COMPARISON OF PHYSIOLOGICAL VARIABLES TO PERCEIVED EXERTION DURING AEROBIC AND ANAEROBIC EXERCISE

A Thesis
by
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Abstract

COMPARISON OF PHYSIOLOGICAL VARIABLES TO PERCEIVED EXERTION DURING AEROBIC AND ANAEROBIC EXERCISE

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Rate of Perceived Exertion (RPE) scales are frequently used in different exercise testing environments and have been found to relate to exercise intensity in both aerobic and resistance exercise. In addition, RPE has also been found to relate to other physiological and metabolic values. Examples include maximal oxygen uptake tests (VO_{2max}), heart rate (HR), blood lactate concentrations (BLA), submaximal oxygen uptake (VO_2), and RPE increase as well. Maximal tests in resistance exercise are often one-repetition maximum attempts. In order to compare to the fatiguing nature of VO_{2max} tests, resistance exercise to failure can also be considered a maximum test to evaluate muscular endurance. The purpose of this study was to compare the relationship of RPE to HR, BLA, and VO_2 during aerobic and resistance maximal tests as well as during resistance exercise over time when performed to a predetermined number of repetitions and to failure at varying intensities. Twelve male volunteers (age: 21.4 ± 1.7 years, height: 176.8 ± 4.8 cm, weight: 77.6 ± 10.3 kg, VO_{2max}: 53.8 ± 5.9 mL/kg/min, 1RM: 119.8 ± 22.8 kg) who had a minimum training

experience of two years with both aerobic and resistance exercise were recruited. Volunteers were required to visit our laboratory three times to take part in three separate maximal tests; a treadmill VO_{2max}, a back squat 1RM, and a squat protocol involving six sets of 50%, 70%, and 90% of 1RM to a predetermined number of repetitions (3) as well as to failure (F): 50-3, 50-F, 70-3, 70-F, 90-3, 90-F. VO_2, HR, BLA, and RPE using the Borg 6-20 scale were measured throughout all three maximal tests. RPE was found to significantly relate to resistance exercise intensity only when performing sets to a predetermined number of repetitions (50-3, 70-3, 90-3: R = 0.73; 1RM protocol: R = 0.85), but not when performing to failure (50-F, 70-F, 90-F: R = -0.12); it also had no significant relationship to any physiological variable in resistance exercise. HR (50-3: 129.1 ± 13.9 bpm, 70-3: 141.9 ± 16.3 bpm, 90-3: 147.5 ± 19.9 bpm) showed a trend similar to RPE (50-3: 9.6 ± 2.1, 70-3: 12.1 ± 1.4, 90-3; 14.9 ± 2.7) when performing sets to a predetermined number of repetitions, but no significant difference to failure (HR: 50-F: 159.9 ± 24 bpm, 70-F: 161 ± 11.8 bpm, 90-F: 150.6 ± 17.2 bpm; RPE: 50-F: 16.3 ± 1.7, 70-F: 16.2 ± 2.3, 90-F: 15.7 ± 2.1). VO_2 related more to repetitions instead of intensity during the squat protocol (vs. repetitions: R = 0.71, vs. intensity: R = -0.21). BLA showed no significant effect to repetitions during the squat protocol (R = 0.16) or intensity (R = -0.06). Overall, RPE only relates to resistance exercise intensity during a 1RM protocol and during sets to a predetermined number of repetitions. There is no relationship between RPE and intensity when performing sets to failure or to any physiological variable during either protocol and therefore, should be used with caution if measuring resistance exercise intensity.

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Chapter 1

Introduction

Rate of perceived exertion (RPE) scales are continuously being studied for their many uses with physical activity. The scales (i.e., Borg 6-20 scale) which measure an individual's psychosomatic response to exercise, were originally shown to increase as aerobic exercise intensity increases (Borg, Hassmén, & Lagerström, 1987; Buckley & Borg, 2011). However, the Borg 6-20 scale is now being used to rate perceived effort during resistance exercise as well. The Borg scale has been found to correlate to heart rate (HR) and blood lactate during incremental aerobic exercise (Borg et al., 1987; Borg, Ljunggren, & Ceci, 1985; Noble, Borg, Jacobs, Ceci, & Kaiser, 1983; Scherr et al., 2013), but little is known on the relationship with RPE scales and heart rate or blood lactate levels during resistance exercise.

Maximal exercise tests are used in both aerobic and resistance exercise in laboratory settings as well as training programs. Blood lactate concentrations, HR, and RPE are frequently used to ensure volitional exhaustion is reached. However, it is often necessary to use both as feedback variables because not all individuals will have the same physiological and psychosomatic responses (Borg, 1970). As a natural instinct, one evaluates exercise based on the work performed and the fatigue felt. RPE simply applies numerical values that can be used universally in laboratory and practical settings (Borg, 1970). Knowing if there

are relationships with RPE scales and the two different exercise modalities can aid in implementing corresponding guidelines during maximal testing and training.

Comparing the use of RPE scales among aerobic and resistance exercise have increased over the years. Different methods of evaluating volitional failure during resistance exercise have also been developed to accurately and practically estimate effort during laboratory and real-life settings (Day, McGuigan, Brice, & Foster, 2004; Foster et al., 2001; Singh, Foster, Tod, & McGuigan, 2007; Sweet, Foster, McGuigan, & Brice, 2004). Acute, session, active muscle, and overall RPE are examples of manipulating RPE. Most RPE scales were developed using algorithms in which values would increase as aerobic exercise intensity increased (Borg et al., 1987; Buckley & Borg, 2011; Suminski et al., 1997). Similar results have been found for resistance exercise (Kraemer et al., 1993; Lagally et al., 2002; Lins-Filho et al., 2012; Thornton & Potteiger, 2002; Vianna et al., 2011). For example, RPE was found to increase both in aerobic and resistance exercise as intensity increased (Sweet et al., 2004; Thornton & Potteiger, 2002). While RPE has been used in both exercise modalities, there is little known about its relationship to other physiological variables during maximal effort tests, especially in resistance training.

Maximal oxygen uptake tests (VO_{2max}) are used in laboratory settings in order to assess the interaction of the cardiovascular, respiratory, and muscular systems in individuals (Schrieks, Barnes, & Hodges, 2011). The tests usually involve incremental exercise in which HR, RPE, and blood lactate concentrations (BLA) are taken to understand the physiological response as well as determine volitional exhaustion of the participant. During a VO_{2max} test,

it is suggested that failure has been reached if the HR is within a percentage of the age-predicted maximum, high post-exercise blood lactate concentration is seen (>8mmol/L), and if RPE has reached a minimum of 17 on the Borg 6-20 scale (Howley, Bassett, & Welch, 1995; Thornton & Potteiger, 2002). In order to work at a predetermined level, percentages of VO_{2max} and are used frequently to develop testing and training protocols. In addition to VO_{2max}, HR and BLA are assessed to evaluate effort. Heart rate increases during exercise as the need for oxygen and other nutrients increase. Age predicted HR is often used as a maximal value that is safe for individuals to work at based on their age. Percentages of maximum HR can be used like $\%VO_{2max}$ in quantifying endurance training loads thus being able to use HR as a training tool (Wicks, Oldridge, Nielsen, & Vickers, 2011; Wong et al., 2011). Performing incremental aerobic exercise on treadmills and cycle ergometers elicit strong relationships between RPE and HR and BLA values (Scherr et al., 2013). In addition, Scherr et al. (2013) also determined that RPE had a strong relationship with lactate threshold when examined in a large cohort of outpatient cardiovascular screening patients and can be used to work at and therefore train to increase lactate threshold. RPE can also be used to estimate lactate threshold during incremental cycle ergometry (Fabre et al., 2012).

In resistance training, maximal strength tests are often used to determine the highest load one can perform in a single repetition of a specific exercise (1RM). The test can be performed to find maximal strength in single-joint, multi-joint, and power movements. Similar to VO_{2max}, the 1RM can help in developing testing and training protocols for resistance exercise as well as measuring progress. Although no physiological parameters are

measured during a 1RM test aside from strength and/or power, it is possible that HR, blood lactate concentrations, VO_2, and RPE can also be used to determine maximal effort.

Heart rate, while relatively easy to observe, is not regularly measured during maximal strength tests due to the short nature of the exercise bout. Thus, HR response during resistance training has only been minimally studied. Most studies that have been performed investigate effects on special populations such as cardiovascular patients, although HR's relationship to RPE has been studied. Miller et al. (2009) compared HR response and RPE in resistance training during four different concentric, eccentric, and traditional concentric-eccentric exercises in 31 females and found that eccentric movements elicit significantly lower HR and RPE values compared to concentric and traditional resistance exercise gives the highest values. Additionally, Suminski et al. (1997) determined that HR does not seem to relate to overall body RPE using the CR-10 scale in resistance training even when comparing two different intensities on eight male recreational weight lifters. The CR-10 category ratio scale was developed in order to give a simpler range of numbers to individuals' levels of exertion (Borg, 1982). Thus, the relationship with HR and other RPE scales is unknown and more research on HR response to resistance training is warranted.

Blood lactate concentration values increase as loads of increasing %1RM are performed (Kraemer, Noble, Clark, & Culver, 1987; Suminski et al., 1997). Blood lactate also has been found to have a strong correlation to RPE during resistance training (Kraemer et al., 1987). While RPE increases with intensity, BLA does not increase as suddenly due to the anaerobic nature of resistance exercise. Lagally et al. (2002) found that while overall

RPE and RPE of the active muscle increased when performing resistance exercises to a predetermined number of repetitions from 30% (twelve repetitions), 60% (six repetitions) and 90% (four repetitions) of 1RM, BLA only increased significantly between the 30% and 90% trials when lactate was measured before and after each intensity on twenty female recreational weight lifters. This suggests that BLA as a physiological indication of fatigue may not be as sensitive as a psychosomatic variable such as RPE.

RPE has been found to relate to physiological variables such as heart rate and lactate and is considered a valid marker of stress during resistance exercise (Hollander et al., 2003). It has been speculated that while RPE increases as a function of intensity, HR increases due to the adrenaline response to a greater stress (Wickwire, McLester, Green, & Crews, 2009). Alternatively, the increase in RPE is likely due to the increase in blood lactate concentrations, making the movements feel more difficult (Borg, 1998). When comparing intermittent resistance exercise to continuous aerobic interval training at the same relative intensity, Bloomer (2005) found that RPE values tend to be greater during resistance exercise, but VO_2, energy expenditure and total work were greater in aerobic exercise. Heart rate was not significantly different between the two different types of exercise indicating that RPE may not correlate to all physiological variables within varying methods of exercise.

