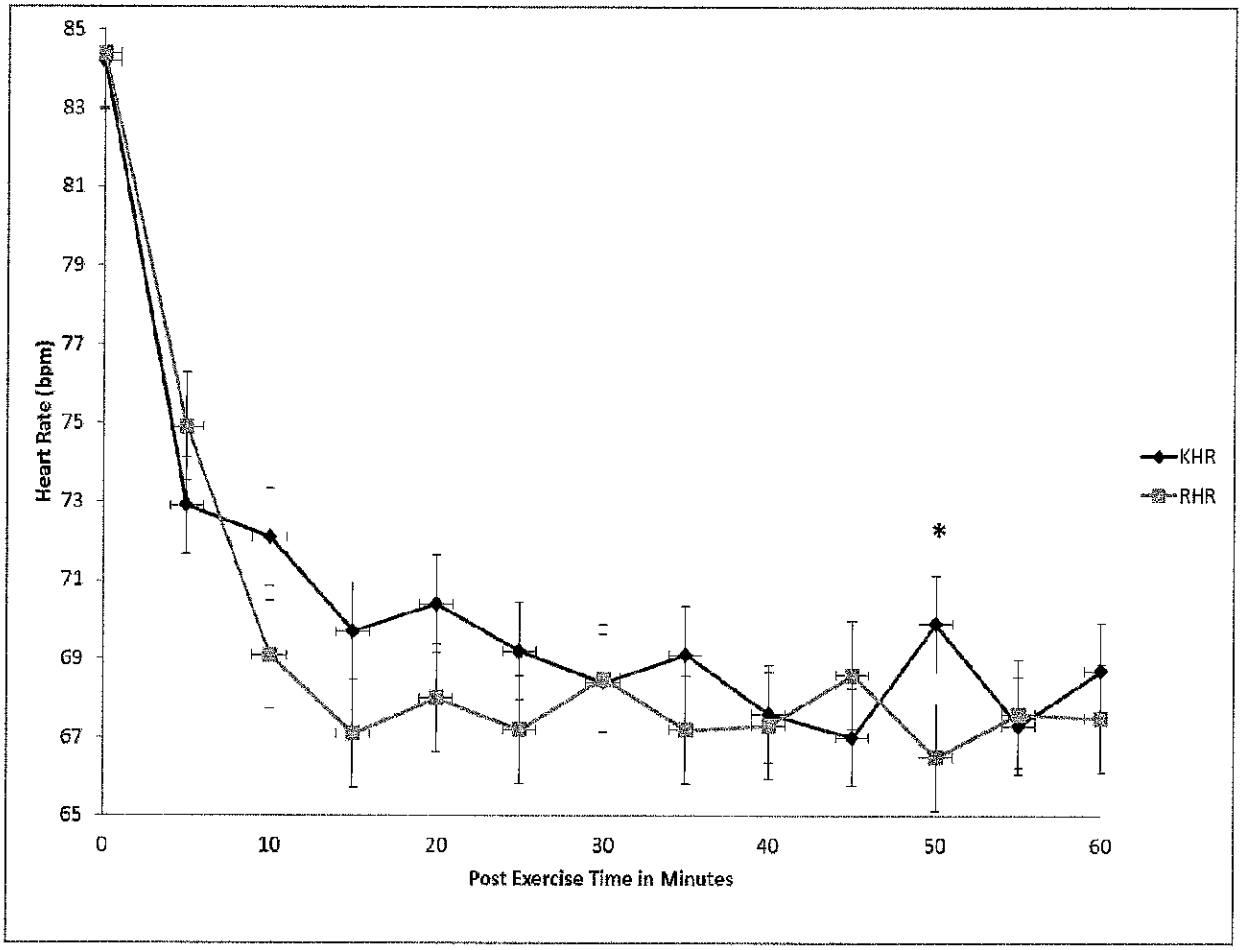

Figure 3 – Post Exercise Heart Rate

KHR = Blood Flow Restriction Post Exercise Trial (Heart Rate)

RHR= Normal Post Exercise Trial (Heart Rate)

CHAPTER 4

DISCUSSION

The goal of this study was to determine if blood flow restricted exercise elicits the same post-exercise hypotension response that is typically noted with exercise using no blood flow restriction. In this study, apparently healthy college age subjects were examined to test the hypothesis that traditional exercise will yield greater post-exercise hypotension than exercise with blood flow restriction. The results of this study supported our hypothesis as we witnessed a more pronounced post-exercise hypotension with the normal exercise trial compared to the exercise with blood flow restriction at the majority of the measurement time points.

