UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

RECOVERY PATTERNS FROM HIGH-INTENSITY INTERVAL RESISTANCE EXERCISE IN MALE AND FEMALE ROTC CADETS

A THESIS

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

Degree of

MASTER OF SCIENCE

By

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Norman, Oklahoma
2018

RECOVERY PATTERNS FROM HIGH-INTENSITY INTERVAL RESISTANCE EXERCISE IN MALE AND FEMALE ROTC CADETS

A THESIS APPROVED FOR THE
DEPARTMENT OF HEALTH AND EXERCISE SCIENCE

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Acknowledgements

First and foremost, I would like to thank all of my past teachers and professors that I have had throughout my entire academic years. Each of you played a cruicial part in my educational growth and I would not have been able to succeed in college or graduate school without everything you all taught me, not only as a student but also as a an adult.

Most importantly, my parents and my sisters have been my ultimate supporters and cheerleaders. You all have showed intelligence, kindness, strength and humility in everything you do and it has been something I have been able to look up to my entire life that has molded me into who I am today. I truly owe all my successes and acomplishments to you all. I love you with all my heart. Thank you!

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Abstract

Background: Army Reserve Officers' Training Corps (ROTC) must meet military expectations mentally and physically. Training for ROTC cadets cadres around improving 2-mile run time, push-ups and sit ups which is primarily endurance focused. It is important for ROTC to incorporate resistance training into their normal training routine to improve military tasks and load carriage. Little evidence is presented in past literature covering the effect of high-intensity resistance exercise on ROTC cadets. **Primary Aim:** The primary aims of this study are 1) To determine the time-course for recovery in Army ROTC cadets following a bout of high-intensity interval resistance exercise, 2) To examine if there are any sex differences for recovery following high-intensity interval resistance exercise, and 3) To validate the use of CMJ as a measure of fatigue following a bout of high-intensity interval resistance exercise. **Methods:** 19 subjects, 10 male and 9 female ROTC cadets performed a bout of high-intensity interval resistance exercise using their 10RM load. The exercise consisted of a 3 circuit exercise using 8 exercise machines. Subjects provided soreness ratings and perceived recovery status (PRS) prior to performing upper and lower body counter-movement jumps (CMJ). Following CMJs, subjects performed the high-intensity resistance exercise by doing 3 rounds of the 8 exercises with 60 seconds of work at their 10RM and 60 seconds of rest between exercise machines. Subjects gave RPE after each round and once the exercise was complete, subjects performed another 5 upper and lower body CMJs. Thirty-minutes post exercise, subjects provided session RPE (sRPE) to rate the exercise as a whole. Subjects performed this protocol 4 different times; at baseline and 24, 48 and 72 hours post baseline. The last three experimental times were randomized

and counterbalanced. **Results:** Exercise performance recovery was determined by the total repetitions performed for each of the 4 experimental trials. Male and female subjects did not differ in exercise performance recovery for all time points. Baseline performance was the lowest compared with 24H, 48H and 72H while 24H, 48H and 72H were not different from each other. CMJ performance was not significantly different from pre-to-post exercise for 24H, 48H and 72H. Baseline CMJ performance decreased from pre-to-post. Males had greater CMJ variables compared with women. Soreness ratings showed that 24H had the greatest soreness compared with baseline and 72H. Upper body soreness ratings were higher compared with lower body soreness for baseline, 24H and 48H. Males and females did not differ in soreness ratings. PRS was significantly lower at 24H compared with baseline and 72H. PRS was also highly correlated with soreness ratings for all time points. sRPE did not differ between time points or male and female subjects. RPE following each round of the exercise showed that set 1 had the lowest RPE compared with set 2 and 3 for all time points and set 2 was lower than set 3 for 24H and 72H. Males and females did not differ in RPE for all sets. **Conclusion:** ROTC cadets were able to recover 24H following a bout of high-intensity interval resistance exercise with no difference seen between male and female cadets. CMJ did not decrease from pre-to-post exercise and did not match the change in exercise performance as hypothesized. Soreness ratings were greatest at 24H indicating both male and female cadets were most sore 24H following a bout of high-intensity interval resistance exercise. PRS matched the pattern of soreness ratings which indicates that PRS is mainly associated with soreness and not exercise performance recovery. sRPE was unchanged between time points meaning subjects perceived similar exertion

between time points. Overall, more investigating needs to be conducted to analyze recovery patterns following a bout of high-intensity interval resistance exercise in ROTC cadets while incorporating CMJs to validate the use of CMJ as a surrogate to measure performance. However, this resistance exercise could be a good initial exercise to improve performance in ROTC cadets.

Chapter 1: Introduction

Introduction

Army Reserve Officers' Training Corps (ROTC) cadets must meet military expectations mentally and physically. It is critical that military men and women have the physical performance capacity that prepares them for military occupational duties. To help ensure that ROTC cadets attain the necessary physical competency, they traditionally undergo physical training (PT) 3 times per week[1]. ROTC physical training typically consists of a dynamic warm-up, upper- and lower-body callisthenic exercises, and a 2-5 mile run. The Army Physical Fitness Test (APFT) is used to assess their fitness level by having the cadets perform a 2-minute sit-up and 2-minute push-up test for maximum repetitions and a 2-mile run for time. The main component of their PT is endurance training consisting of long periods of continuous exercise at moderate intensity[2]. The Army ROTC has utilized traditional endurance training and more recently included high-intensity interval training (HIIT) to improve APFT performance in the 2-mile run. However, their military duties also require the ability to carry loads from 16-40 kg over long distances. This requirement highlights the need for a muscular strength and endurance PT component to help ensure military readiness and protection from injury. This requirement must be met in an expeditious manner, since time outside of military-specific job training is limited.

Consequently, ROTC command at various cadres around the country have also begun to implement various types of resistance training programs in an attempt to reduce injury rates resulting from load carriage. Additionally, due to time constraints,

others have begun to experiment with the incorporation of high-intensity resistance training circuits. Strength circuits represent a time efficient mode for increasing muscular strength and endurance that also matches the operational tempo associated with field training exercises. These field training exercises often involve complex movements over uneven terrain where the risk of musculoskeletal injury is exacerbated. The increased interest in high-intensity interval training (HIIT) in the tactical athlete population is mainly due to its demonstrated capacity to elicit similar increases in physical performance while reducing the time needed to complete a training session. Gist et al. (2015) found similar APFT scores when Army ROTC cadets performed high-intensity training consisting of burpees compared with traditional PT. Investigations in other populations have demonstrated similar positive results between lower intensity, high-volume resistance training when compared to high intensity, low volume resistance training being under consideration by the military[4,5,6,7]. Low-volume circuit training has also been shown to be an effective mode of exercise in women for maintaining strength when compared to high-volume, multiple set training[4]. Nevertheless, there has been little to no research done following high-intensity resistance exercise in ROTC cadets. Additional investigations are required to properly evaluate the safety and effectiveness of this mode of exercise in this population.

Adaptation, fatigue, and recovery patterns following traditional resistance training have been investigated previously[8, 9,10,11,12, 13]. However, there is a minimal number of research investigations that have evaluated these attributes following high-intensity, low volume resistance training exercise. Fatiguing exercise may lead to increased muscle soreness, reduced power, decreased vertical jump performance,

reduced sprint performance and diminished endurance performance[10]. Recovery may then be described as the ability to meet or exceed performance in an activity following fatigue[11]. If a tactical athlete is fatigued and proceeds with physical activity or competition without being fully recovered, it can eventually result in injury from overtraining[11]. Having an optimal recovery period between training sessions or competitions will allow the tactical athlete to train at greater intensities with reduced potential for injury[9].

Recovery is often measured by physical performance. If an athlete is able to perform at the same maximal capacity following an intense exercise bout, they are considered to be recovered from fatigue. Recovery has more recently been measured by using changes in counter movement jump (CMJ) performance. The concept is related to the CMJ's ability to measure ground reaction force and the resulting power and velocity associated with the jump. CMJ's have been validated to assess fatigue by examining these ground reaction forces in previous studies following intense resistance training and sport training[14, 15, 16]. The pre-stretch characteristic of a CMJ make it an optimal measure of power to assess fatigue and recovery from dynamic exercise[15].

Lastly, there is evidence of fatigue and recovery differences in male and females following isometric contractions [17, 18, 19, 20] and dynamic contractions [12, 21, 22]. Males tend to fatigue faster and recover at a slower rate following isometric contractions compared to women[18, 20]. Females also recovered faster following a bench-press exercise compared to males[22]. In contrast, females tended to have greater fatigue following eccentric exercise compared to males [21] and there were no differences seen in recovery following maximal velocity contractions for the elbow flexor and knee extensor

muscles[12]. There is strong evidence for sex differences following isometric contractions but there is still a sparse amount of evidence related to recovery following different types of dynamic resistance training.

Therefore, the aims for this study are as follows: 1) To determine the time-course for recovery in Army ROTC cadets following a bout of high-intensity interval resistance exercise, 2) To examine if there are any sex differences for recovery following high-intensity interval resistance exercise, and 3) To validate the use of CMJ as a measure of fatigue following a bout of high-intensity interval resistance exercise. The exercise session will be performed in a circuit-style fashion consisting of 8 upper and lower body resistance exercises performed in series. The exercises include the following: leg press, chest press, lat pull down, shoulder press, knee extension, knee flexion, and biceps curl and triceps extension. Fatigue and recovery will be assed using CMJ's, session RPE, subjective soreness ratings, and a perceived recovery scale.

Research Questions

1. What is the time-course for recovery in Army ROTC cadets following a bout of high-intensity interval resistance exercise?
    - What differences exist for recovery in male and female ROTC cadets, as measured by the number of repetitions performed, after completing a bout of all-body, high-intensity interval resistance exercise?
2. Do the changes in counter-movement jump performance match the pattern of change in exercise performance following a bout of all-body, high-intensity interval resistance exercise?

- What differences in counter-movement jump performance exist between male and female ROTC cadets following all-body, high-intensity interval resistance exercise?

3. What is the time course and characteristics related to delayed onset muscle soreness (DOMS) related to exercise-induced muscle damage (EIMD) following a bout of all-body, high-intensity interval resistance exercise?
    - What are the sex differences in delayed onset muscle soreness (DOMS) related to exercise-induced muscle damage (EIMD) and subjective ratings for soreness on a 100-mm visual analog scale (VAS) and objective ratings using an algometer for body region and global soreness between male and female ROTC cadets following a bout of all-body, high-intensity interval resistance exercise?
    - Will there be sex differences in the time course to reach peak soreness, as well as, to return to baseline?

Hypotheses

1. There will be differences in recovery between male and female ROTC cadets, as followed by the number of repetitions performed, after completing all-body, high-intensity resistance circuit exercise.
2. Changes in counter-movement jump performance match the pattern of change in exercise performance in ROTC cadets following all-body, high-intensity resistance circuit exercise.

1. There will be differences in countermovement jump performance between male and female ROTC cadets following high-intensity interval resistance exercise.

3. There will be differences in DOMS related to EIMD between male and female ROTC cadets following a bout of all-body, high-intensity resistance circuit exercise.