Although few studies assess RPE during maximal resistance tests, many conclude that RPE increases as intensity during resistance exercise increases (Buckley & Borg, 2011; Gearhart et al., 2002; Lagally, McCaw, Young, Medema, & Thomas, 2004; Lins-Filho et al., 2012; Suminski et al., 1997; Sweet et al., 2004; Tiggemann et al., 2010). If RPE increases as

the %1RM increases, it can be assumed that the RPE value should reach a plateau or threshold similar to an aerobic maximal test upon reaching volitional failure. Over time VO_2, HR, blood lactate concentrations, and RPE have been seen to increase throughout fatiguing exercises (Mielke et al., 2009). In order to properly compare the physiological and psychosomatic differences between resistance and aerobic exercise, it is necessary to evaluate the parameters during both maximal tests and when each are performed at different comparable intensities to failure, therefore ensuring maximal effort. Therefore, the purpose of this study is to compare the relationship of RPE to HR, blood lactate, and oxygen uptake during aerobic and resistance maximal tests as well as during resistance exercise over time when performed to a predetermined number of repetitions and to failure at varying workloads.

Chapter 2

Methodology

Twelve male volunteers (age: 21.4 ± 1.7 years, height: 176.8 ± 4.8 cm, weight: 77.6 ± 10.3 kg, VO_{2max}: 53.8 ± 5.9 mL/kg/min, 1RM: 119.8 ± 22.8 kg) were recruited from the general student population of Appalachian State University through posted flyers and mass e-mails. Recruitment criteria included being a male aged 18-25 years, with no contraindications to exercise, and currently involved in a training program that involved both aerobic and resistance exercise for a minimum of two years. Each subject signed an informed consent form approved by the Institutional Review Board as well as the Appalachian Screening Questionnaire for Research Involving Exercise in order to ensure voluntary involvement and to screen for any contraindications to the exercises to be performed. Subjects were notified to refrain from exercise outside of the research study for a minimum of 48 hours prior to the first session and throughout the duration of the data collection.

Study Design

Subjects were required to report to the Holmes Convocation Center on the campus of Appalachian State University on three occasions each separated by a minimum of three days. All tests were performed in the Human Performance Laboratory (HPL) and Neuromuscular and Biomechanics Laboratory (NBL). Day 1 involved the completion of a medical history

questionnaire as well as having height (cm) and body mass (kg) recorded. Subjects then completed either a treadmill VO_{2max} test or a one repetition max test (1RM) in a traditional back squat. The maximal tests were randomized in order to decrease any possibility of error of muscular fatigue during Day 3. Day 2 involved the remaining maximal test. On Day 3, subjects performed a squat protocol (SP) of six randomized sets of resistance exercise at various percentages of their 1RM.

During each testing session, the subject was attached to a Parvo Medics TrueOne 2400® Metabolic cart (Sandy, UT) in order to assess oxygen uptake (VO_2). Breath-by-breath analysis of percent expired carbon dioxide (CO_2), percent expired oxygen (O_2), and total volume of expired air was collected and analyzed. During resistance exercise, time was noted at the beginning and end of each set and VO_2 was averaged during this time period for data analysis. Prior to each testing session the cart was calibrated to room air and a known gas (16% O_2 and 4% CO_2) as instructed by the manufacturer's specifications. Heart rate (HR) was measured using a Polar Pacer heart rate monitor strapped at sternum level of the subject. A 0.7µL blood sample was taken in order to analyze blood lactate (BLA) by a finger prick using a Lactate Plus analyzer (Nova Biomedical, Waltham, MA). Trained and experienced individuals administered all maximal tests and collected blood lactate samples. Prior to each use, the Lactate Plus analyzer was calibrated according to the manufacturer's specifications.

RPE

Perception of effort was evaluated throughout each testing session using Borg's 6-20 scale (Borg, 1970). The 6-20 scale has been used in both resistance training and aerobic exercises to determine volitional fatigue and has been found to elicit proper readings in

relation to work and intensity in resistance training despite being developed with aerobic exercise in mind (Borg, 1982; Gearhart et al., 2002). Various scales have been employed throughout recent investigations; including CR-10, OMNI, as well as modified scales (Day et al., 2004; Gearhart et al., 2002; Gearhart, Lagally, Riechman, Andrews, & Robertson, 2009; Hardee et al., 2012; Lagally & Robertson, 2006; Lagally et al., 2002; Suminski et al., 1997) and the 6-20 scale, with proper category properties was thought to be the most widely accepted and therefore simplest to use. Borg's 6-20 scale has been determined to be valid for use during resistance exercise (Gearhart et al., 2001).

Prior to each testing session the subjects were each shown the RPE board and were asked to familiarize themselves with the 15 point scale as described by Noble and Robertson (1996). The scale is presented in whole numbers ranging from six to twenty, some of which are anchored to verbal descriptions of exertion. Prior to each session it was explained that immediately following each set of resistance exercise or phase of aerobic exercise, the subject would be shown the scale and asked to provide his value describing their effort during that particular set, where the number six is equal to the effort exerted while resting, seven could be associated with walking or body weight squats, and twenty is the highest level of effort the subject could have possibly applied.

VO_{2max} Testing

An incremental treadmill test to volitional failure was performed by each subject in order to calculate the maximum rate at which oxygen could be utilized by the working muscles, as well as change in HR, BLA, and RPE during aerobic exercise. Subjects had a minimum of five minute rest during which resting HR and BLA were acquired. The VO_{2max}

protocol used was modified to involve a period between each stage during which the subject refrains from running in order to collect the necessary data. The protocol involves a warm-up stage of where the subject walks at 3 miles per hour (mph) and 0% grade for 3 minutes with each following stage lasting 4 minutes. Rate of perceived exertion was taken with 40 seconds left in the stage, at which time the subjects were asked to stop exercise and straddle the treadmill belt with approximately 30 seconds left in each stage so blood lactate measures can be taken. Stage one begins at 6 mph and 1% grade. From stage one to stage five, speed increases 1 mph per stage and grade remains at 1% so that by stage five subjects are to be running at 10mph on a 1% grade. From stage five to stage seven the speed continues to increase at 1 mph and grade increases 1% every stage, so that at stage seven subjects are running 12mph at 3% grade. From stage seven to stage ten, speed remains the same, and grade increases by 1% every stage until it reaches 5% so that by stage 10 the speed is 12mph and the grade is 5%. At the end of each two minute period, HR, BLA, and RPE (using the Borg 6-20 scale) were collected. Verbal encouragement was provided to each subject to motivate the subject to exhaustion. The test was continued until volitional exhaustion was reached.

1RM Testing

The subjects also reported to the NBL on either Day 1 or Day 2 to perform a one-repetition maximum test of a traditional back squat. After a minimum of five minute rest during which resting HR and BLA were found, a warm-up protocol consisting of 1 set of 10 repetitions (WU10), 1 set of 6 repetitions (WU6), and 1 set of 3 repetitions (WU3) with progressively increasing weight was used prior to maximal repetitions. Subjects began the

squat by standing with their feet shoulder width apart, with a barbell positioned on their upper back. They were asked to squat down as low as possible, allowing a minimum of a 70 degree angle between the calf and hamstring, and return to a standing position. The subject stood on a force plate in order to calculate force, velocity, and power performed during each repetition, and consequently throughout the entire set. Linear Position Transducers (LPTs) attached to the barbell were used to visualize squat depth and frequency using LabVIEW 2012. One repetition max was determined as the maximum amount of weight that is lifted properly with no help from a spotter. A spotter stood on each end of the bar in order to avoid interference with force plate data. Verbal encouragement was offered throughout the session. A minimum of five minutes rest were given between each warm-up set and between each following maximal attempt. Research shows the need for at least 5 minutes of rest between sets of multiple-joint exercises in order to decrease influence on RPE and number of repetitions able to be executed (Senna et al., 2011). Heart Rate, BLA, and RPE were assessed immediately after each set and maximal attempt. In addition, the subject was attached to the Parvo Medics Metabolic cart throughout the testing session to determine oxygen consumption during each set. Oxygen uptake was also monitored after the set and when values reached resting numbers, subjects were allowed to remove the face mask to drink water ad libitum or move around the lab as desired.

Resistance Exercise Bouts

On Day 3, the subjects were asked to perform six randomized sets of squats at approximately 50%, 70%, and 90% of the previously determined 1RM to complete the squat protocol (SP). The weight used was within 2 kilograms of the actual percentage of the 1RM.

Each workload was then performed to three repetitions (50-3, 70-3, 90-3) as well as to volitional failure (50-F, 70-F, 90-F) As in the 1RM testing day, all resistance exercises were performed on a force plate and using a bar attached to two LPTs after a minimum of five minutes rest during which resting HR and BLA were found. A spotter stood at each end of the bar to offer assistance when the subject failed. Verbal encouragement was offered throughout each set. Immediately following each set, the subjects were asked to provide the level of volitional fatigue using the Borg 6-20 scale, at which time HR and BL were also assessed. The subjects were then given a minimum of 10 minutes rest in between each set. The metabolic cart was used throughout each. Time was noted as exercise began and ended in order to account for duration of the set and to evaluate the proper data for analysis. After the completion of the set, VO_2 values were monitored until they returned to resting values, at which time the subjects were allowed to remove the mouthpiece. During each 10 minute rest, subjects were allowed water ad libitum as well as freedom to stretch or move about the laboratory as they so desired.

Peak Power

Custom-designed LabVIEW (National Instruments, Version 8.2, Austin, Texas, USA) programs were used to analyze the data. Linear position transducers (LPT, Celesco Transducer Products, PT5A-150, Chatsworth, California, USA) that are mounted to the top of a rack, anterior and posterior to the subject, were attached to a standard 20kg weightlifting bar. The LPTs transmit signals to the LabVIEW program to determine vertical displacement of the bar during the squats. Each set of squats was performed on a force place (AMTI, BP60011200; Watertown, MA) transmitting signals to LabVIEW measuring velocity and

force of the subject during each squat. The analog signals were collected at 1000 Hz using a BNC-2010 interface box with an analog-to-digital card (National Instruments, NI PCI-6014, Austin, Texas, USA). Spotters stood at each end of the bar and were instructed not to step on the force place. Peak power exerted throughout the displacement of each single squat was calculated as well as peak power by repetition and total power per set.

Statistical Analysis

Student's *t*-tests were used to determine significant differences between means of separate data of resistance exercise sets, $p \leq 0.05$. Pearson's Moment was used to assess any correlations between RPE, intensity and repetitions to each physiological variable during each of the resistance exercise sets. All statistical analyses were run on Microsoft Excel 2010.