Post Exercise Hypotension

Post-exercise hypotension can be observed after various modes of large muscle mass dynamic exercise. In previous research, post-exercise hypotension has been witnessed when exercise bouts last 30-60 minutes at moderate intensity of 50-60% of the aerobic capacity (Halliwill, 2001). In the current study, the "normal" exercise trial was 60 minutes of moderate intensity exercise at 60% of the subject's VO_2 max, which yielded increased post-exercise hypotension. The results from the current investigation support the previous research showing a post-exercise hypotensive response of 4 ± 2 mmHg ($p<.05$, minutes 30-40) compared to pre-exercise values.

Blood Flow Restriction Exercise

In the current study, post-blood restricted exercise hypotension occurred, but was not as pronounced as that seen in the NE trial, and based on previous research, this was likely due to increased TPR in response to BFR. When compared to the normal exercise trial, blood flow restriction exercise had a much higher peak exercise diastolic blood pressure, systolic blood pressure, and heart rate. This is likely due to the restriction on the leg muscle causing the greater increases in peripheral blood flow where the restriction is taking place and less visceral blood flow back to the heart.

Even at low intensities, aerobic exercise with blood flow restriction requires greater cardiac work and decreases endothelial function (Renzi, Tanaka, Sugawara, 2009). Thus it is possible that different exercise intensities have distinct effects on cardiovascular changes after exercise. In the current study, we witnessed a greater demand on the heart during the BFR condition as opposed to the NE. This is evidenced by an average systolic blood pressure of 146 ± 2.9 mmHg, a diastolic blood pressure of 97 ± 2.1 mmHg and a heart rate of 105 ± 5 beats/min during the BFR condition compared to the NE bout which showed an average systolic blood pressure of 136 ± 2.9 mmHg, a diastolic blood pressure of 78 ± 2.1 mmHg and heart rate 116 ± 1.2 beat/min. These results were consistent with previous research which showed peak post-exercise blood pressure taking place between minutes 30-45 (Williams, Pricher, Halliwill, 2005). The increased demand on the heart during the exercise with blood flow restriction was likely due to the restriction of the venous blood flow back to the heart, which then caused more blood to be pumped to the area of restriction, causing diastole to last almost twice as long as systole post exercise. The greater cardiac stress associated with blood flow restriction at low intensities does not appear to cause enhanced vasodilation post exercise. This suggests that exercise with blood flow restriction may not be as beneficial in lowering blood pressure in hypertensive individuals as normal exercise. There is also a concern of safety due to the substantial cardiac stress from the much higher systolic and diastolic blood pressure during exercise with blood flow restriction. Further investigation of the safety of exercise with blood flow restriction should be undertaken prior to prescribing this type of exercise to older adults or adults with cardiovascular disease.

Limitations

This study did not take into consideration individuals muscle mass in the leg when looking at the blood flow restriction exercise trial. In the current study, the pressure on the leg cuff should have related to the individuals body fat percentage instead of a consistent pressure of 160 mmHg. Individuals have different percentage body fat and during this study individuals with a greater percentage body fat seemed to be more pain during the blood flow restriction exercise trial, because of the increased pressure on the muscle in the leg. Furthermore because of the pain associated with the pressure cuff doing a training study or a study with an elderly population could cause some participants to back out of the study.

In addition, the two exercise trials were very different in duration and intensity which makes direct comparison of the exercise trial variables difficult. The BFR exercise trial was a total of 20 minutes in duration, and the NE trial was 60 minutes in duration. Statistically, the two exercise trials were difficult to compare, if there was study conducted with a longer BFR exercise trial that matched the duration of the NE trial there would be an easier way to compare the 2 studies. The intensity of both exercise trials were also very different, the BFR exercise trial had greater demand on the heart with an average blood pressure of 146/97 mmHg and an average heart rate of 105 beats/min as opposed to the NE which had an average blood pressure of 136/78 mmHg and an average heart rate of 105 beats/min. The 2 different protocols were used because previous research has indicated that Post-exercise hypotension is consistently elicited after 30-60 min bouts of moderate intensity (50-60% peak aerobic capacity) exercise (various modes can trigger the response) (Halliwill, 2001) and the protocol that has been used most in previous research for BFR exercise was 67m/min (2.5mph) for two 10 minute bouts of BFR exercise. So the protocols were in relation to previous research and these 2 protocols were used to compare the BFR exercise to the NE trial when it came to post exercise hypotension.

Future Directions

Exercise with blood flow restriction needs to be investigated further in an older population before we safely suggest exercise with blood flow restriction in an older adult population or individuals with cardiovascular disease.

CHAPTER 5

CONCLUSION

Exercise with blood flow restriction utilizing a lower duration and intensity of exercise does not appear to yield the same post exercise hypotension as normal exercise in healthy young people. This suggests that blood flow restriction exercise needs to be completed for a longer period of time to see more pronounced post-exercise hypotension.

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