1. There will be differences between male and female ROTC cadets in the subjective ratings for soreness on a 100-m VAS for body region and global soreness.

2. There will be differences between male and female ROTC cadets in soreness measures using an algometer device for body region.

2. There will be differences in the time course to reach peak soreness, as well as, to return to baseline in male and female ROTC cadets.

Significance

This study will highlight the ability of a high-intensity resistance circuit protocol to stimulate fatigue and soreness in ROTC cadets that will allow for investigation of recovery patterns. This work will help clarify the relative value of utilizing of CMJ's to quantify fatigue and recovery in male and female ROTC cadets compared to other objective and subjective performance measures. Lastly, this investigation will help identify any sex differences following a high-intensity resistance exercise and could provide evidence for the use of high-intensity resistance training protocols into ROTC PT.

Assumptions

The assumptions of this study include the following:

1. Participants will give their maximal effort on all repetitions for each exercise.
2. Participants will provide truthful answers for all soreness and recovery questions.
3. Participants have received the same level of physical training through the ROTC.

Delimitations

The delimitations of this study include the following:

1. Participants are male and female ROTC cadets enrolled at the University of Oklahoma.
2. Participants will be between the ages of 18-35 years of age
3. Participants are recreationally active and participate in ROTC physical training three days per week.
4. Participants are free of musculoskeletal injuries that would prevent them from doing any form of resistance exercise.
5. Participants will not be eligible to participate if they answered “yes” to any of the questions on the physical activity readiness questionnaire (PAR-Q).
6. Female participants will be tested during the follicular phase to control for menstrual cycle related variations in exercise performance, fatigue, and recovery.

Limitations

The limitations of this study include the following:

1. The cohort for this study will be a convenience sample of ROTC cadets and therefore does not incorporate random selection. The results of this study can only be applied to male and females in the Army ROTC.

2. No direct measurement of changes related to force production will be investigated, such as; twitch interpolation via electromyography (EMG).

3. No direct measurement of changes related to muscle damage will be assessed such as creatine kinase levels, lactate dehydrogenase levels, interleukin 6, etc.

Operational Definitions

1) **Army Physical Fitness Test (APFT):** Test comprised of timed sit-ups, push-ups, two-mile run and sit-and-reach[23].
2) **Counter Movement Jump (CMJ):** Performing a countermovement in the lower limbs prior to jumping and landing in the same spot as take-off while the hands remain on the hips throughout the jump[15].
3) **Delayed Onset Muscle Soreness (DOMS):** Muscle tenderness, pain on palpation, and mechanical stiffness in the muscle that results in pain when the muscle is passively stretched or activated[10].
4) **Fatigue:** Comprising sensations of tiredness and associated decrements in muscle performance and function[24].
5) **Exercise-Induced Muscle Damage (EIMD):** Immediate and prolonged reductions in muscle function following dynamic exercise[10].
6) **Recovery:** Ability to meet or exceed performance in a particular activity[11].

7) **Reserve Officer Training Corps (ROTC):** Program that exists on University campus across the United States that provide a source of reserve officers for the U.S. Army[1].
8) **Session RPE:** Single global rating of the perceived intensity for the entire training session[25].
9) **Visual Analog Scale (VAS):** Unidimensional pain rating scale that asks for the patient to make a mark on a 100-mm line with one end reading "least possible pain" and the other "worst possible pain"[26].

Chapter 2: Literature Review

The literature related to the effects of fatigue and recovery following high intensity resistance exercise, as well as, sex differences in fatigue and recovery is reported in this chapter. The literature is presented under the following topics: (1) High-Intensity Training, (2) Fatigue Following Resistance Exercise, (3) Recovery Following Resistance Exercise, (3) Fatigue and Recovery Sex Differences, (4) Countermovement Jump to Assess Fatigue, (5) Session RPE to Assess Exercise Intensity, (6) ROTC Cadet Training and (7) Summary. The search terms include Army Reserve Officer Training Corps (ROTC), Physical Readiness Test (PFT), High-intensity Interval Training (HIIT), resistance exercise, fatigue, recovery, sex differences, countermovement jump and session RPE.

High-Intensity Training

Low-volume high intensity exercise, such as high-intensity interval training (HIIT), has been shown to elicit similar results as high-volume training while utilizing a more time-efficient regimen[4, 5, 6, 7]. HIIT has also been shown to increase skeletal muscle mitochondrial capacity and exercise performance[5, 7]. Trapp et al., (2008) found that 20 minutes of HIIT on a cycle ergometer had similar significant reductions in body fat as 40 minutes of steady-state exercise in women. Gibala et al., (2006) found that men performing four to six repeats of 30-second maximal cycling bouts at 250% VO2max for six sessions over 14 days elicited similar results to cycling for 90-120 minutes at 65% VO2max. These results show how endurance based interval training can elicit similar responses as traditional endurance training. However, there has been

sparse research done investigating high-intensity interval training with resistance exercise.

Resistance exercise puts mechanical stress on the body by lifting or pushing a load that ultimately causes muscle growth through multiple cellular mechanisms[27]. The signaling responses that cause muscle growth are stimulated by resistance exercise choice, load, volume, rest periods and exercise order[27]. Activating large muscle groups with high loads can evoke a greater hormonal response than activating smaller muscle groups with low loads. There is a dose-response for the number of sets per exercise to evoke strength gains[28]. There are greater muscular adaptations with utilizing multiple-set exercises than with single-set exercises. A high-volume workout involves a great number of sets and repetitions with a lower resistance. The protein synthesis pathway has been shown to be stimulated with resistance training workouts consisting of low set and repetition ranges with a higher resistance and exercise intensity[27]. Low-volume, single-set circuit training has been shown to be effective for maintaining strength but did not evoke greater strength gains than high-volume periodized training[4]. This could be due to the low volume training containing the same relative intensity as the high-volume training, resulting from the heavier loads used by the low volume group's participants. Since high-intensity interval training has been shown to be a beneficial approach to endurance training, it seems rational that resistance exercise may reap similar benefits when utilizing a high-intensity interval format.

Fatigue Following Resistance Exercise

High-intensity resistance exercise has been shown to create a transient reduction in muscular strength [8] that is predominantly the result of eccentric contractions[10]. This change is a decrease in muscle function and performance and may be thought of as demonstrating some degree of neuromuscular fatigue or skeletal muscle fatigue[8, 10, 29]. The decrease in muscle function could be due to central factors or peripheral factors. The central factors generally focus around a person's motivation to complete a task or exercise. Peripheral factors generally relate to the motor unit where there is damage to the contractile components of the muscle fibers[10, 29]. Fatigue and the accompanying characteristics related to fatigue following eccentric exercise have been assessed reliably and validly through changes in power, vertical jump performance, sprint performance, endurance performance, as well as, associated with changes to subjective soreness rating[10].

Men and women both demonstrate decreases in maximal force and neuromuscular performance following high-intensity resistance exercise across various research investigations employing different testing methodologies[8, 18, 20, and 21,24,30,31]. Performing one maximal squat-lift with 100% 1RM decreased maximal force significantly and lengthened force relaxation in male and females[8]. The maximal voluntary contraction (MVC) force was reduced following repeated static contractions of the adductor pollicis muscle in 5-s intervals until exhaustion in male and females[18]. Male and females demonstrated a decrease in MVC and motor unit activation following dynamic, submaximal contractions of the elbow flexor and knee extensors[20]. Female handball players had reductions in voluntary isokinetic knee

extensions, jump height and 20m sprint time following handball training sessions and matches[30]. Rugby players had increased muscle soreness and decreased countermovement flight time following a rugby match[24, 31]. However the presence of sex differences in fatigue and soreness patterns following high intensity resistance exercise require further evaluation.

Recovery Following Resistance Exercise

Recovery is the ability to meet or exceed performance in a particular activity following a training session[11]. Recovery is measured mainly by physical performance[9,22,30,32,33,34,44] which can be tested by performing a baseline exercise protocol and assessing the participant's ability to replicate the same volume and intensity of work after a given time period has passed, by tracking daily variation in CMJ performance variables, the assessment of subjective muscle soreness, and perceived recovery, to name a few.

In an investigation by McLester et al. (2003), 10 recreationally trained males were recruited to perform 3 sets of 8 resistance exercises for the evaluation of recovery. Each exercise was performed with a 10 RM load. Subjects were unable to replicate their baseline performance with 24 hours of recovery. However, performance was not significantly different than baseline after 48 hours, and at that point, subjects were considered to be fully recovered. Judge & Burke (2010) tested male and females on their recovery following a bench press training session. Each subject went through a 3-week training period prior to strength testing. On the strength testing day, the subjects performed 5 sets of a percentage of their 1RM, starting at 50% and increasing to 70%, 85%, 95% and 100% for a bench-press exercise. The subjects rested for 4-, 24- or 48

hours in consecutive order for three weeks. Recovery was measured by the subjects repeating the strength protocol and their total weight lifted was recorded. They found that males were unable to perform their baseline measures after 4- and 24- hours but returned to their baseline performance 48- hours later. Females were able to replicate their baseline measures 4 hours later, demonstrating an enhanced recovery capacity among female participants. Ronglan et al. (2006) found that female handball players were unable to replicate their baseline measures during a 5-day training camp and during an international tournament. Leg strength and jump height were used to assess physical performance among the handball players and both were reduced after a high-intensity training session. Additionally, the group was unable to meet baseline measures 3 days after the high-intensity session. Radaelli et al. (2012) found that untrained women were unable to recover 72 hours post performing 4 sets of 10 repetitions of elbow flexion at 80% of 1RM. Muscle soreness was measured using the 100mm visual analog scale and soreness was found to be significantly greater 24-hours and 48-hours post in the participants' dominant arm compared to their non-dominant arm. Howatson et al. (2016) found that elite track athletes were not recovered 24 hours after performing 12 sets of maximal strength resistance exercise, consisting of squats, split-squats and push presses. These results show that recovery may be task specific and thus must be evaluated based on the type of training stimulus endured.

Fatigue and Recovery Sex Differences

There is evidence of sex differences related to fatigue[13, 17, 18, 19,20,21,35] and recovery[18, 20, 22]. Albert, et al. (2006) conducted a study to review the sex differences of fatigue during upper and lower isometric contractions. They found that males had a

greater loss of force, greater rate of fatigue and were unable to maintain 50% MVC for 30-seconds during the fatiguing contractions compared to females. However, Sewright et al. (2008) found that females had greater strength loss after eccentric exercise compared with male subjects. Females also tend to recover at a faster rate than males after isometric exercises[18, 20]. There has been little research done regarding sex differences for fatigue and recovery following dynamic exercises. Sex differences in muscle fatigue of dynamic contractions coincide with the task being performed, including velocity of contraction and the muscle group involved[30]. Senefeld et al. (2013) found that women did not have the same fatigue resistance during dynamic contractions as isometric contractions. There were no sex differences in fatigue during repeated maximal velocity contractions or recovery of elbow flexion and knee extension muscles. Currently, the literature is sparse regarding sex differences that may or may not exist following high-intensity circuit resistance training.