Chapter 3

Results

Subject characteristics for each subject are represented in Table 1. Each subject was aerobically fit according to American College of Sports Medicine standards and had an average 1RM of 1.5 times body mass.

Table 1. *Subject characteristics*

Age	21.4 ± 1.7
Height (cm)	176.8 ± 4.8
Weight (kg)	77.6 ± 10.3
VO_{2max} (mL/kg/min)	53.8 ± 5.9
1RM (kg)	119.8 ± 22.7
Resting HR (bpm)	75.8 ± 13.0
Resting BLA (mmol/L)	2.3 ± 1.3
Resting VO_2 (mL/kg/min)	5.5 ± 1.0

Values at volitional exhaustion from the VO_{2max} test are represented in Table 2. Maximal oxygen consumption was achieved by each subject according to the following criteria: a plateau in oxygen consumption prior to volitional exhaustion, an increase in RPE ≥ 17, HR within 95% HR_{max}, and BLA > 8 mmol/L (Howley et al., 1995). As expected, as exercise intensity increased, each variable also increased.

Table 2. *VO_{2max} Maximal Values*

RPE	19.1 ± 1.0
HR (bpm)	191.6 ± 9.6
BLA (mmol/L)	13.6 ± 2.5

Table 3. *Results, 1RM protocol and Squat Protocol (Mean* ± SD)

	RPE	HR (bpm)	BLA (mmol/L)	AVG VO_2 (mL/kg/min)
1RM				
WU10	10.8 ± 2.0	136.8 ± 22.3	3.9 ± 1.5	15.9 ± 3.3
WU6	13.0 ± 1.3 ^	147.2 ± 16.3	4.5 ± 2.0	13.4 ± 2.6
WU3	14.8 ± 1.2 +	142.9 ± 12.2	4.9 ± 2.3	12.3 ± 1.7 ^
1RM	17.4 ± 1.2 &	140.3 ± 15.6 +	4.5 ± 2.6	12.6 ± 1.3 ^
Squat				
50-3	9.6 ± 2.1	129.1 ± 13.9	8.2 ± 4.7	11.1 ± 3.0
70-3	12.1 ± 1.4 *	141.9 ± 16.3 *	7.2 ± 2.0	14.1 ± 4.1
90-3	14.9 ± 2.7 #	147.5 ± 19.9	9.2 ± 5.4	14.0 ± 3.6
50-F	16.3 ± 1.7	159.9 ± 24.0 ~	11.0 ± 5.6 *	29.7 ± 10.7 ~
70-F	16.2 ± 2.3	161.0 ± 11.8 ~	10.8 ± 5.9 *	27.6 ± 12.1 ~
90-F	15.7 ± 2.1	150.6 ± 17.2	8.5 ± 6.3	16.2 ± 4.7

RPE, HR, BLA, and Average VO_2 during resistance exercise. ^: Significantly different than WU10, +: significantly different than WU6, &: significantly different than WU3, *: significantly different than 50-3, #: significantly different than 70-3, ~: significantly different than 90-F. ($p < 0.05$)

Means and standard deviations during both resistance exercise protocols are presented in Table 3. During resistance exercise, RPE was found to be significantly different according to intensity when completing sets to a predetermined number of repetitions (50-3: 9.6 ± 2.1, 70-3: 12.1 ± 1.4, 90-3: 14.9 ± 2.7) and when completing the 1RM protocol (WU10: 10.8 ± 2.0, WU6: 13.0 ± 1.3, WU3: 14.8 ± 1.2, 1RM: 17.4 ± 1.2). RPE values during the SP are shown in Figure 1. The 50-3 and 70-3 RPE values were significantly lower than any other condition to three or to failure. However, the three conditions to failure did not show significantly different RPE values despite the varying resistance exercise intensity (50-F: 16.3 ± 1.7, 70-F: 16.2 ± 2.3, 90-F: 15.7 ± 2.1). During the 1RM protocol, RPE values increased significantly throughout the warm-up until the maximum intensity. 1RM RPE was significantly higher than each of the sets completed to a predetermined number of repetitions, but was not significantly different than the values of the sets completed to volitional failure. Nonetheless, RPE only exhibited a strong relationship with resistance exercise intensity during the 1RM protocol (R = 0.88) and during sets completed to a predetermined number of repetitions (R = 0.72). RPE also elicited a strong negative correlation to repetitions during the 1RM protocol (R = -0.85). Repetitions and duration for each set during SP are shown in Table 4. RPE did not relate to intensity during sets completed to volitional failure (R = -0.12) or overall among both protocols (R = 0.54).

Table 4. *Repetitions and Duration, SP*

	Repetitions	Duration (sec)
50-3	3.0 ± 0.0	14.7 ± 5.1
70-3	3.0 ± 0.0	16.2 ± 4.4
90-3	2.8 ± 0.4	20.9 ± 7.8
50-F	33.5 ± 7.6	140.4 ± 53.4
70-F	16.3 ± 5.0	75.9 ± 27.8
90-F	3.33 ± 2.7	31.3 ± 22.5

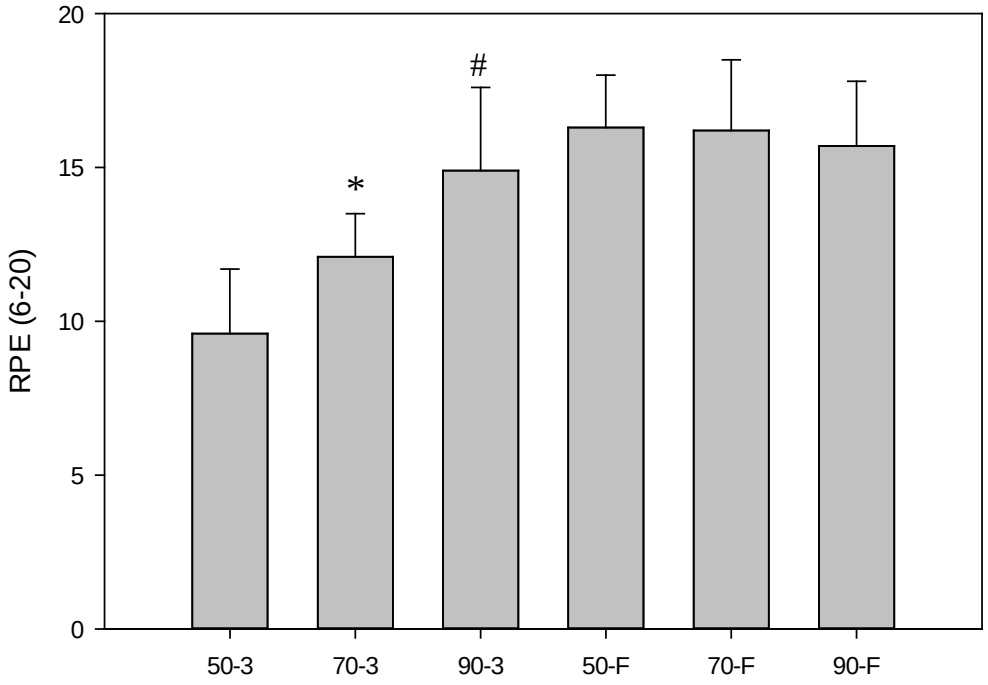

Figure 1. Ratings of Perceived Exertion across SP resistance exercise conditions. RPE significantly different only when sets were completed to a predetermined number of repetitions ($p<0.05$). *: significantly different than 50-3, #: significantly different than 70-3.

Heart Rate was significantly higher than resting values throughout both the 1RM and squat protocols. The only significant difference found between sets of the 1RM protocol was found between the WU6 and 1RM values (147.2 ± 16.3 bpm vs. 140.3 ± 15.6 bpm, $p = 0.02$). Values can be seen in Figure 2 for the SP. HR during 50-3 was significantly lower than each of the other sets to three and to failure. HR increased with intensity in the sets completed to a predetermined number of repetitions, although there was no significant increase between the 70-3 and 90-3 conditions (141.9 ± 16.3 bpm and 147.5 ± 19.9 bpm respectively). HR remained elevated throughout most of the sets completed to failure, although it was significantly different between 50-F to 90-F ($p = 0.05$) and 70-F to 90-F ($p = 0.05$). Nonetheless, HR did not exhibit a strong correlation to RPE (1RM: $R = 0.00$, SP: $R = 0.44$)

or intensity (1RM: $R = 0.04$, SP: $R = 0.31$) during resistance training in either the 1RM protocol or SP.

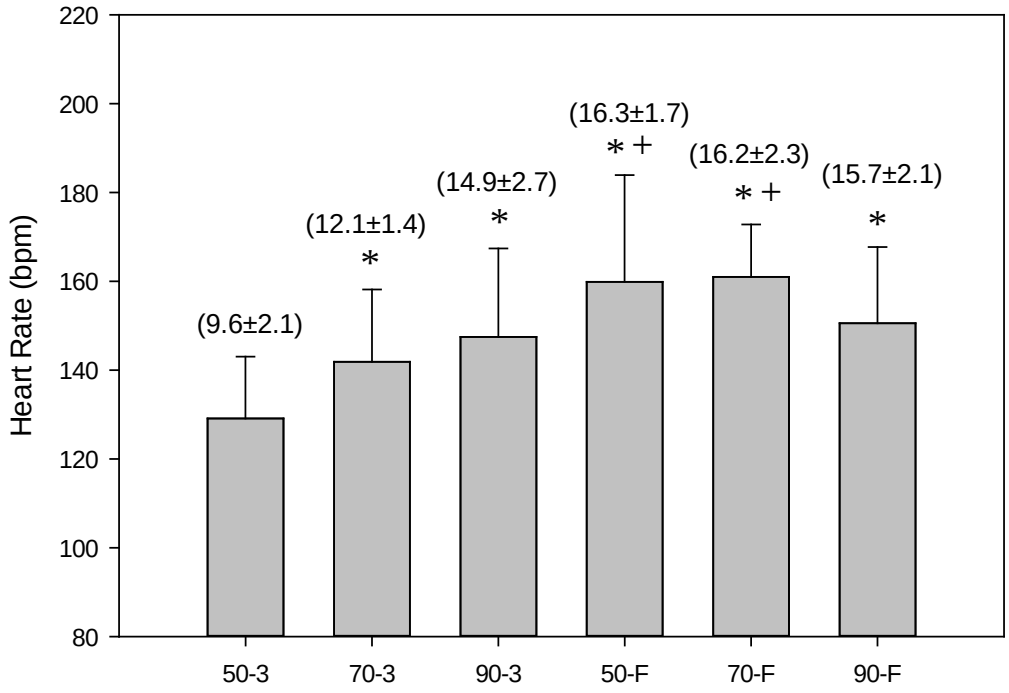

Figure 2. Comparison between Heart Rate response across conditions. Corresponding RPE values for each condition are displayed in parenthesis. *: significantly different than 50-3, +: significantly different than 90-F.