Countermovement Jump to Assess Fatigue

Madigan, et al. (2003) investigated fatigue on the lower extremities and its effect on ground impact force by examining landing kinematics and kinetics. Subjects performed a series of single-leg squats to initiate fatigue and followed that with two single-leg landings on a force plate. The force plate collected the ground reaction force and the kinematic data for each landing. They found that peak vertical ground reaction force decreased with fatigue and ankle and knee flexion increased with fatigue. Based on these findings, it can be concluded that using a force plate will show a decrease in ground reaction force with an increase in fatigue.

Jumping is a compound movement that requires both upper- and lower-body contractile components[15]. Its explosive action makes for a suitable measure of performance by the athlete needing to produce force quickly[15]. Many jumps have been used as field tests to assess explosive power but, Markovic, et al. (2004) determined the counter movement jump (CMJ) to be the most accurate measure of power based on its pre-stretch capabilities. The CMJ was validated as an accurate measure to assess fatigue with 1 or 5 CMJs[36], following an explosive effort sequence[37], comparing it with other popular jump tests such as Sargent's jump, standing long jump, and Abalakov's jump[15] and assessing intra/interday reliability for neuromuscular function following a fatiguing protocol[16].

Session RPE to Assess Exercise Intensity

Foster et al. (2001) developed a method that integrates the rating of perceived exertion (RPE) with the training impulse known as session RPE. The session RPE is used as a "global rating" of intensity during an entire exercise bout instead of just a specific moment during that exercise[38]. They investigated the relationship between session RPE and heart rate (HR) based methods of monitoring training while the subjects endured different types of exercise. They used an exercise score that was calculated by the time of completion multiplied by the session RPE. Session RPE and HR methods were found to be highly correlated and therefore can be used as a surrogate to HR to monitor internal training load[38]. Session RPE has been used as an individual indicator of training response in soccer players due to the high correlation with minutes played[39].

Session RPE has been used for quantifying exercise intensity during resistance exercise as well[25, 40, 41]. Single set resistance exercise showed a corresponding increase in session RPE with an increase in intensity[25]. Session RPE was found to be greater for super-slow (55% 1RM) and traditional (80% 1RM) resistance exercise compared with maximal power[40]. This difference was due to the two methods containing a higher load and volume. The super-slow method had the highest session RPE and Egan et al. (2006) suggested that was due to greater time under tension.

ROTC Cadet Training

Thomas et al. (2004) found that male and female cadets scored in the 55th percentile and 30th percentile for a bench press maximum while scoring in the 83rd percentile on push-ups, sit-ups and 2-mile run when compared with normative data from APFT data bank and from age- and sex-matched peers. ROTC cadet training does not include resistance training according to Thomas et al. (2004). They suggest that the addition of supplementing a resistance training program, especially for females, will improve their muscular strength[1, 42, 43].

To find improvements in ROTC cadets' fitness, the effect of low-volume, high-intensity whole-body calisthenics[3] and interval training[2] were studied. Gist et al. (2015) found that a low-volume, high-intensity protocol of burpees maintained metabolic capacities and physical performance that were similar to traditional cadet training. The cadets only exercised for a total of 33 minutes over the course of 12 sessions and stated the exercise was more difficult as measured by session RPE. Interval training is arguably more relevant to the tasks that cadets will need to perform[2]. This training is linked with increased cardiorespiratory fitness and aerobic

metabolism. However, Gibala et al. (2015) did not measure the effect of resistance interval training on muscular strength and this type of training's ability to optimize maximal strength and power[42]. Currently, a gap exists in the literature surrounding the efficacy and utility of this training mode and its possible positive outcomes for ROTC cadets.

Summary

There has been a plethora of research related to fatigue and recovery patterns for males following resistance training and the sex differences associated with traditional, multiple set, high volume, low to moderate intensity resistance training. Males tend to show greater fatigue and slower recovery rates compared to females when comparing CMJ performance and session RPE to assess fatigue and recovery. However, little research related to high-intensity resistance circuit exercise training, its associated fatigue, and required recovery has been performed. ROTC cadet training mainly consists of endurance exercise with some calisthenics. Research is needed to further investigate the recovery patterns of male and female ROTC cadets following a high-intensity resistance exercise and its incorporation into their weekly training.

Chapter 3: Methodology

Participants

The participants came from a convenience sample consisting of male and female cadets from the University of Oklahoma Army ROTC. The sample size was chosen based on the findings of previous research [9, 45] incorporating a similar testing protocol and an apriori power analysis via G*Power software. A sample size of 19 was able to detect an effect size of 0.7 SD's (a large effect size) and to have a statistical power of 0.8. Therefore, 19 participants (n_1 = 10 male cadets and n_2 = 9 female cadets) was able to provide significant statistical power and therefore recruited for the study. Each participant was be free of musculoskeletal injuries or had been released to exercise by their doctor at least 6 months prior to the study. The participants were asked to abstain from all other strenuous activities related to their participation in ROTC. The participants provided written consent which was approved by the University of Oklahoma Institutional Review Board.

Experimental Design

The ROTC cadets who voluntarily consent to participate in the study were randomized to a recovery scheme (e.g. 24, 48, 72 hrs. vs 72, 48, 24 hrs.). All recovery schemes were counter-balanced to minimize ordering effects. The study was a within and between-groups design with repeated measures. There were a total of 6 visits over a 21 day period. Briefly, the 6 visits consisted of the following; informed consent and familiarization 1, familiarization 2, baseline measures and counter-balanced recovery schemes consisting of 24-, 48-, 72 hours of recovery following resistance exercise. Additionally, visit 1 and visit 2 were separated by 3-5 days; visit 2 and visit 3 were

separated by 10 days. The timing of visits 4, 5, and 6 depended on the recovery scheme participants were randomly assigned for their post-baseline measurements. An overview of the experimental design is presented in Figure 1.

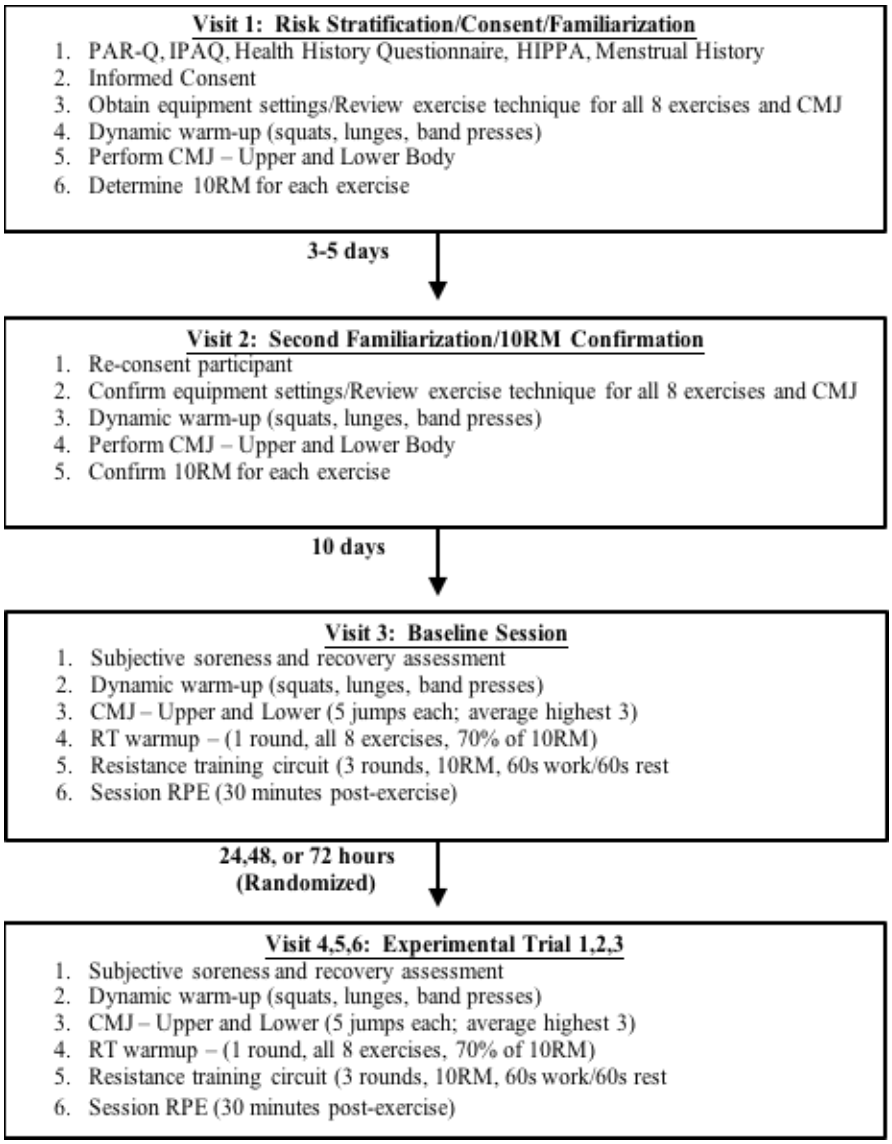

Figure 1. Overview of experimental procedures

Visit 1: Informed Consent and Familiarization 1

The first visit consisted of each participant providing written consent, HIPAA information, PAR-Q, IPAQ, health history questionnaire and menstrual cycle

information for the female subjects. Each subject was given an overview of the protocol and once they gave consent, their height, weight, age and academic grade (Freshman, Sophomore, Junior or Senior) was recorded. Height was measured using a Stadi-O-Meter (Novel Products Inc., Rockton, IL) by having the subjects stand with shoes off and back against the Stadi-O-Meter. Height was recorded on their data sheet. Weight was measured using the ForceDecks software with independent, dual force platforms (FD4000, NMP ForceDecks Ltd., London, England). Each subject stepped onto the force plate and distributed their weight evenly on both sides. A video display was present to assist the subject with obtaining this even weight distribution between two force plates. The data collector saved the subject's weight once the ForceDecks software showed a 50:50 distribution of force on each plate. Weight was recorded on the subject's data sheet.

Each subject participated in a familiarization for the upper and lower body countermovement jump and with proper technique for each exercise and the exercise equipment itself. The subjects practiced performing the upper body countermovement jump by getting in the push-up position with arms straight, bending the elbows, rapidly pushing off the ground, landing on both hands simultaneously with elbows bent and then straightening the arms. The subjects practiced performing the lower body countermovement jumps by following the protocol provided by Markovic et al., (2004). Each subject stepped on the platform and when given the verbal signal "ready, set, go", the subject bent at the knees, maximally jumped vertically in the air and landed in the spot that they took-off while keeping hands at the hips. Once the subjects were familiar and comfortable performing both countermovement jumps, 10 RM was recorded for

each of the 8 exercise machines. The machines that were utilized for the investigation were Cybex selectorized machines (Cybex International, Inc., Medway, MA) except the leg press machine which was a plate loaded machine (Body-Solid Leg Press & Hack Squat GLPH1100, Body-Solid Inc., Forest Park, IL). For each exercise machine, the seat height and depth, as well as arm and leg positions was recorded to help ensure consistency of the subject's technique across data collections.

Visit 2: Familiarization 2

Each participant entered the testing lab area and was re-familiarized with the CMJ's and confirmed their 10RM from visit 1. The participant performed 5 upper body CMJ followed by 5 lower body CMJ's. Each participant went through each of the 8 exercise machines and validated their 10RM. If, the subject's 10RM changed, the highest 10RM was used for the remainder of testing.

Visit 3: Baseline Measurements

The subjects' sensitivity to pain was examined by using an algometer (Force Dial FDK 20, Wagner Instruments, Greenwich, CT) to quantify pressure pain threshold at each of the main muscle sites; quadriceps, hamstrings, gluteus medius, pectoralis major, latissimus dorsi, deltoid, biceps and triceps. Participants also performed general range of motion techniques which consisted of having the subjects perform 5 unweighted squats to assess lower body soreness, 5 unweighted chest press motions to assess pectoralis soreness, 5 biceps curl and triceps extension to assess biceps and triceps soreness, 5 over head press motions to assess shoulder and latissimus dorsi soreness. Subjects rated soreness on a scale of 0 to 10 with 0 indicating no soreness and 10 indicating extreme soreness on a 100-mm visual analog scale (VAS) [26]. Subjects

estimated recovery using the perceived recovery status (PRS) scale by stating what is believed to represent recovery with 0 signifying "very poorly recovered/ extremely tired" and 10 "very well recovered/ highly energetic" [46]. A dynamic warm-up was done before completing upper and lower countermovement jumps which consisted of performing 10 push-ups, 10 lunges and 10 unweighted squats lasting approximately 5 minutes prior to CMJ testing. The participants again performed 5 upper and 5 lower body CMJ's. Five minutes following the countermovement jump tests, each participant performed a warm-up of the circuit exercise by performing 10 repetitions at 70% of their 10RM for each machine. Following the warm-up with 70% of their 10RM, they performed a resistance circuit exercise that contained the 8 resistance machine exercises performed at the 10 RM load for 3 rounds. The participants had 60 seconds to perform as many repetitions possible and 60 seconds of rest between exercise machines. After each set of 8 exercises, subjects provided rating of perceived exertion (RPE) using the 6-20 Borg scale, with 6 indicating "no exertion at all" and 20 indicating "maximal exertion". Participants provided RPE after all 3 rounds of the resistance exercise circuit. There was 120 seconds of rest between each round. After completing all 3 rounds, subjects repeated upper and lower countermovement jumps. After a 30-minute wash-out period following completion of the exercise session, subjects were asked to give session RPE[25] using the Borg scale of 6-20, with 6 indicating "no exertion at all" and 20 indicating "maximal exertion" and was recorded on the subject's data sheet.

Visit 4, 5, and 6: 24-, 48- or 72 hours post-exercise

The post-baseline recovery day scheme was randomized for each subject. Subjects were randomized to a different order of recovery days following baseline

measures. For example, subject 1 had the following recovery scheme; 24-, 48, and 72-hours post baseline, and subject 2 had the following recovery scheme; 72-, 48, 24-hours post baseline. Figure 2 illustrates the timeline between the randomized recovery schemes following baseline measures. Subjects performed the same protocols as on the baseline measurement days; pressure pain threshold, soreness evaluation, PRS, CMJ warm-up, upper and lower countermovement jump, resistance circuit exercise warm-up, resistance circuit exercise, RPE between each set, upper and lower countermovement jump and session RPE.

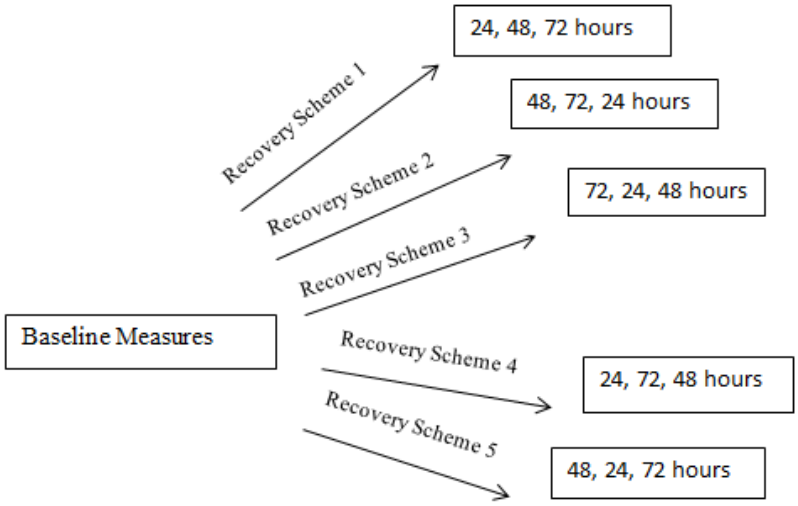

Figure 2. Randomized recovery scheme

Experimental Procedures

10 RM Determinations

A 10 RM was established for each of the 8 exercises. Subjects began with a light load that allowed them to perform about 15-18 repetitions. The load increased by 5-10 lbs. for upper body and 15-20 lbs. for lower body for the next set depending on the level

of difficulty. If the subject was able to produce more than 10 repetitions with this load, it increased again by 5-10 lbs. or 15-20 lbs. until the subject could only produce 10 repetitions maximum. Between each set, the subject rested for 2-4 minutes to ensure recovery [9]. The 10 RM for each exercise machine was recorded on the subject's data sheet. If the subject 10RM increased between familiarization 1 and familiarization 2, the highest 10RM load was used for all resistance circuit exercises including both baseline measures and post-baseline recovery measures.

Force Platform & CMJ

The bilateral force plate system and accompanying software (ForceDecks v2.3, London, UK) was used to evaluate the subject's fatigue and recovery before and after performing the resistance circuit exercise via repeated CMJ's. The bilateral force plates were placed on a solid flat surface and plugged into a laptop computer loaded with the ForceDecks software. Once the station was set up, the data collector launched ForceDecks and a unique, anonymous alphanumeric code was created for the subject. The data collector zeroed the force plate scale and asked the subject to step onto the force plate by evenly distributing the subject's weight on both the right and left force plate. Once weight was evenly distributed, the collector saved the subject's weight. The data collector then instructed the subject to perform the CMJ's by giving a verbal cue "ready, set, go". Each participant performed 5 lower body CMJ's with 3-5 seconds in between each jump followed by 5 upper body CMJ's with 3-5 seconds in between each jump. The data collector zeroed the platform again following the lower body CMJ's prior to the upper body CMJ's. In each case, the 3 CMJ's with the highest relative peak power was retained and averaged for statistical analysis. The subjects performed the

lower body countermovement jumps by following the protocol provided by Markovic et al., (2004). The subject will begin standing with legs evenly distributed between the two force plates, with legs straight and hands placed on the hips. Upon hearing the "ready, set, go" verbal cue, the subject will quickly bend the knees, followed rapidly with a jump off of the force platform and a subsequent landing on both feet simultaneously while slowly decelerating the body and return to the initial standing position. A low density band of gauze was placed across the force plate and the height of the gauze band was adjusted for each subject in order to standardize a tactile position between subjects The upper body CMJ began with the subject in the prone position with arms and legs straight, head neutral, hips extended (standard military push-up) and hands split between the two force platforms. Upon hearing the "ready, set, go" verbal cue, the subject quickly bent the elbows to ~90^0, followed rapidly with a maximal push off from the force platform and a subsequent landing on both hands simultaneously while slowly decelerating the body and returned to the initial pushup position. The data from each series of jumps was saved and was uploaded for data analysis. The metrics of interest for analysis included peak power (PP), concentric mean power (ConMP), eccentric mean power (EccMP), concentric peak force (ConPF), eccentric peak force (EccPF), concentric mean force (MF), eccentric mean force (EccMF), concentric rate of force development (ConRFD) and concentric impulse (ConIMP) (Gathercole et al., 2015). All variable were relative to the subject's body weight except for ConMF and EccMF.

Resistance Exercise Protocol

The 8 exercises in the resistance circuit included the leg press, chest press, shoulder press, lat pulldown, knee extension, triceps extension, knee flexion and bicep

curl [9]. The order at which each subject performed these exercises was randomized. Each exercise was performed with Cybex selectorized machines and a Body-Solid leg press machine and was located in the Neuromuscular Laboratory in the S.J. Sarkeys Complex in the Department of Health and Exercise Science at the University of Oklahoma. The subject began the first set of exercises by sitting in the first assigned machine. The seat height was already positioned for the subject and the 10 RM load that was determined between the two familiarization days was set. The subject had 60 seconds to produce as many repetitions as possible. Once 60 seconds was complete, there was 60 seconds of rest until the next set of repetitions on the next machine. This was repeated until all 8 exercises were completed. The completion of the 8^{th} exercise machine represented the first round of the circuit. There was 2 minutes of rest before starting the next round and the subjects stated their RPE for the first round and it was recorded during this 2-minute recovery period. This cycle continued for the second and third round of circuit exercise. Subjects were asked for session rating of perceived exertion (sRPE) of the entire exercise session following a 30-minute wash-out period, post-exercise. The main outcome variable used to determine recovery status was the mean delta score for total repetitions performed in one exercise session minus the repetitions performed in the preceding exercise session. Additionally, all time points were compared to the individual's baseline session to observe effects of accumulated fatigue over the four exercise sessions, as well as, across similar recovery time points to understand the pattern of recovery when different rest intervals (i.e. 24, 48, or 72 hrs. in different combinations) are employed.

sRPE

Thirty-minutes post-exercise following the three recovery days, the participants were asked to provide the sRPE for that bout of exercise[25] by the data collector asking "how would you rate the exercise intensity and your exertion during the exercise using the scale from 6-20; with 6 indicating "no exertion" and 20 indicating "maximal exertion". The scale used was the Borg scale which ranges from 6-20 where 6 indicates "no exertion at all" and 20 indicates "maximal exertion". The sRPE was recorded on the subject's data sheet.

Perceived Performance Score (PPS)

In order to show a blend of how hard the exercise bout was and how much work was actually done by the subject, a perceived performance score (PPS) was calculated by dividing the total number of reps the participant performed for that exercise bout by the respective sRPE. For example, if a subject performed 387 total reps and had a sRPE of 15, they would have a value of 25.8 for that session (387/ 15 = 25.8). However, if in the next session they performed 361 total reps and had a sRPE of 16, they would have a value of 22.5 (361/ 16 = 22.5). A higher value would represent either more work for the same absolute RPE value or the same work at a lower absolute RPE value. In both cases, this would seem to indicate increased recovery and/ or performance of the participant. A lower value would represent the opposite scenario and thus a lower level of participant performance or recovery.

Pressure-Pain Threshold & Soreness Assessments

To measure pressure-pain thresholds, an algometer was used on each major muscle. Each muscle was measured from its origin to insertion, based on body

landmarks, and half the length was noted and recorded so the middle of the muscle was used for each measurement. The data collector instructed the participant to say "stop" when they first started to feel pain. The data collector pressed the end of the algometer on the surface of the participant's muscle and pressed down progressively until the participant instructed the data collector to stop due to pain. The data collector will make note of the force reading, in kg, on the algometer and record that number on the participant's data sheet. Soreness ratings were evaluated using a 100-mm VAS. The VAS was anchored at 0 and 10 with 0 relating to "no soreness" and 10 relating to "extreme soreness" [26]. Participants were asked to take each joint through a full range of motion. Once each participant went through the range of motion for each joint and each major muscle group, the participant marked on the VAS line to represent their soreness level for each muscle as well as, overall soreness.