Blood lactate concentrations increased significantly from resting values ($p < 0.00$) to each working set in both resistance exercise protocols. However, there were no differences found throughout the 1RM protocol. Figure 3 illustrates the significant increases in 50-3 vs. 50-F and 70-F, as well as 70-3 vs. 50-F and 70-F during the SP trials. Blood lactate concentrations were also significantly higher in each of the sets in the SP compared to the 1RM values ($p < 0.03$). Correlations of BLA to RPE (1RM: $R = -0.10$, SP: $R = 0.28$) or

resistance exercise intensity (1RM: $R = 0.01$, SP: $R = -0.10$) were not significant in either resistance exercise protocol.

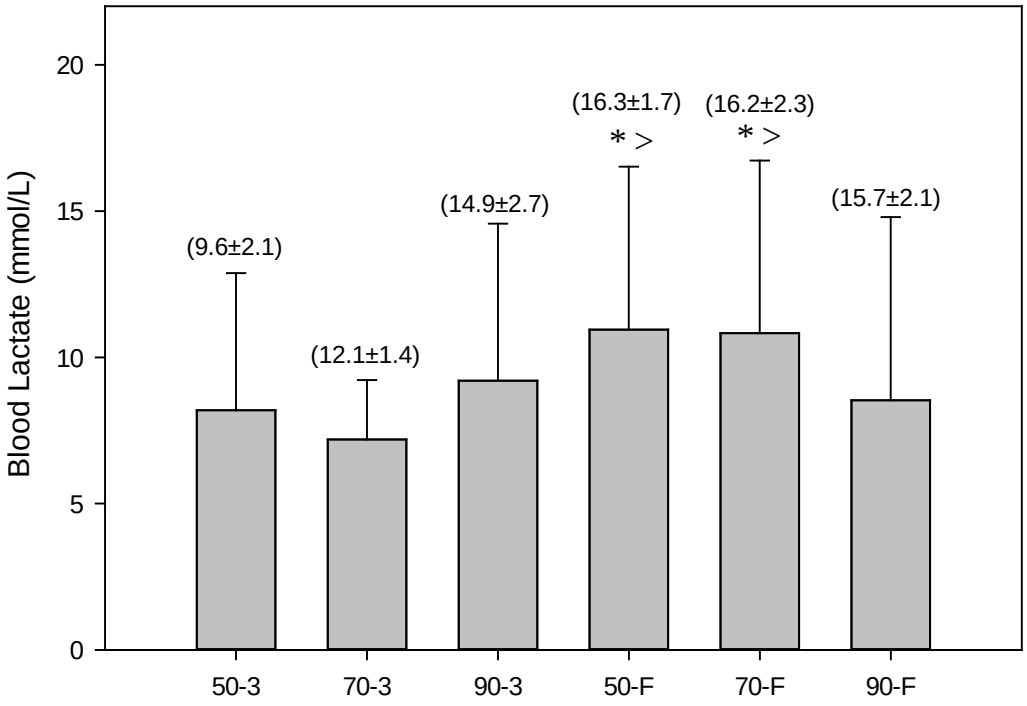

Figure 3. The difference between BLA concentrations across conditions. Corresponding RPE for each condition is displayed in parenthesis.*: significantly different than 50-3, >: significantly different than 70-3.

Average VO_2 throughout each resistance exercise set was significantly higher than resting values in both resistance exercise protocols ($p < 0.00$). During the 1RM protocol, WU10 was significantly higher than WU3 and 1RM ($p \leq 0.01$). As seen in Figure 4, during the squat protocol, 50-3 values are significantly lower than any other condition ($p \leq 0.00$). More specifically, 90-F was significantly lower than both 50-F and 70-F ($p = 0.00$). However, no significant differences were found when comparing 70-3 and 90-3 ($p = 0.88$) or

50-F to 70-F (p = 0.08). Average VO_2 during a resistance exercise set was not found to correlate to RPE (1RM: R = -0.30, SP: R = 0.40) or to intensity (1RM: R = -0.29, SP: R = -0.21). Average VO_2 did correlate to repetitions (time) during the SP (R = 0.71).

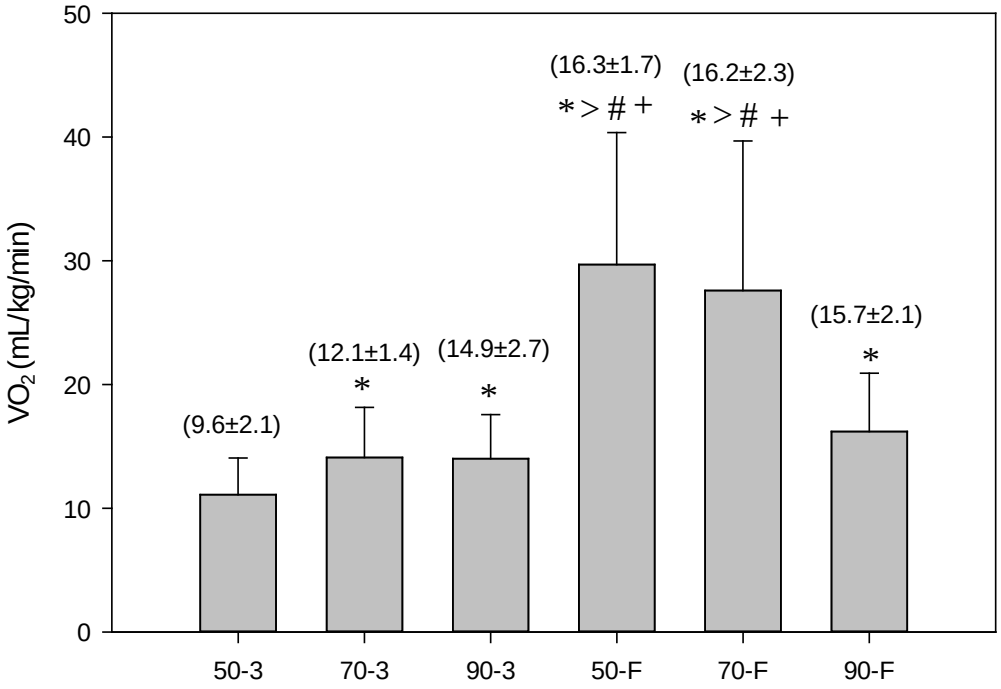

Figure 4. The graph shows the relationship Avearge VO_2 values throughout Day 3 squat protocol. The RPE values are represented inside parenthesis for each condition. *****: significantly different than 50-3, >: significantly different than 70-3, #: significantly different than 90-3, +: significantly different than 90-F.

Peak Power (PP) was calculated during the SP in order to evaluate fatigue as shown by the difference of PP between the first repetition and the last repetition in each condition. As shown in Figure 5, there were no significant differences (p > 0.05) between PP in each of the three conditions completed to a predetermined number of repetitions (50-3: 1377.1 ± 355.0 W vs. 1426.0 ± 350.5W, 70-3: 1475.5 ± 385.1W vs. 1488.9 ± 407.5 W, 90-3: 1514.1 ± 493.0 W vs. 1623.5 ± 451.2 W). However, PP did elicit a significant decrease (p < 0.05)

during the last repetition from the first in each condition performed to volitional failure (50-F: 1440.4 ± 364.6 W vs. 975.7 ± 430.1 W, 70-F: 1667.8 ± 282.0 W vs. 1109.0 ± 324.3 W, 90-F: 1772.8 ± 477.3 W vs. 1460.8 ± 449.6 W).

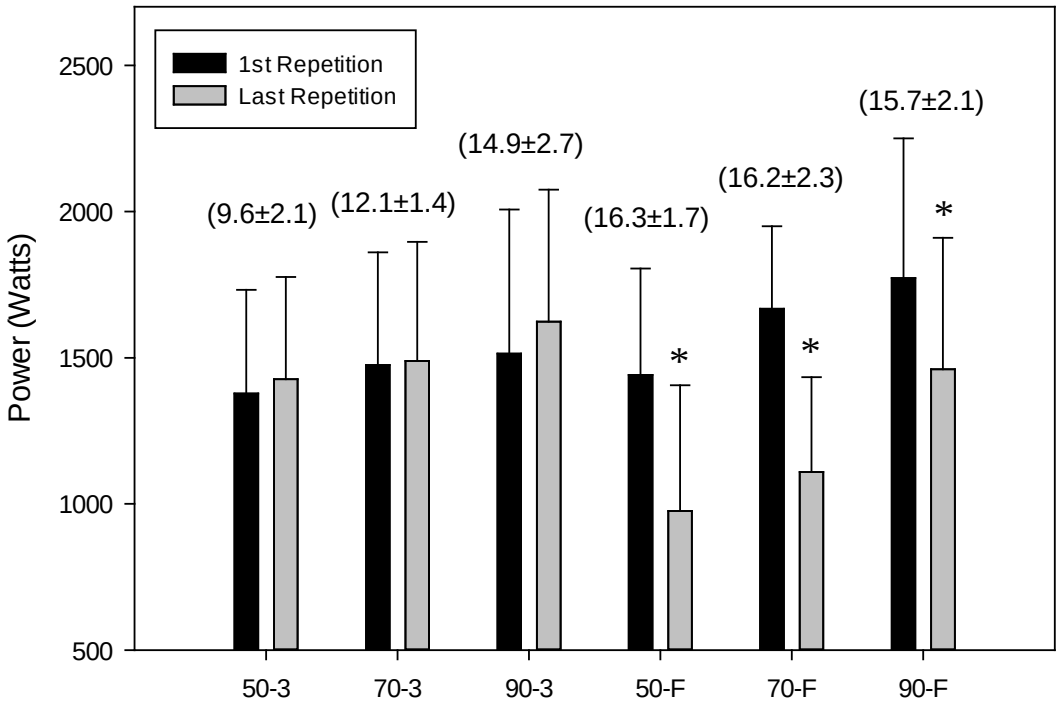

Figure 5. Change in Peak Power from 1st repetition vs. last repetition in all conditions. Corresponding RPE is displayed above each condtion in parenthesis. Peak Power did not change in conditionsto a set number of repetitions, but when completed to failure, the last repetition was significantly lower than the first regardless of exercise intensity ($p<0.05$).

Chapter 4

Discussion

The findings of this study are that RPE, HR, BLA, and VO_2 do not relate to exercise intensity in both aerobic and resistance training maximal tests. RPE relates to resistance exercise intensity only when completing a 1RM protocol or sets to a predetermined number of repetitions. Although each increases significantly, virtually no physiological changes occur during a 1RM protocol although RPE significantly increases during each stage unlike a $VO_{2\ max}$ test where each value increases until failure.