Perceived Recovery Status (PRS) Scale

The PRS was used to investigate how well each participant perceived their recovery. The scale ranged from 0-10 with 0 indicating "very poorly recovered/ extremely tired" and 10 indicating "very well recovered/ highly energetic" [46]. The data collector asked the participant to provide their PRS by asking how they felt and how well did they think they would perform the exercise. The participants circled the PRS value on the PRS data sheet once they have arrived for the testing session.

Statistical Analysis

IBM SPSS version 24 was used to perform all analyses. A two-way repeated measures factorial analysis of variance (ANOVA) for GENDER x TIME was performed on all performance, CMJ, pain, and perceived recovery dependent variables.

These analyses were observed across baseline and the 3 recovery periods between male and female ROTC cadets with the main performance variable being the mean delta change in total repetitions performed in one exercise session from the preceding exercise session. If there was a significant interaction effect found, then Bonferroni post hoc testing was performed to characterize any significant differences between the groups at various time points. If there was no significant interaction found, then main effects for gender and time were interpreted via one-way ANOVA. Statistical significance was set at $p \leq 0.05$ and all data were expressed as mean ± SD.

Chapter 4: Results

Subject Characteristics

Twenty four subjects were recruited for this study; however 5 subjects, 3 males and 2 females, did not complete the study due to schedule conflicts. Nineteen subjects, 10 males and 9 females, completed the study. Descriptive data for all participants that completed the study (age, height, weight, and 10RM for each exercise) are presented as means ± SD in Table 1.

Paired-samples t-tests were conducted to compare 10RMs between familiarization days for male and females. There was a significant increase in 10RM for males from familiarization 1 to familiarization 2 for chest press ($p=0.019$), shoulder press ($p=0.048$), knee extension ($p=0.030$), knee flexion ($p=0.007$), bicep curl ($p=0.018$) and triceps extension ($p=0.022$). There was no significant difference seen for males between familiarization 1 and familiarization 2 10RMs for leg press ($p=0.068$) or lat pulldown ($p=0.055$). There was a significant increase in 10RM for females from familiarization 1 to familiarization 2 for knee extension ($p=0.034$) and triceps extension ($p=0.030$). Females showed no significant difference in 10RMs between familiarization 1 and familiarization 2 for leg press ($p=0.290$), chest press ($p=0.276$), lat pulldown ($p=0.102$), shoulder press ($p=0.347$), knee flexion ($p=0.082$) and bicep curl ($p=0.347$).

A one-way ANOVA by sex was conducted for 10RM loads and is shown in Table 1. Females showed a significantly lower 10RM compared with the males for leg press ($p=0.006$), chest press, lat pulldown, shoulder press, knee extension, knee flexion, bicep curl and triceps extension ($p\leq0.01$).

Table 1. Subject Characteristic

Variable	Male	Female
n	10	9
Age (years)	20.5±2.2	20.2±1.6
Height (cm)	178.3±8.6	164.9±5.5
Weight (kg)	78.6±10.2	66.7±7.3
Leg Press 10RM (kg)	230.9 ± 65.9	153.2 ± 34.8*
Chest Press 10RM (kg)	72.1 ± 19.3	31.8 ± 6.8*
Lat Pulldown 10RM (kg)	70.3 ± 15.6	36.9 ± 4.7*
Shoulder Press 10RM (kg)	61.2 ± 13.7	31.8 ± 5.1*
Knee Extension 10RM (kg)	82.8 ± 19.8	48.5± 7.1*
Knee Flexion 10RM (kg)	83.3 ± 19.1	51.7 ± 10.7*
Bicep Curl 10RM (kg)	38.2 ± 11.1	16.8 ± 4.3*
Triceps Extension 10RM (kg)	41.2 ± 9.1	21.1 ± 4.7*

Values are mean ± SD
*indicates significant difference from male values ($p \leq 0.05$)

Exercise Performance

One-way ANOVA by sex was conducted to compare total reps for each time point between male and female subjects. There was no significant difference between male and females for baseline (p=0.110), 24 hours of recovery (24H) (p=0.209), 48 hours of recovery (48H) (p=0.099) and 72 hours of recovery (72H) (p=0.313). Since there were no significant differences found between male and female subjects, all subjects were collapsed and one-way repeated measures ANOVAs were conducted to compare total reps for the exercise and total reps for each set with-in and between each of the time points, along with mean delta scores between time points. Cohen's *d* was used for effect sizes for comparisons between all time points.

A significant difference was found between the time points ($p<0.001$; Table 2). A Bonferroni pairwise comparison showed that baseline was significantly lower than 24H ($p=0.001$, Cohen's $d=0.799$), 48H ($p<0.001$, Cohen's $d=1.126$) and 72H ($p<0.001$, Cohen's $d=1.094$). There was no significant difference between 24H and 48H ($p=0.145$, Cohen's $d=0.481$) or 72H ($p=0.117$, Cohen's $d=0.412$). Also there was no significant difference seen between 48H and 72H ($p=1.000$, Cohen's $d=0.081$). The percent change in total reps between baseline and visit 1, regardless of recovery period was 11.1% increase; between 24H and 48H was 11.1% increase; between 24H and 72H was 9.0% increase; and between 48H and 72H was 1.9% decrease. Table 3 describes the mean delta scores for total repetitions for 24, 48 and 72 hours between the preceding exercise session. For example, 24H mean delta score was calculated using the previous visit, whether it be baseline, 48H or 72H. There was no significant difference in mean delta scores between 24H and 48H ($p=0.246$) or 24H and 72H ($p=0.235$). There was also no difference seen in mean delta scores between 48H and 72H ($p=0.645$).

A significant difference was found between sets for baseline ($p<0.001$), 24H ($p=0.021$), 48H ($p=0.007$) and 72H ($p=0.002$). For baseline, set 1 was significantly greater than set 2 ($p<0.001$) and set 3 ($p<0.001$) while set 2 and 3 were not significantly different ($p=1.000$). A significant difference was found between sets for 24H ($p=0.021$). At 24H, set 1 was significantly greater than set 2 ($p=0.001$) but not significantly different than set 3 ($p=0.156$) and set 2 and 3 were not significantly different ($p=1.000$). A significant difference was found between sets at 48H ($p=0.007$). At 48H, set 1 was significantly greater than set 2 ($p=0.017$) but not significantly different than set 3 ($p=0.088$) and set 2 and 3 were not significantly different ($p=1.000$). A significant

difference was found between sets at 72H ($p=0.002$). At 72H, set 1 was significantly greater than set 2 ($p<0.001$) and set 3($p=0.030$) but set 2 and 3 were not significantly different ($p=1.000$).

A significant difference was found for set 1 between the time points ($p<0.001$). Baseline set 1 was significantly lower than 24H set 1 ($p=0.020$), 48H set 1 ($p<0.001$) and 72H set 1 ($p<0.001$). Set 1 at 24H was not significantly different than 48H ($p=0.197$) or 72H ($p=0.268$). Set 1 was not significantly different between 48H and 72H ($p=1.000$). A significant difference was found for set 2 between the time points ($p<0.001$). Baseline set 2 was significantly lower than 24H ($p<0.001$), 48H ($p<0.001$) and 72H ($p<0.001$). Set 2 for 24H was not significantly different from 48H ($p=0.139$) or 72H ($p=0.085$). Set 2 for 48H was not significantly different from 72H ($p=1.000$). A significant difference was found for set 3 between the time points ($p<0.001$). Baseline set 3 was significantly lower than 24H ($p=0.006$), 48H ($p<0.001$) and 72H ($p<0.001$). Set 3 for 24H was not significantly different from 48H ($p=0.177$) or 72H ($p=0.254$). Set 3 was not significantly different between 48H and 72H ($p=1.000$).

Figure 3 describes performance recovery, in terms of total reps, for subjects during the resistance exercise for baseline, 24, 48 and 72H, as well as % change in total reps between time points. Figure 3 and 4 illustrate male and female individual performance recovery during baseline, 24, 48 and 72 hour recovery in reference to the group mean for male and female subjects.

Table 2. Repetition Performance

Variable	Baseline	24H	48H	72H
n	19	19	19	19
Total Reps	331.89±62.31[a]	385.26±70.94	427.89±103.25	419.84±95.04
Set 1 Reps	123.84±17.38[a,b,c]	135.74±20.75[b]	148.84±29.37[b]	146.79±28.84[b,c]
Set 2 Reps	104.95± 22.13[a]	124.26±22.33	139.26±34.90	136.37±29.80
Set 3 Reps	103.11±25.95[a]	125.26±31.77	139.73±40.822	136.68±37.84

Values are mean ± SD
BL = baseline, 24H = 24 hour recovery, 48H = 48 hour recovery, 72H = 72 hour recovery
[a] Indicates significant difference from 24, 48 and 72H values ($p \leq 0.05$)
[b] Indicates significant difference from set 2 ($p \leq 0.05$)
[c] Indicates significant difference from set 3 ($p \leq 0.05$)

Table 3. Mean Delta

Variable	24H	48H	72H
Mean Delta	28.7±37.7	40.3±41.05	48.2±41.4

Values are mean ± SD
[a] indicates significant difference from 24H($p \leq 0.05$)
[b] indicates significant difference from 48H($p \leq 0.05$)
[c] indicates significant difference from 72H($p \leq 0.05$)

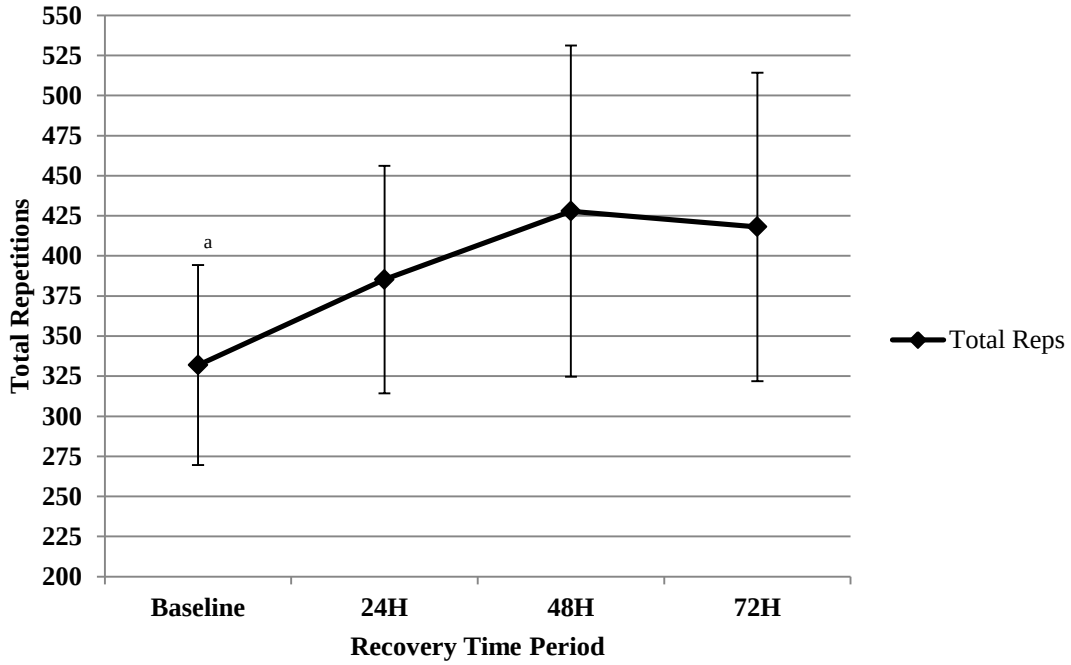

Figure 3. Mean total repetition performance across baseline, 24 hour recovery (24H), 48 hour recovery (48H) and 72 hour recovery (72H).
[a] indicates significant difference from 24, 48 and 72H values (p≤ 0.05)

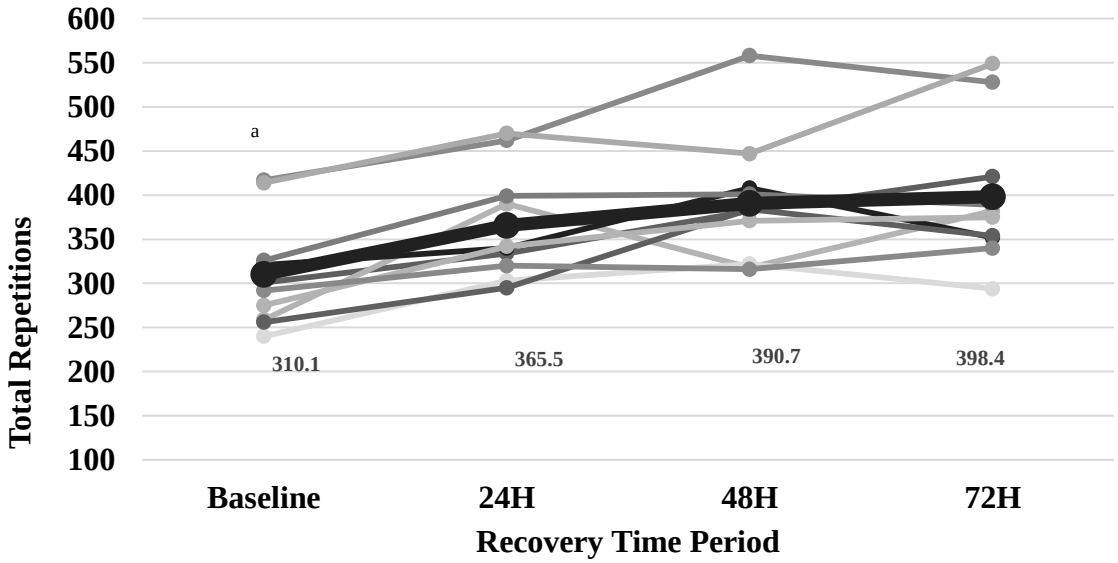

Figure 4. Mean total repetition performance for individual male subjects across baseline, 24H, 48H and 72H. [a] indicates significant difference from 24, 48 and 72H values (p≤ 0.05)

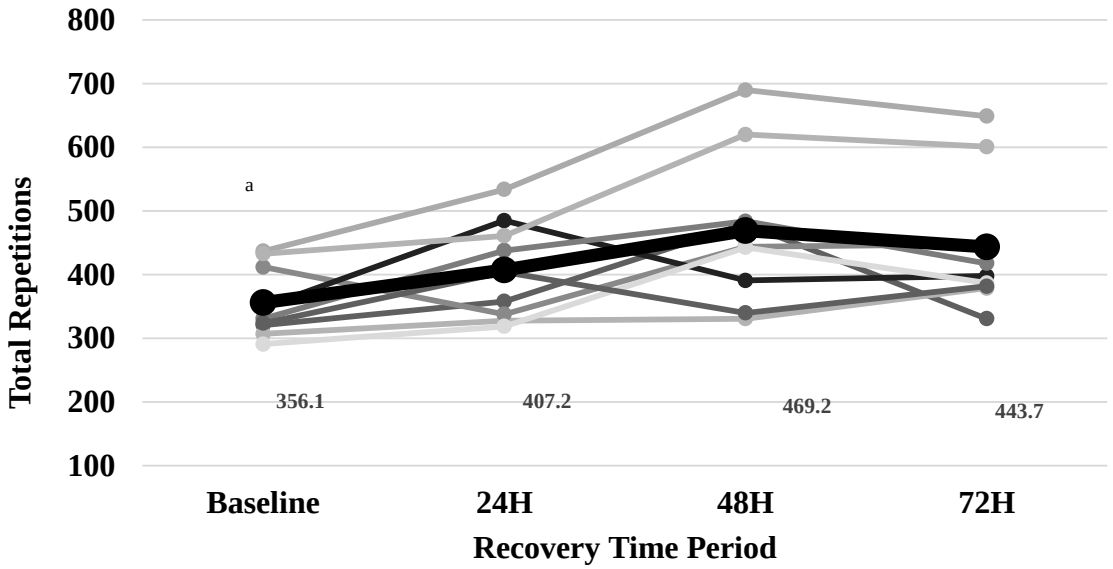

Figure 5. Mean total repetition performance for individual female subjects across baseline, 24H, 48H and 72H. [a] indicates significant difference from 24, 48 and 72H values ($p \leq 0.05$)

CMJ Performance

Lower Body

One-way ANOVAs were conducted to compare the CMJ variables between men and women, paired-samples t-tests were performed to compare pre and post CMJ variables and one-way repeated measures ANOVA with a Bonferroni pairwise comparisons were done to compare CMJ variables between time points. All lower body CMJ variables are represented in Table 3 as means ± 1 SD and were taken from the three highest lower body CMJs based on relative Peak Power (PPr). The corresponding measures were then averaged, and expressed relative to each subject's body weight except for Mean Force which was expressed as an absolute value.

Male performance during lower body CMJs showed a significant decrease from pre- to post-exercise variables at baseline for ConMP ($p=0.023$), EccMP ($p=0.014$),

EccPF (p=0.007) and ConMF (p=0.013). There was no significant difference at baseline for males PPr (p=0.804), ConPF (p=0.243), EccMF (p=0.395), ConRFD (p=0.165) and ConIMP (p=0.277). There was a significant increase at 24H for males for ConRFD (p=0.042) while there was no significant difference for PPr (p=0.583), ConMP (p=0.947), EccMP (p=0.065), ConPF (p=0.104), EccPF (p=0.986), ConMF (p=0.674), EccMF (p=0.702) and ConIMP (p=0.377). There was a significant increase at 72H for males for ConPF (p<0.001) while there was no significant difference for PPr (p=0.843), ConMP (p=0.235), EccMP (p=0.325), EccPF (p=0.140), ConMF (p=0.105), EccMF (p=0.339), ConRFD (p=0.053) and ConIMP (p=0.352). There was no significant difference from pre to post at 48H for males for all variables; PPr (p=0.458), ConMP (p=1.000), EccMP (p=0.180), ConPF (p=0.367), EccPF (p=0.292), ConMF (p=0.808), EccMF (p=0.382), ConRFD (p=0.221) and ConIMP (p=0.861).

Female performance during lower body CMJs showed a significant increase in 72H EccMF (p=0.039) from pre to post while no significant difference was found for PPr (p=0.130), ConMP (p=0.183), EccMP (p=0.300), ConPF (p=0.404), EccPF (p=0.920), ConMF (p=0.238), ConRFD (p=0.358) and ConIMP (p=0.053). There was no significant difference between pre and post measures for baseline PPr (p=0.496), ConMP (p=0.232), EccMP (p=0.275), ConPF (p=0.611), EccPF (p=0.220), ConMF (p=0.569), EccMF (p=0.673), ConRFD (p=0.130) and ConIMP (p=0.201); 24H PPr (p=0.255), ConMP (p=0.308), EccMP (p=0.956), ConPF (p=0.787), EccPF (p=0.799), ConMF (p=0.629), EccMF (p=0.169), ConRFD (p=0.592) and ConIMP (p=0.621); or 48H PPr (p=0.654), ConMP (p=0.738), EccMP (p=0.454), ConPF (p=0.264), EccPF

(p=0.906), ConMF (p=0.512), EccMF (p=0.544), ConRFD (p=0.683) and ConIMP (p=0.669).

Lastly, Males showed no significant mean differences at any time point between baseline, 24, 48, or 72 hours of recovery for pre PPr (p=0.280), post PPr (p=0.996), pre ConMP (p=0.234), post ConMP (p=0.218), pre EccMP (p=0.549), post EccMP (p=0.101), pre ConPF(p=0.053), post ConPF (p=0.505), pre EccPF(p=0.214), post EccPF (p=0.296), pre ConMF(p=0.254), post ConMF (p=0.202), pre EccMF (p=0.802), post EccMF (p=0.900), pre ConRFD (p=0.193), post ConRFD (p=0.332), pre ConIMP (p=0.070) and post ConIMP (p=0.928).

Females also showed no significant difference at any time point between baseline, 24, 48 and 72 hours of recovery for pre PPr (p=0..948), post PPr (p=0.156), pre ConMP (p=0.830), post ConMP (p=0.159), pre EccMP (p=0.514), post EccMP (p=0.071), pre ConPF (p=0.376), post ConPF (p=0.445), pre EccPF (p=0.956), post EccPF (p=0.380), pre ConMF (p=0.685), post ConMF (p=0.708), pre EccMF (p=0.834), post EccMF (p=0.349), pre ConRFD (p=0.776), post ConRFD (p=0.788), pre ConIMP (p=0.817) and post ConIMP (p=0.206)