In the current study, RPE did not relate to HR, BLA, or VO_2 during maximal resistance exercise such as with maximal aerobic exercise. When considering all resistance exercise bouts, RPE was not found to relate to intensity, time, or any physiological adaptation. Due to the short nature of most traditional resistance exercise sets, the lack of relationship to any physiological change can be expected.

Previous literature has found conflicting results when it comes to the relationship of RPE to various responses during resistance exercise intensity. RPE was found to be related to intensity (Gearhart et al., 2002; Kraemer et al., 1993; Lagally et al., 2004; Lagally et al., 2002; Lins-Filho et al., 2012; Sweet et al., 2004; Thornton & Potteiger, 2002), heart rate (Hollander et al., 2003; Scherr et al., 2013; Thornton & Potteiger, 2002), blood lactate concentrations (Hollander et al., 2003; Kraemer et al., 1987; Lagally et al., 2002; Scherr et

al., 2013; Thornton & Potteiger, 2002) and oxygen uptake (Beckham & Earnest, 2000; Willoughby, Chilek, Schiller, & Coast, 1991). In contrast Beckham and Earnest (2000), Kalb and Hunter (1991), Kang et al. (2005), Ratamess et al. (2007), and Thornton and Potteiger (2002) all indicated RPE did not relate to physiological values during resistance training. Similar to our results, de Sousa et al. (2012) found RPE relate to repetitions/duration of a resistance exercise set. Our results indicate that RPE only relate to intensity when performing a 1RM protocol or sets to a predetermined number of repetitions. High RPE values were found for each set to failure as well as with increasing intensity in the 1RM protocol and SP to a predetermined to number of repetitions. This may be due to the increased firing rate and motor unit recruitment needed to complete those specific sets versus to the load being lifted. While each subject was asked to give an RPE value of 20 when he could have not possibly exerted any additional effort during each testing session, the RPE at exhaustion during the VO_{2max} is significantly higher ($p = 0.00$) than the RPE values at 1RM or any intensity to volitional failure during resistance exercise. Nonetheless, our findings indicate that RPE during the 1RM set and each of the failure sets were not significantly different from each other despite the fact that none of the intensities matched that of the 1RM, ensuring failure during each set.

Heart Rate exhibited similar qualities to RPE, increasing in the conditions to a predetermined number of repetitions, but staying fairly higher in the conditions to failure. In fact, this was the only physiological change that somewhat mirrored that of RPE during the SP. This was not seen in the 1RM protocol, where HR was similar throughout the protocol except for one significant difference between WU6 and 1RM. The decrease in HR for the 1RM, the conditions to a predetermined number of repetitions (50-3, 70-3, 90-3), and the 90-

F condition may be explained by the shorter duration of the sets compared to the conditions to failure. Although, HR did not relate to RPE, intensity, or repetitions (time) it is likely some sets did not last long enough to cause the HR to increase aside from adrenaline or anxiety of the upcoming set. For example, de Sousa et al. (2012) found that during constant-load resistance exercise during several sets interspersed with one minute rest periods, HR as well as VO_2 will increase initially until reaching a steady state due to the increase in metabolic demand from the exercise. It is possible that in our study, the short duration of the sets do not allow for any significant HR response to occur. When assessing if HR was a mediator of exercise intensity, Beckham and Earnest (2000) found that HR should not be used to assess resistance exercise intensity of free weight circuit training as compared to $\%VO_2$. Compared to a Bruce Protocol VO_{2max}, HR response reached >60% of HR_{max} but <32% of $VO_{2\ max}$ although different loads were used and there were significantly different HR responses between intensities in both males and females. Although our methodology and resistance exercise loads were different from this study, it can be refuted that intensities in resistance training do not necessarily show differences in HR. This suggests that longer duration sets do not require an increase in cardiac output, but the change in HR is likely from an increase in catecholamine response due to stress. When comparing different intensities of resistance exercise, HR has also been found to increase when intensity is increased as well as VO_2 (Willoughby et al., 1991) as well as increase when intensity is increased regardless of no difference in VO_2 during exercise (Thornton & Potteiger, 2002). During two conditions of work equated intensities, it was found that HR was significantly higher during the high intensity condition, no change in exercise oxygen consumption was seen, although an increase in excess post-exercise oxygen consumption (EPOC) was found during the high

intensity condition. These findings support our results that HR increases as resistance exercise intensity increases when completing sets to a predetermined number of repetitions.

In the present study, HR showed a trend with intensity during predetermined number of repetitions, but not to failure while VO_2 did not change the same way. Our findings illustrate that VO_2 relates more to repetitions compared to intensity. VO_2 was significantly higher during the failure sets than any of the sets to three suggesting when working to increase metabolic cost, it is important to perform more repetitions as none of the VO_2 values reached 30% of VO_{2max} in the conditions performed to a predetermined number of repetitions despite the varying intensities.

Our results are similar to other studies that found no change of VO_2 with increasing loads or a decreasing VO_2 with increasing loads (Buitrago, Wirtz, Yue, Kleinoder, & Mester, 2012; Kalb & Hunter, 1991; Kang et al., 2005; Ratamess et al., 2007; Thornton & Potteiger, 2002). Kang et al. (2005) found that during resistance exercise performed at varying intensities and volumes, VO_2 only reached 20-25% of VO_{2max}, and VO_2 immediately post exercise was higher in the low and middle intensities compared to the high intensity. It was concluded that volume was more important than intensity if the desired outcome was to increase oxygen uptake. Our findings support these findings, specifically during the 1RM protocol when intensity increased but volume decreased. In addition, there were no differences from any other set except for WU10, which was the only set of a somewhat longer duration during that protocol.

Physiological responses to different resistance exercises depend on the intensity and the number of repetitions performed, where the number of repetitions performed also depends on the intensity (Buitrago et al., 2012). In agreement with the findings of our study,

more repetitions can be completed when the intensity is decreased. Unlike our study, Buitrago et al. (2012) showed that there was no change in average VO_2 with increasing intensity, despite the decrease in repetitions. They also did not see a significant difference in HR across intensities and a significant decrease in BLA was only seen in the high intensity condition. Although our study did not control for speed or frequency of each repetition, Buitrago et al. (2012) found that a faster mode can also increase the average VO_2 during the set due to the greater need for ATP during the frequent activation and relaxation cycles or an increased need in recruited muscle fibers. Considering this factor, those individuals who performed the repetitions at a quicker pace may also have elicited higher BLA and HR responses compared to those individuals who had a slower pace.

Blood lactate concentrations are not meant to represent the usage of anaerobic pathways that resistance exercise uses in the majority. Our results, while finding an increase from resting values throughout both protocols, did not show any differences between intensities when completing a 1RM protocol, sets to a predetermined number of repetitions, or sets to failure. This suggests that BLA does not increase as intensity increases or as repetitions (time) increase. While the VO_2 data indicate that the 50-F and 70-F sets are increasingly aerobic, the BLA values do not show any difference from the rest of the sets. Each value during the SP was significantly higher than any value during the 1RM protocol possibly because BLA was not cleared as efficiently in each subject. Kang et al. (2005) discussed that individuals who are more aerobically fit are able to return to homeostasis at a faster pace and avoid long periods of fatigue during recovery between resistance exercise sets. Our subjects were males who were aerobically fit according to VO_{2max} values and active in both aerobic and resistance exercise. However, most individuals tend to favor one

modality over the other. Therefore, it may be that subjects who trained more aerobically than anaerobically were able to clear out BLA in ten minute rest periods. The lack of difference in BLA in our results could be that the ten minute rest periods were not sufficient to clear out the previous sets. However, randomizing the six sets during the SP allowed for a decrease in error, although there may still be an effect.

While our results do not show any type of trend of BLA in resistance exercise, there are conflicting ideas in other studies similar to HR and VO_2. During aerobic exercise, it is understood that BLA is an indicator of maximal effort (Howley et al., 1995), however the same is not necessarily the case in resistance exercise. Lagally et al. (2002) and Thornton and Potteiger (2002) both found higher BLA during higher intensities when comparing two loads performed with work equated. Contrary to our study, Kraemer et al. (1993) found that BLA increased at a higher intensity even if less work was performed. Blood lactate concentrations have also been found to relate to RPE immediately post resistance exercise (Hollander et al., 2003). In agreement with our data, Buitrago et al. (2012) found no difference between BLA across resistance exercise intensities.

Peak power found during each repetition has helped determine fatigue rate and how that affects RPE. When looking at RPE and power across sets to failure at varying percentages of 1RM, Naclerio et al. (2011) found that power decreased significantly from the first repetition to the last repetition as in the current study. RPE also significantly changed from the first repetition to the last repetition regardless of intensity. While RPE did increase with intensity after the first repetition, the final repetitions after failure were all maximal values regardless of intensity. It is important to maintain power output in a strength training program in order to see improvements and increases in strength. It is necessary to exercise

caution when a high RPE value is seen in order to prevent fatigue and decreases in performance.

In conclusion, RPE does not relate to physiological changes the same way in resistance training as it does in aerobic exercise. When comparing all resistance exercise sets, there is no relationship between RPE to HR, BLA, VO_2, or intensity. Our results indicate that unlike maximal aerobic exercise tests, physiological changes do not occur due to exercise intensity and do not have any effect on RPE in various types of maximal resistance exercise tests. Physiological variables may not be adequate for determining resistance exercise intensity or fatigue as compared to aerobic exercise. It is recommended to exercise caution with using RPE as a mediator of intensity during resistance exercise as it is possible that a high RPE value may only be given due to fatigue and a longer recovery period may be needed in order to decrease the chance of a drop in power output, which is particularly important in a training or coaching perspective.

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Appendix

Request for Review of Human Participant Research

Appalachian Human Research Protection Program

IRB # 13-0167

Instructions: ***Complete and send the request form electronically to*** **irb@appstate.edu**.
Note: *checkboxes can be checked by putting an "x" in the box.*

Section I: Study Description

1. Study Title: Comparison of Physiological Variables during Aerobic and Anaerobic Exercise.

2. Study Description: *Please describe briefly the objectives of the study with the purpose, research question and any relevant background information.* Rate of Perceived Exertion (RPE) scales are often used to measure exercise intensity during aerobic exercise. RPE has been observed to correlate with heart rate, blood lactate concentrations and oxygen intake during various aerobic exercise tests. However, study of the efficacy of utilizing an RPE scale for determining intensity specifically in resistance training and correlating RPE to physiological changes during both modalities of exercise is limited. The purpose of this study is to compare the differences of RPE, heart rate, lactate, and VO2 during aerobic and anaerobic maximal tests and during resistance exercise over time when performed to a set number of repetitions and to failure at varying workloads.

3. Principal Investigator(s) and responsible faculty member if student is the PI:
Dr. Jeffrey M. McBride
Department(s): HLES

4. By submitting this request, the Principal Investigator (and responsible faculty member if PI is a student) accepts responsibility for ensuring that all members of the research team: 1) complete the required CITI training and any other necessary training to fulfill their study responsibilities, 2) follow the study procedures as described in the IRB approved application and comply with *Appalachian's Guidelines for the Review of Research Involving Human Subjects* and all IRB communication and 3) uphold the rights and welfare of all study participants.

The parties (i.e., the IRB and the Principal Investigator and responsible faculty member if PI is a student) have agreed to conduct this application process by electronic means, and this application is signed electronically by the Principal Investigator and by the responsible faculty member if a student is the PI.

My name and email address together constitute the symbol and/or process I have adopted with the intent to sign this application, and my name and email address, set out below, thus constitute my electronic signature to this application.

Jeffrey M. McBride	mcbridejm@appstate.edu
PI Name	PI Email address
Responsible Faculty Name if PI is a student	Responsible Faculty Email address if PI is a student

5. Do you plan to publish or present off-campus? [ ] No [X] Yes

6. Does this research involve any out-of-country travel? [X] No [ ] Yes

7. Type of Research, check all that apply:
- [X] Faculty Research
- [X] Dissertation/Thesis/Honor's Thesis
- [ ] Product of Learning
- [ ] Class Project – Course Number:
- [ ] Educational Research Involving Normal Education Practices
- [ ] Other: describe

8. Source of Funding
- [X] Not Funded
- [ ] Federally Funded
- [ ] Funds Awarded
- [ ] Funds Pending
- [ ] University Funded: describe

If funds awarded/pending, provide sponsor name, Sponsored Programs number:

Attach a copy of the contract/grant/agreement.

9. Is another institution engaged in the research (i.e., an agent of another institution will obtain informed consent, interact with participants to obtain information, or access private identifiable information about participants)?
[X] No [ ] Yes If yes, list institution(s) and whether that IRB will review or rely on the ASU IRB.

10. What, if any, relationship exists between the researcher(s) and agencies (e.g., schools, hospitals, homes) involved in the research? *Attach statement*

of approval (e.g., letter of agreement) from any agencies that will be involved with the research. N/A (no agencies involved).

Section II: Research Personnel

Enter each team member (including PI) in the table below. (*A member of the research team is defined as one who will: 1) access participants' private identifiable information, 2) obtain informed consent **or** 3)interact with participants.)*

Name	**Role** (e.g., PI, co-I, Research Assistant, Research Coord., Faculty Advisor, etc.)	**Responsibilities**: Select all that apply from the list of Responsibilities below (e.g., "a, b, c")	**Receive IRB Correspondence** (Y/N)? If yes, provide preferred email address.
Jeffrey M. McBride	PI	a, b, c, f, g, h, j, l, m	mcbridejm@appstate.edu
Ligia Vasquez	Co-I	a, b, c, f, g, h, j, l, m	vasquezlm@appstate.edu

(Note: If you need additional room, you can add rows by going to right click, insert, and then insert rows below. Personnel changes made after IRB approval can be submitted via email with the above information.)

Responsibilities:

a. Screens potential participants	**h**. Conducts physical exams
b. Obtains Informed Consent	**i**. Collects biological specimens (e.g., blood samples)
c. Has access to identifiable data	**j**. Conducts study procedures
d. Administers survey	**k**. Dispenses medications
e. Conducts interviews	**l.**Supervises exercise
f. Enters subject data into research records	**m.** Educates participants, families, or staff
g. Analyzes data with identifiable information	**n.** Other: describe

Note: In some cases, expertise to perform study procedures (e.g., blood draws, interviewing participants about sensitive topics) should be documented by the IRB to show that risks to participants is minimized. The IRB uses the Research Personnel Form to document investigator expertise.

Section III: Conflict of Interest

1. Are there any known or potential conflicts of interest related to this research?

Conflict of interest relates to situations in which financial or other personal considerations may compromise or involve the potential/have the appearance for compromising an employee's objectivity in meeting University responsibilities including research activities.

Examples of conflicts of interest include but are not limited to: an investigator has equity in a business that conducts research in a related area; an investigator will receive an incentive/bonus based on the number or speed of enrollment or outcome of a study; or an investigator or family member is a consultant, holds an executive position or serves as a board member of the research sponsor or its holdings.

[X] No [ ] Yes If yes, describe and explain how participants will be protected from the influence of competing interests.

Section IV: Participant Population and Recruitment

1. Number of participants sought: 15

2. Targeted Participant Population (check all that apply):

X	Adults (>= 18 yrs old)	X	College Students (only 18 or older)
	Minors (< 18 yrs old) Age range:		College Students (under 18 may participate)
	Minorities		Prisoners
	Institutionalized Participants		Cognitively or emotionally impaired
	Inpatient participants		Non-English speaking
	Outpatient participants		Pregnant Participants
	International research		Employees of a profit or non-profit organization

3. Federal regulations have established guidelines for the equitable selection of participants. Are participants an appropriate group to bear the burdens of this research?

Are participants a subset of the population most likely to receive the benefits of this research?

[X] Yes [ ] No If no, please explain:

4. Explain any inclusion and exclusion criteria for the study: Subjects must be male and between the ages of 18 and 25 and have a minimum of 2 years' experience in treadmill running and the squat exercise. Subjects who are at moderate or high risk of a cardiovascular event will be excluded. Males will be utilized in order to compare data from this investigation to previous investigations involving male subjects.

5. Recruitment Procedures (how will you find participants?)

- [ ] Student Subject Pool; indicate pool:
- [x] Email/Mailing/Handout
- [ ] Website ad/Newspaper ads/Flyers/Postings
- [ ] School children with request sent to parents
- [ ] Participants will be approached by staff members
- [ ] Other (explained below)

A copy of any recruitment materials must be submitted with this application.

6. Explain details of recruitment (e.g., obtain list of student emails from Registrar's office and send them recruitment email): Subjects will be males between the age of 18 and 25. They will be recruited from the general population based on the criteria stated in Section IV (#4). Subjects will not be excluded solely on the basis of race, color, or any other demographic characteristic other than age and gender. Participants in the study will not be recruited from Dr. Jeffrey McBride's classes.

7. Does the research include any compensation, monetary inducements, or reimbursement for participation in this research study?

[X] No [ ] Yes If yes, explain payment schedule:

Section V: Informed Consent Process

1. Explain how informed consent will be obtained. *If applicable, include information about: the setting, whether participants will have an opportunity to ask questions, and the roles of any non-research personnel involved. If potential participants or their legally authorized representatives (e.g., parents) are non-English speaking, please explain how the investigator will identify these participants and ensure their ability to understand information about the study to provide consent.* One week prior to the first day of data collection participants will be given an informed consent sheet upon entering the Neuromuscular & Biomechanics Laboratory. A verbal explanation of research procedures will be given, and subjects will also be instructed to read through the information and ask questions at any time. A Research Assistant (Vasquez) will be available as they read through the form to answer any questions.

2. If applicable, describe the safeguards in place to protect the rights and welfare of any vulnerable participants *(e.g., children, prisoners, pregnant persons, or any population that may be relatively or absolutely incapable of protecting their interests through the informed consent process).* N/A

3. Select factors that might interfere with informed consent:

- [X] None known
- [ ] Research will involve current students in a course/program taught by member of research team
- [ ] Participants are employees whose supervisor is recruiting/requiring participation
- [ ] Participants have a close relationship to research team
- [ ] Other (please specify/indicate any relationship that exists between research team and participants):

For selected factors, describe any efforts to mitigate:

4. Will participants sign a consent form?
[X] Yes [ ] No

If no, participants must still be provided with a statement regarding the research and one of the following criteria must be met and selected and followed:

[ ] The only record linking the participant and the research is the consent document and the principal risk is potential harm resulting from a breach of confidentiality, and the research is not FDA-regulated. Each participant will be asked whether he/she wants documentation linking the participant with the research and the participants wishes will govern; OR

[ ] The research presents no more than minimal risk of harm and involves no procedures for which written consent is normally required outside of the research context.

5. Are you requesting a modification to the required elements for informed consentfor participants or legally authorized representatives?
[X] No [ ] Yes If yes, address criteria to waive elements of consent:

Section VI: Study Procedures

1. Projected data collection dates: January 28, 2013- January28, 2014

2. Describe research procedures as they relate to the use of human participants. *Information should include what participants will be asked to do, duration of procedures, and frequency of procedures*.

Subjects will be required to report to the Holmes Convocation Center on the campus of Appalachian State University on three occasions each separated by a minimum of 3 days. Each session will last approximately one hour. The subject will perform all tests in the Human Performance Laboratory (HPL) and Neuromuscular and Biomechanics Laboratory (NBL). Day 1 will involve completion of a medical history questionnaire and height and body mass will be recorded. Subjects will then either complete a VO_{2max} test or a one repetition max test. These maximal tests will be randomized in order to decrease any possibility of error on the study. Day 2 will then involve the remaining maximal test. On day 3, subjects will perform six randomized sets of resistance exercise at various percentages of their 1RM.

The VO_{2max} protocol involves a warm-up stage of where the subject will walk at 3 miles per hour (mph) and 0% grade for 3 minutes. Each following stage will last four minutes. Rate of perceived exertion will be taken with 40 seconds left in the stage, at which time the subjects will be asked to hop off and straddle the treadmill belt at approximately 30 seconds left in each stage so lactate measures can be taken. Stage one is 6 mph at 1% grade. From stage one to stage five, mph increases 1 mph per stage and grade remains at 1% so that by stage 5 subjects are

to be running at 10mph on a 1% grade. From stage five to stage seven the speed continues to increase at 1 mph and grade increases 1% every stage, so that at stage seven subjects are running 12mph at 3% grade. From stage seven to stage ten, speed remains the same, and grade increases by 1% every stage until it reaches 5% so that by stage 10 the speed is 12mph and the grade is 5%. At the end of each two minute period, HR, blood lactate concentration, and RPE (using the Borg 6-20 scale) will be collected. This will continue until volitional failure at which time all data will be collected and the subject will be permitted to cool down as long as necessary.