Table 4. Lower Body CMJ Performance

		BL		24H		48H		72H	
Variable	Time	M	F	M	F	M	F	M	F
PPr	Pre	47.2±6.5	33.7±4.1[b]	45.7±5.8	33.4±3.4[b]	45.3±4.7	33.6±4.5[b]	46.4 ± 6.3	33.7±4.2[b]
(W/Kg)	Post	46.7±10.3	33.1±4.8[b]	46.3±7.4	34.4±3.9[b]	46.6±7.5	33.9±3.0[b]	46.6±6.7	32.2±3.2[b]
ConMP	Pre	23.6±3.9	16.2±2.3[b]	22.7±3.3	15.7±2.7[b]	22.9±3.7	16.3±2.0[b]	21.9±3.5	16.3±1.7[b]
(W/Kg)	Post	21.3±3.7[a]	15.3±2.7[b]	22.7±4.2	16.6±2.6[b]	22.9±4.2	16.4±1.4[b]	23.2±4.2	15.6±1.9[b]
EccMP	Pre	5.6±1.5	5.1±1.2	5.8±0.8	5.2±1.7	5.7±1.0	5.4±1.3	5.3±1.6	5.3±1.5
(W/Kg)	Post	4.6±1.8[a]	4.7±1.6	5.5±0.8	5.2±1.5	5.4±1.1	5.3±1.2	5.6±0.9	5.5±1.4
ConPF	Pre	22.2±3.1	19.2±1.6[b]	20.9±1.5	19.6±2.3	21.7±2.8	18.9±1.0[b]	20.8±1.6	19.5±1.6[b]
(N/Kg)	Post	21.6±2.4	18.9±1.7[b]	21.5±1.7	19.7±1.9[b]	22.1±2.6	19.2±1.1[b]	21.9±1.7[a]	19.2±1.2[b]
EccPF	Pre	19.9±4.4	17.7±2.1	18.9±2.2	17.6±3.9	19.6±2.9	17.4±2.1	18.3±2.9	17.7±2.9
(N/Kg)	Post	17.9±4.1[a]	16.7±2.9	18.9±2.7	17.7±3.0	19.1±2.7	17.4±2.2	19.4±2.7	17.8±2.6
ConMF	Pre	1387.1±265.6	1014.3±118.8[b]	1350.5±235.6	1003.2±128.4[b]	1379.8±259.0	1013.0±114.1[b]	1335.2±251.4	120.9±118.8[b]
(N)	Post	1320.6±245.2[a]	1002.2±158.8[b]	1358.9±243.8	1012.0±96.4[b]	1374.5±234.5	1019.1±120.3[b]	1383.0±247.4	1003.4±123.5[b]
EccMF	Pre	768.2±98.2	661.0±72.7[b]	767.2±103.9	658.9±70.9[b]	770.9±96.6	659.1±75.5[b]	770.3±97.8	660.3±72.8[b]
(N)	Post	763.1±101.4	663.6±78.7[b]	766.7±101.4	657.1±72.0[b]	765.2±93.2	657.4±72.6[b]	767.3±99.3	662.9±73.7[b]
ConRFD	Pre	16.1±16.0	13.1±11.3	12.2±10.6	10.0±7.6	21.7±30.1	11.6±9.5	11.7±9.1	12.0±16.3
(N/s)	Post	18.4±16.2	10.0±8.8	16.6±14.5[a]	11.6±14.9	24.0±31.3	10.1±9.7	17.7±15.3	9.1±9.5
ConIMP	Pre	196.8±42.7	130.7±14.8[b]	194.4±41.5	128.8±12.7[b]	190.4±37.7	130.2±16.5[b]	196.4±43.9	130.2±14.6[b]
(N*s)	Post	189.1±50.5	126.5±14.9[b]	190.8±44.1	130.4±13.9[b]	191.3±47.7	129.1±14.0[b]	192.3±43.1	123.9±13.3[b]

Values are mean ± SD
BL = baseline, 24H = 24 hour recovery, 48H = 48 hour recovery, 72H = 72 hour recovery
[a] indicates significant difference from pre-exercise measures ($p \leq 0.05$)
[b] indicates significant difference between males and females ($p \leq 0.05$)

Upper Body

Upper body CMJ variable statistics were only conducted for the male subjects due to only one female being able to perform the task. Paired-samples t-tests were conducted to compare pre and post CMJ variables and one-way repeated measure ANOVAs with Bonferroni pairwise comparisons were done to compare CMJ variables between the time points. All upper body CMJ variables are represented in Table 4 as means ± SD and were taken from the three highest upper body CMJs based on relative Peak Power (PPr). Baseline, 24, 48 and 72 hour recovery upper body CMJ variables were not significantly different from pre to post exercise ($p>0.05$). EccPF significantly increased from 48 to 72 hour recovery ($p=0.001$). ConRFD significantly decreased from 24 hour recovery to 72 hour recovery ($p=0.040$). PPr ($p=0.885$), ConMP ($p=0.227$), EccMP ($p=0.449$), ConPF ($p=0.063$), ConMF ($p=0.089$), EccMF ($p=0.106$) and ConIMP ($p=0.535$) were not significantly different between baseline, 24, 48 and 72 hour recovery ($p>0.05$).

Table 5. Upper Body CMJ Performance

Variable	Time	BL	24H	48H	72H
n (pre/post)		8/7	9/9	9/9	9/8
PPr	Pre	35.89±11.60	35.06±10.42	40.28±14.10	35.66±22.80
(W/Kg)	Post	38.31±13.17	34.27±13.16	49.44±53.94	39.16±17.80
ConMP	Pre	22.22±11.82	19.37±3.66	23.07±14.20	16.97±9.91
(W/Kg)	Post	19.31±6.81	18.04±3.46	22.92±16.12	24.82±16.19
EccMP	Pre	3.92±3.56	3.83±2.01	5.28±6.15	2.42±2.70
(W/Kg)	Post	2.42±1.89	2.79±1.70	2.68±2.27	5.49±6.34
ConPF	Pre	16.00±5.60	19.69±2.57	18.71±4.18	17.92±4.90
(N/Kg)	Post	18.15±2.22	18.99±3.11	19.97±3.51	17.00±5.15
EccPF	Pre	13.16±1.52	16.22±2.72	15.55±3.66[a]	14.18±3.03
(N/Kg)	Post	13.20±2.22	14.47±2.26	15.57±3.77	14.77±2.96
ConMF	Pre	530.63±192.65	642.92±90.43	602.55±154.29	549.64±169.38

(N)	Post	624.52±75.72	614.37±77.38	618.81±107.69	538.08±158.08
EccMF	Pre	443.02±85.22	474.25±72.04	465.40±88.64	507.00±118.13
(N)	Post	489.14±48.73	482.40±65.26	488.62±63.06	444.25±86.07
ConRFD	Pre	24.80±16.84	26.32±11.67[a]	21.81±14.33	17.60±13.92
(N/s)	Post	19.70±14.23	24.05±11.67	24.95±15.25	22.84±11.55
ConIMP	Pre	90.90±42.55	99.52±47.54	103.23±38.34	84.14±74.64
(N*s)	Post	119.66±44.58	95.31±46.38	87.54±49.97	87.95±34.21

Values are mean ± SD
BL = baseline, 24H = 24 hour recovery, 48H = 48 hour recovery, 72H = 72 hour recovery
[a] indicates significant difference from 72H value ($p \leq 0.05$)

sRPE

One-way repeated measures ANOVA was conducted to compare sRPE between time points and RPE for set 1, 2 and 3 with-in and between time points with a Bonferroni pairwise comparison. sRPE was not significantly different between all time points (p=0.876). Figure 6 illustrates the mean RPE for set 1, 2 and 3 across all time points. RPE following set 1, 2 and 3 was not significantly different between all time points (p=0.645, p=0.146, p=0.288). Baseline RPE showed a significant difference between sets (p<0.001). RPE for set 1 was significantly lower than set 2 (p<0.001) and 3 (p=0.001) while set 2 and set 3 were not significantly (p=0.360). RPE between sets for 24H was significantly different (p<0.001). RPE for set 1 was significantly lower than set 2 (p=0.007) and set 3 (p=0.001) and set 2 was significantly lower than set 3 (p=0.008). RPE between sets for 48H was significantly different (p=0.001). RPE for set 1 was significantly lower than set 2 (p=0.002) and set 3 (p=0.006) while set 2 and 3 were not significantly different (p=0.529). For 72 hour recovery, RPE between sets was significantly different (p<0.001). RPE for set 1 was significantly lower than set 2 (p=0.004) and set 3 (p<0.001) and set 2 was significantly lower than set 3 (p=0.001).

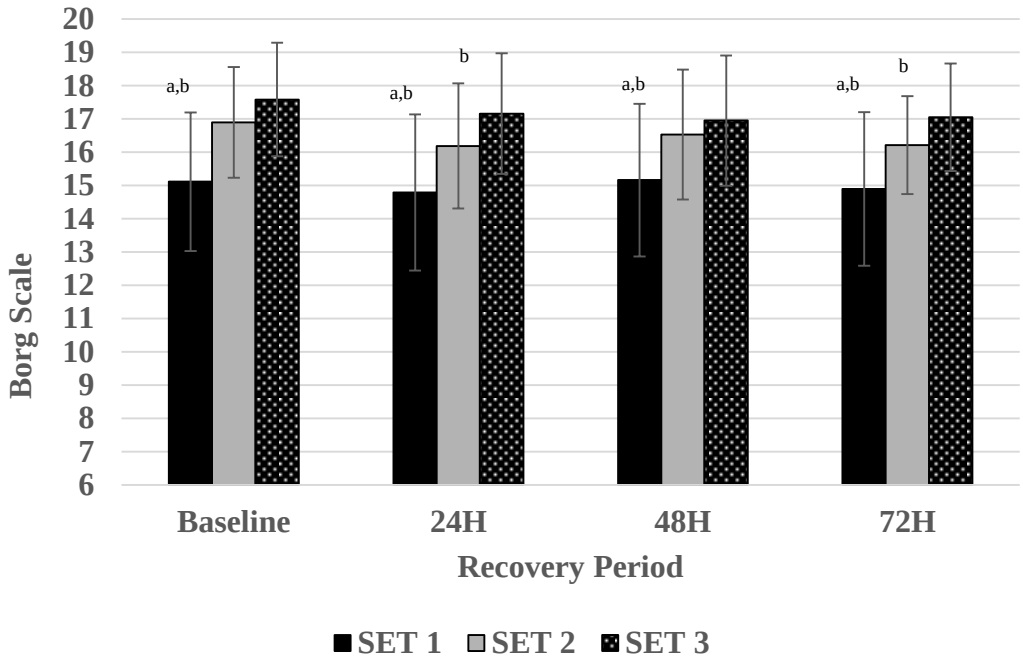

Figure 6. Mean RPE for set 1, 2 and 3 across baseline, 24H, 48H and 72H. [a] indicates significant difference from set 2 (p≤0.05). [b] indicates significant difference from set 3 (p≤0.05).

Pressure-Pain Threshold and Muscle Soreness

Pearson's r correlation was conducted to compare algometer and VAS measures, one-way repeated measures ANOVA was done to compare algometer measures between time points and paired-samples t-tests were performed to compare upper and lower body algometer measures. Algometer measures did not correlate with VAS measures for upper body measures for baseline (r=-0.282, p=0.243), 24H (r=-0.450, p=0.053) and 48H (r=-0.358, p=0.133) while they did negatively correlate for 72H (r= -0.484, p=0.036). Algometer measures did not correlate with VAS for lower body for baseline (r=-0.414, p=0.078), 24H (r=-0.250, p=0.303), 48H (r=-0.189, p=0.438), 72H (r=-0.227, p=0.350). However, all measures did follow a negative linear correlation. Upper body algometer measures were significantly lower than lower body algometer

measures for baseline, 24 hour recovery, 48 hour recovery and 72 hour recovery ($p<0.001$). Upper and lower body algometer measures were not significantly different between all time points ($p=0.054$, $p=0.129$).

One-way repeated measures ANOVAs with Bonferroni pairwise comparisons were performed to compare overall, upper and lower body soreness measures between the time points. Paired-samples t-tests were done to compare upper and lower body soreness measures. Figure 7 describes overall VAS soreness ratings for male and female across all time points. Overall VAS showed a significant difference between time points ($p=0.001$). Analysis showed that 24H was significantly higher than baseline ($p<0.001$) and 72 ($p=0.002$) and not significantly different from 48H ($p=0.592$). Baseline was not significantly different from 48 ($p=0.301$) or 72H ($p=0.064$) and 48H was not significantly different from 72H ($p=1.000$).