The subject will return to the HPL on a separate occasion from the VO_{2max} test to perform a one repetition max test in a standard back squat. A warm-up protocol consisting of 1 set of 10 repetitions, 1 set of 6 repetitions, and 1 set of 3 repetitions with progressively increasing weight will be used prior to maximal repetitions. Subjects begin the squat by standing with their feet shoulders width apart, with a barbell positioned on their upper back. They will squat down to a 70 degree knee angle as determined by the researcher, and return to a standing position. Squat exercise performance will be monitored by an individual who is a Certified Strength & Conditioning Coach as regulated by the National Strength & Conditioning Association. One repetition max will be determined as the maximum amount of weight that is lifted properly with no help from a spotter. Five minute rest periods will be given between each warm-up set and between maximal attempts. Heart Rate, blood lactate concentration, and RPE will be assessed at the end of each set and maximal attempt. The subject will also be attached to the Parvo Medics Metabolic cart in order to have oxygen consumption measured throughout the session.

On Day 3, the subject will perform six randomized sets of squats at approximately 50%, 70%, and 90% of the predetermined 1RM. The actual weight used will be within 2 kilograms of the actual percentage. Each workload will be performed to three repetitions as well as to volitional failure (50-3, 50-F, 70-3, 70-F, 90-3, 90-F). The resistance exercises will be performed on a force plate and using a bar attached to two linear position transducers (LPT). The subject will be given a minimum of 10 minutes rest in between each set. The force plate will be used to calculate force, velocity, and power performed during each repetition, and consequently throughout the entire set. LPTs will be used to visualize squat depth and frequency using LabVIEW 2012. Immediately following each set, the subject will provide the level of volitional fatigue using the Borg 6-20 scale. During each 10 minute rest, the subject was allowed water ad libitum as well as freedom to stretch or move about the laboratory as he so desired. Heart rate, blood lactate concentrations, and VO_2 will be taken at the completion of each set.

During each testing session, the subject will be attached to a Parvo Medics Metabolic cart in order to assess oxygen uptake. Breath-by-breath analysis of percent expired carbon dioxide (CO2), percent expired oxygen (O2), and total volume of expired air will be collected and analyzed. Heart rate will be measured using a Polar Pacer heart rate monitor strapped at sternum level of the subject. Lactate will be taken and analyzed by a finger prick using a lactate plus analyzer (nova biomedical). A trained and experienced individual will perform the tests and

lactate technique and blood will be collected in a hygienic setting with sterile materials and biohazard protection measures to minimize these risks.

3. Participants' identification (check one):

- [ ] Information is collected so that participants CANNOT be identified directly (by names, images or other identifiers) or indirectly (by linking responses to participants).
- [X] Information is collected so that participants CAN be identified, either directly or indirectly, by the research team but identifying information will not be disclosed publicly.
- [ ] Information is collected so that participants CAN be identified, either directly or indirectly, by the research team and identifying information will be disclosed publicly.

4. Check all locations of study procedures that apply:

- [ ] N/A – online survey
- [**X**] Appalachian campus, indicate building: Holmes Convocation Center, Neuromuscular &Biomechanics Laboratory, Human Performance Laboratory
- [ ] School system(s):
- [ ] Human Performance Lab, NCRC
- [ ] Off-campus location(s). List:

5. Data collection

5a. Please check all data collection activities involved in this study:

- [ ] Paper Surveys / Questionnaires
- [ ] Online Surveys / Questionnaires Name of Survey Provider:
- [ ] Telephone Surveys / Questionnaires Name of Survey Provider:
- [ ] Standardized Written / Oral / Visual Tests
- [ ] Interviews
- [ ] Focus Groups
- [ ] Tasks
- [ ] Public Observation
- [ ] Classroom Observation/Work Site Observation
- [ ] Voice, video, digital or image recordings made for research purposes
- [ ] Materials (i.e., data, documents, records/specimens) that have been collected or will be collected for **non research** purposes
- [ ] Collection or study of materials (i.e., data, documents, records/specimens) that are publicly available or if the information is recorded so that participants cannot be identified, directly or indirectly through identifiers
- [ ] Materials (i.e., data, documents, records/specimens) that have been collected for another research project
- [**X**] Moderate exercise and muscular strength testing
- [ ] Other:

5b. If your study <u>does not involve biomedical procedures skip to question #6</u>. Otherwise, select all data collection activities that apply:

[X] Blood samples by finger stick, heel stick, ear stick or venipuncture

Indicate the type of participants and how much blood will be drawn:

- [X] from healthy, non pregnant adults who weigh at least 110 pounds
- [ ] from other adults or children
- [X] How many times per week will blood be drawn? 2
- [X] How much blood will be drawn at one time? 100 μL
- [X] How much blood will be drawn in an 8-week period? 1500 μL
- [X] How often will collection occur? Blood collection will occur throughout each test: VO_{2max}, 1RM, and resistance training protocol. Approximately 5-7 times per visit

[ ] Noninvasive procedures to collect biological specimens for research purposes

[X] Sterile Surgical/Invasive procedures

[ ] Banking of biological materials

[ ] Noninvasive procedures to collect data such as use of physical sensors applied to surface of body and electrocardiography

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[ ] Procedures involving x-rays (e.g., DEXA scan for body composition)

[ ] Ingestion of wholesome foods without additives

[ ] Ingestion/application of substances other than wholesome foods without additives

[ ] Clinical study of a drug/medical device

[ ] Obtaining medical data from a health care provider, health plan or health care clearinghouse

[ ] Genetic Testing

[ ] Other: describe

5c. Is this research FDA-regulated (i.e., It is an experiment that involves one or more of the following test articles: foods/dietary supplements that bear a nutrient content/health claim, infant formulas, food/color additives, drugs/medical devices/biological products for human use)?

[X] No [ ] Yes

6. Is deception involved?

[X] No [ ] Yes If yes, please describe:

7. Does the data to be collected relate to any illegal activities (e.g., immigration status, drug use, abuse, assault)?

[X] No [ ] Yes If yes, please describe:

Section VII: Confidentiality and Safeguards

1. In most cases, the research plan should include adequate provisions to protect

the privacy of subjects. How will the confidentiality of participants be maintained (e.g., how will access to participants be controlled)?
Subjects will be referred to only by subject code and all data and results will be kept in a locked file cabinet in the Neuromuscular & Biomechanics Laboratory. The key to the subject code will be destroyed within two years of collecting data. Individual data will not be reported in results of final publication.

2. Will collected data be monitored to ensure the safety of subjects (e.g., survey includes a question about suicidality so the investigator will…)?

[X] No [ ] Yes If yes, please explain procedures to ensure safety of participants:

3. Describe what will be done with the data and resulting analysis:
The data will be analyzed and statistical significance testing will be performed for interpretation of the results. A manuscript will be submitted for publication and the study will be presented at a national conference.

4. Describe measures you are taking to safeguard study data (check all that apply):

- [ ] Data is not linked to identifying information
- [**X**] Maintain consent forms in a separate location from data
- [X] Using subject codes on <u>all</u> collected data and maintaining the key linking subject codes with identifiable information in a separate location from data
- [X] Locking cabinets/doors. List location: Neuromuscular & Biomechanics Laboratory
- [X] Data kept in area with limited public access. List location: Neuromuscular & Biomechanics Laboratory
- [X] Password protected computers
- [ ] Encryption
- [ ] PDAs and removable media (e.g., CDs, etc.) will be kept in a secure location. List location:
- [ ] Other, please describe:

5. Data Sharing

5a. What type of data will be shared? (*Note: Sharing includes releasing, transmitting and providing access to <u>outside</u> of the research team.)* Check all that apply:

- [ ] Data collected anonymously
- [ ] Anonymized or De-linked data. Identity was once associated with data/specimen but identifying information destroyed
- [**X**] Coded and linked data (Data is coded. With the code, the data may be linked back to identifiers, but the link back to identifiers will not be shared.)
- [ ] Identifiable Data (e.g., names, email addresses, date of birth, IP addresses) Indicate which secure method(s) of transmission will be used:

5b. If identifiable data will be shared within or outside of the research team, please explain how it will be shared (check all that apply):

- [ ] Secured Website. Please provide name of website:
- [ ] Encrypted email
- [ ] U.S. Postal Service or other trackable courier services
- [ ] Fax in a secured area
- [ ] Shared drive with password protection
- [ ] Personal delivery by member of research team
- [ ] Private telephone conversation to member of research team
- [ ] Other, please describe:

6. Secure Disposal: *Note: consent forms should be stored for 3 years after study completion.*

6a. How long will the data be stored?

- [ ] 1 year after study conclusion
- [X] 5 years after study conclusion
- [ ] Indefinitely
- [ ] Data without identifiers stored indefinitely
- [ ] Other, please describe (e.g., sponsor requirements):

6b. How will data be destroyed?

- [X] Paper will be shredded
- [ ] Biological samples will be destroyed by:
- [X] Destroy electronic files from computer/PDAs/removal media (CDs, diskettes) by: Deletion
- [ ] Other, please describe:

Section VIII: Risk and Benefits of Study

1. The risks to participants must be reasonable in relation to anticipated benefits, if any, to participants and the importance of the knowledge that may be reasonably be expected to result. Select all applicable:

- [X] Participants of the study may directly benefit by (describe)*:*

Subjects will receive their individual results from the study and provided with comparative norms to provide them with knowledge of their current performance capabilities in the maximal and submaximal aerobic and anaerobic exercise. [*Note that compensation is not considered a benefit.]*

- [X] Society may benefit from the study by (describe):

Subjects will be informed of their valued participation in expanding the body of knowledge in the area of exercise science.

2. Describe the potential risks (e.g., psychological, legal, physical, social harm, loss of confidentiality) to any individual participating in this project:

Injury potential with both treadmill running and the squat exercise is no more than that of any other type of training exercise or other general types of exercise which includes muscle strains or pulls. The risks of collecting a blood sample from the subject include the possibility of local discomfort (pinch when the needle enters your skin), minor bruising or bleeding at the site (10%), possible temporary lightheadedness, infection (<0.01%), or development of a blood clot (<0.01%). The amount of blood being withdrawn 500 µL (approximately 5 finger pricks per testing session) will not influence the ability of the subject to participate in normal daily activities.

3. Assessment of level of risk:

- ☐ Risks (including physical, emotional, social, legal or financial) are the same as encountered in daily life or during the performance of routine physical or psychological examinations or tests (minimal risk).
- ☒ Risks are more than minimal in that either: a) the probability of harm or discomfort anticipated, or b) the magnitude of harm or discomfort anticipated is greater than that encountered in daily life.
- ☐ Information to be collected could cause participants to be at risk of criminal or civil liability if responses are disclosed outside of the research setting.
- ☐ Information to be collected could be damaging to participant's financial standing, employability, or reputation if disclosed outside of the research setting.

4. Describe procedures for protecting against, or minimizing, the potential risks:
Each subject will be given proper instruction in how to perform the squat exercise. They will also be given instruction as well as step-by-stepdirection during each maximal test (VO_{2max} and 1RM). During this time they will be given time to ask any questions. Subject involvement criteria will be 2 years of experience in both aerobic and anaerobic exercise. Squat performance and VO_{2max} test performance will be monitored by an individual who is a Certified Strength & Conditioning Coach (CSCS) as regulated by the National Strength & Conditioning Association as well as first aid and CPR certification. Research staffs monitoring VO2max tests are CPR certified and knowledgeable about graded exercise tests and procedures for conducting metabolic measurements. The risk of infection associated with the finger prick method of collecting blood lactate is minimal, and will be protected against by cleaning the finger with an alcohol swab before blood collection. A trained and experienced individual will perform the technique and blood will be collected in a hygienic setting with sterile materials and biohazard protection measures to minimize these risks. In the rare case of research personnel exposure to blood or tissue, we will analyze blood for HIV and hepatitis (a positive HIV or hepatitis test will be reported to them).

5. If human subject data/specimens will be used for future research that is not described above, please explain. (Future use of data/specimens should be disclosed to the participant in the informed consent.) Data from this study may be used in a future study comparing different subject populations with different training statuses. N/A

Please check any materials below that will be submitted with your application. Note: please submit as separate files.

- [ ] Recruitment wording
- [X] Consent form(s)
- [ ] Letter(s) of Agreement
- [ ] Research Personnel Form(s)
- [ ] Instruments (Survey questions, interview questions, etc.)
- [ ] Copy of grant/contract/agreement
- [ ] Other (please describe):

Please **send an electronic Word attachment (not scanned) of this application and any accompanying materials to irb@appstate.edu**. Thank you for taking your time to promote ethical human participant research at Appalachian!

Appalachian
STATE UNIVERSITY

Consent to Participate in Research
Information to Consider About this Research

Comparison of physiological variables during aerobic and anaerobic exercise

Principal Investigator: Jeffrey M. McBride

Department: Health, Leisure & Exercise Science

Contact Information:

Jeff McBride, (828-262-6333), mcbridejm@appstate.edu
045 Convocation Center
Boone, NC 28607

What is the purpose of this research?

Rate of Perceived Exertion (RPE) scales are often used to measure exercise intensity during aerobic exercise. RPE has been observed to correlate with heart rate, blood lactate concentrations and oxygen intake during various aerobic exercise tests. However, study of the efficacy of utilizing an RPE scale for determining intensity specifically in resistance training and correlating RPE to physiological changes during both modalities of exercise is limited. The purpose of this study is to compare the differences of RPE, heart rate, lactate, and VO2 during aerobic and anaerobic maximal tests and during resistance exercise over time when performed to a set number of repetitions and to failure at varying workloads.

Why am I being invited to take part in this research?
You are being invited to take part in this research because of your training background in general resistance and aerobic training exercises, more specifically treadmill running and the squat exercise.

Are there reasons I should not take part in this research?

You are free to withdraw from the study at any time without penalty. You are free not to answer any questions or respond to experimental situations that you choose without penalty. There may be circumstances under which the investigator may determine that you should not continue to participate in the study. To participate in this study you should be physically fit. You will be asked to complete a health screening tool to ensure you're able to participate in this study.
If you volunteer to take part in this study, you will be one of about 15 people to do so.

What will I be asked to do?

You will be asked to visit the Holmes Convocation Center's Neuromuscular & Biomechanics Laboratory (NBL) and Human Performance Laboratory (HPL) for a total of three testing sessions. Each test session will last approximately 1 hour. The first two sessions will be randomized. The first visit will include an orientation of the study during which the procedures will be explained to you after which you will be asked to voluntarily sign the informed consent form. You will be asked to complete a health screening tool for potential health reasons prohibiting you from participating in this study. After joining the study you will be asked to refrain from performing any type of resistance exercise or strenuous activity 48 hours prior to each of the two testing sessions. You will be asked to wear appropriate clothes (T-shirt, shorts and athletic shoes), and to be well hydrated and nourished, avoiding alcohol/caffeine/tobacco within 3 hours of the VO2 max test and will be asked to report any medication use to testing staff prior to testing.

In the first testing session your height and weight will be taken and you will perform a maximal test in either aerobic or resistance exercise. The maximal oxygen uptake protocol will take place in the HPL and will involve a treadmill and a metabolic cart which will be used to collect and analyze oxygen and carbon dioxide consumption. During this test you will be hooked up to a face mask and perform an incremental running protocol on the treadmill. Throughout this test you will be asked to provide a Rate of Perceived Exertion value on a scale of 6-20 and will have your finger pricked in order to analyze blood lactate concentration.

The resistance test involves a one repetition maximum (1RM) in a traditional back squat. A warm-up of progressively increasing weight will be allowed. You will begin the squat by standing with their feet shoulders with apart, with a barbell positioned on your upper back. You will squat down to a 70 degree knee angle as determined by the researcher, and return to a standing position. The 1RM will be determined by the maximum amount of weight you are able to squat without any help from a spotter. You will also be attached to the face mask in order to analyze oxygen consumption as well as being asked to evaluate your level of exertion and having your finger pricked for blood lactate.

You will then return for a third session during which you will complete six sets of squats at loads of 50%, 70%, and 90% of your maximal strengthin a randomized order. The three loads will be performed both to failure and to 3 repetitions. A 10-minute rest period will be provided between each set.

What are possible harms or discomforts that I might experience during the research?

Treadmill running and squat performance will be monitored by an individual who is a Certified Strength & Conditioning Coach (CSCS) as regulated by the National Strength & Conditioning Association as well as being certified in first aid and CPR. Injury potential with running as well as the squat is no more than that of any other type of aerobic training exercise, resistance training exercise or other general types of exercise which includes muscle strains or pulls. Risks of VO2 max tests include

abnormal heart beats, abnormal blood pressure response, delayed muscle soreness, joint injury, light headedness, fatigue and in rare cases, a heart attack. The risks of collecting a blood sample from you include the possibility of local discomfort (pinch when the needle enters your skin), minor bruising or bleeding at the site (10%), possible temporary lightheadedness, infection (<0.01%), or development of a blood clot (<0.01%). The amount of blood being withdrawn is 700-1000 µL on day one of testing (7-10 finger pricks) and about 200 µL on day two (two finger pricks) and will not influence your ability to participate in normal daily activities. A trained and experienced individual will perform the technique and your blood will be collected in a hygienic setting with sterile materials and biohazard protection measures to minimize these risks. In the rare case of research personnel exposure to your blood or tissue, we will analyze your blood for HIV and hepatitis (a positive HIV or hepatitis test will be reported to you).

What are possible benefits of this research?

We do not know if you will receive any benefits by taking part in this study. This research should help us learn more about the relationship of RPE scales to both aerobic and resistance exercise intensity and provide scientists with more information so that they can accurately develop training programs to meet an individual's needs. By participating in this study you will be given information concerning your squat performance as well as maximal oxygen consumption. This information may help you to accurately design a training program to enhance your muscle strength and endurance.

Will I be paid for taking part in the research?

There will be no financial compensation for participating in this study.

How will you keep my private information confidential?

Your information will be combined with information from other people taking part in the study. When we write up the study to share it with other researchers, we will write about the combined information. You will not be identified in any published or presented materials. Confidentiality of your records will be maintained at all times during and after your involvement in this study. Individual data collected will remain confidential and will not be disclosed in any published document or shared with anyone but the experimenters.

What if I get sick or hurt while participating in this research study?

If you need emergency care while you are at the research site, it will be provided to you. If you believe you have been hurt or if you get sick because of something that is done during the study, you should call your doctor or if it is an emergency call 911 for help. In this case, tell the doctors, the hospital or emergency room staff that you are taking part in a research study and the name of the Principal Investigator. If possible, take a copy of this consent form with you when you go. Call the principal

investigator, Dr. Jeffrey M. McBride (828-262-6333) as soon as you can. He needs to know that you are hurt or ill.
If you are injured during the study, there are procedures in place to help attend to your injuries or provide care for you. Costs associated with this care will be billed in the ordinary manner, to you or your insurance company. However, some insurance companies will not pay bills that are related to research costs. You should check with your insurance about this. Medical costs that result from research-related harm may also not qualify for payments through Medicare, or Medicaid. You should talk to the Principal Investigator about this, if you have concerns.

Who can I contact if I have a question?

The people conducting this study will be available to answer any questions concerning this research, now or in the future. You may contact the Principal Investigator at 828-262-6333 (Dr. Jeffrey M. McBride). If you have questions about your rights as someone taking part in research, contact the Appalachian Institutional Review Board Administrator at 828-262-2130 (days), through email at irb@appstate.edu or at Appalachian State University, Office of Research and Sponsored Programs, IRB Administrator, Boone, NC 28608.

Do I have to participate? What else should I know?

Your participation in this research is completely voluntary. If you choose not to volunteer, there will be no penalty and you will not lose any benefits or rights you would normally have. If you decide to take part in the study you still have the right to decide at any time that you no longer want to continue. There will be no penalty and no loss of benefits or rights if you decide at any time to stop participating in the study. This research project has been approved by the Institutional Review Board (IRB) at Appalachian State University. This study was approved on2/22/2013. This approval will expire on 2/18/2014unless the IRB renews the approval of this research.

I have decided I want to take part in this research. What should I do now?
The person obtaining informed consent will ask you to read the following and if you agree, you should sign this form:

- I have read (or had read to me) all of the above information.
- I have had an opportunity to ask questions about things in this research I did not understand and have received satisfactory answers.
- I understand that I can stop taking part in this study at any time.
- By signing this informed consent form, I am not giving up any of my rights.
- I have been given a copy of this consent document, and it is mine to keep.

Participant's Name (PRINT) Signature Date

Vita

Ligia Maria Vasquez was born in Guatemala City, Guatemala in 1988 to Marco and Maritza Vasquez. She moved to Winston-Salem, NC in 1991 and there underwent the majority of her education, graduating from Parkland High School in 2006. Ligia then attended High Point University in High Point, NC, where she was involved with Alpha Gamma Delta Fraternity, for which she held various positions including serving on Executive Council as Vice President of Member Development. She graduated from High Point University in 2010 with a Bachelor of Science in Exercise Science, and soon after, accepted enrollment at Appalachian State University. Ligia received a Graduate Teaching Assistantship for Exercise Physiology and a Graduate Research Assistant position in the Neuromuscular and Biomechanics Laboratory. She was awarded her Master of Science in Exercise Science from Appalachian State University in August 2013.