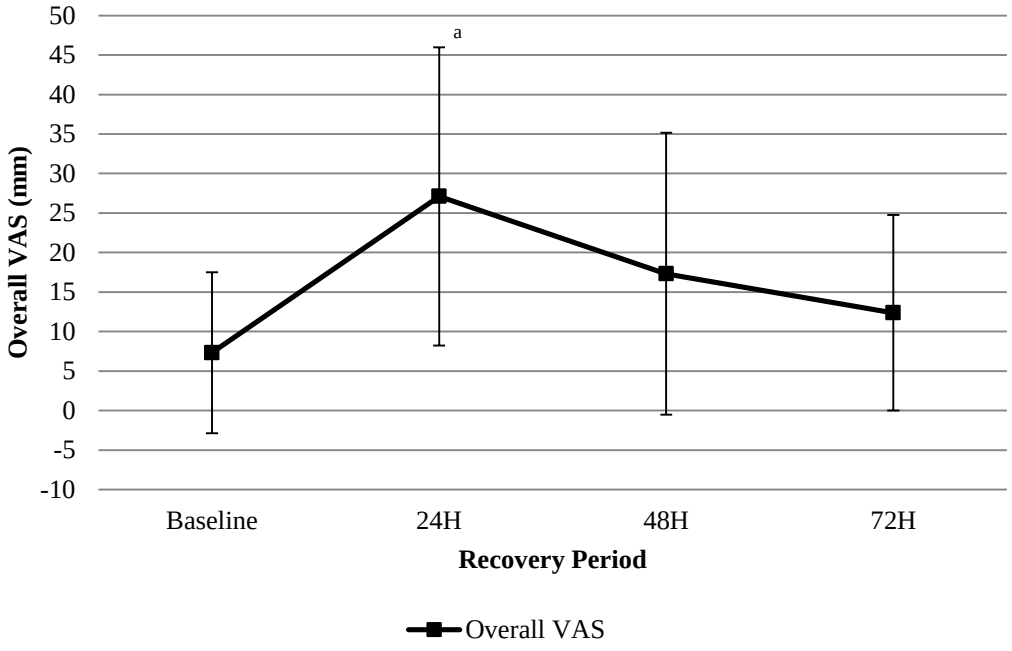

Figure 7. Mean overall VAS soreness ratings across baseline, 24H, 48H and 72H. [a] indicates significant difference from baseline and 72H ($p\leq0.05$).

Figure 8 & 9 illustrate upper and lower body VAS across all time points. Upper body VAS measures were significantly greater than lower body VAS measures for baseline ($p=0.011$), 24H ($p<0.001$) and 48 hour recovery ($p=0.001$). Upper body VAS measures were not significantly different from lower body VAS for 72 hour recovery ($p=0.174$). Upper body was significantly different between time points ($p=0.001$). Twenty-four hour recovery was significantly greater than baseline ($p<0.001$) and 72H ($p=0.003$) and not significantly different from 48H ($p=0.572$). Baseline was not significantly different from 48H ($p=0.157$) or 72H ($p=0.165$) and 48H was not significantly different from 72h ($p=1.000$). There was a significant difference between time points for lower body VAS ($p=0.028$). Twenty-four hour recovery was significantly greater than baseline ($p=0.005$) and 72H ($p=0.027$) and was not significantly different from 48H ($p=1.000$). Baseline was not significantly different from 48H ($p=1.000$) or 72H ($p=0.644$) and 48H was not significantly different from 72H ($p=1.000$).

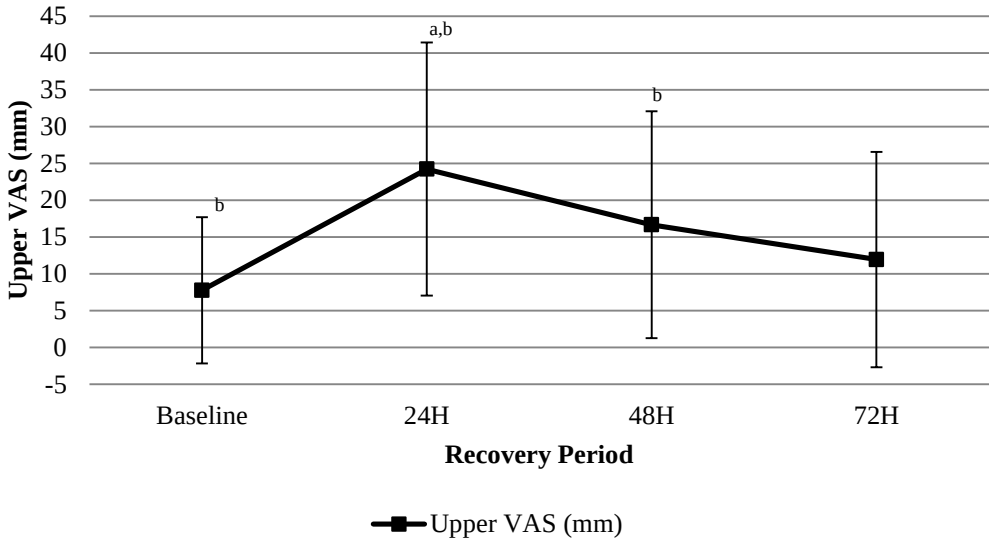

Figure 8. Mean upper body VAS soreness ratings across baseline, 24H, 48H and 72H. [a] indicates significant difference from baseline and 72H ($p \leq 0.05$). [b] indicates significant difference from lower body VAS ($p \leq 0.05$).

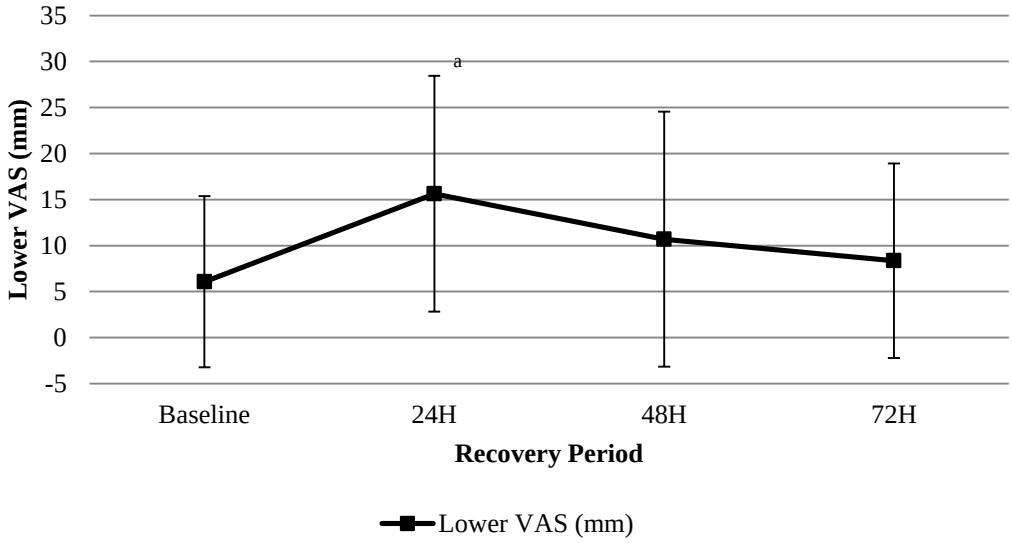

Figure 9. Mean lower body VAS soreness ratings across baseline 24H, 48H and 72H. [a] indicates significant difference from baseline and 72H ($p \leq 0.05$).

PRS

One-way repeated measures ANOVA with Bonferroni pairwise comparisons were performed to compare PRS between time points and Pearson's r correlation was

done to compare PRS with soreness ratings. There was a significant difference between time points for PRS (p=0.001). Twenty-four hour recovery PRS was significantly lower than baseline (p=0.002) and 72H (p=0.025 while 24H was not significantly different from 48H (p=0.633). Baseline was not significantly different from 48H (p=0.082) or 72H (p=0.662) and 48H was not significantly different from 72H (p=0.785).

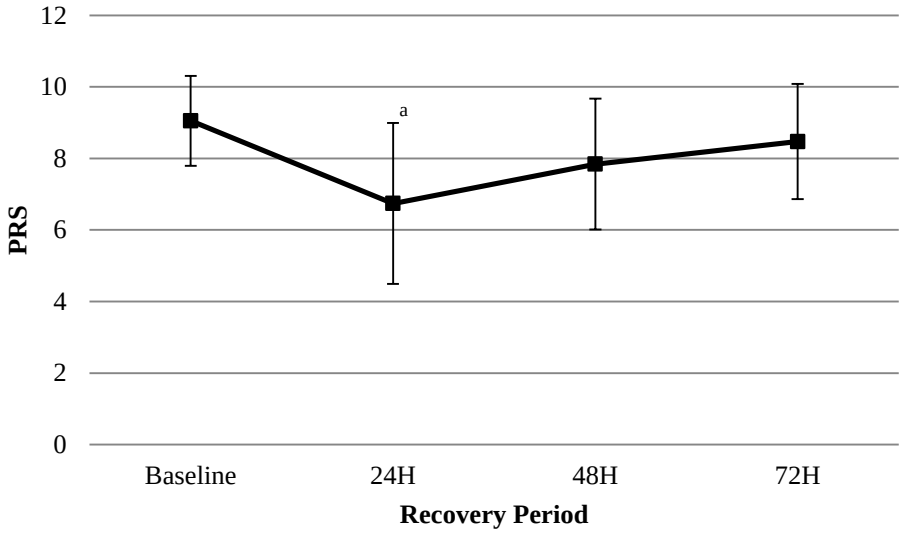

Figure 10. Mean PRS across baseline, 24H, 48H and 72H. [a] indicates significant difference from baseline and 72H (p≤0.05).

PRS had negative correlations with overall VAS for baseline (r=-0.484, p=0.036), 24 hour recovery (r=-0.682, p=0.001), 48 hour recovery (r=-0.503, p=0.023) and 72 hour recovery (r=-0.528, p=0.020).

Perceived Performance Score (PPS)

One-way repeated measures ANOVA was done to compare PPS between time points and Pearson's r correlation was conducted to compare PPS and exercise performance. Figure 11 describes the mean PPS for male and female subjects across all

time points. The PPS (total reps/ sRPE) showed significant differences between baseline, 24, 48 and 72H ($p<0.001$). Baseline PPS was significantly lower than 24 ($p=0.006$), 48 ($p<0.001$) and 72 hour recovery ($p<0.001$). Twenty-four hour recovery was not significantly different from 48H ($p=0.206$) or 72H ($p=0.102$) and 48H was not significantly different from 72H ($p=1.000$)

PPS was significantly correlated with exercise performance for baseline ($r=0.870$, $p=0.000$), 24H ($r=0.863$, $p=0.000$), 48H ($r=0.895$, $p=0.000$) and 72H ($r=0.862$, $p=0.000$).

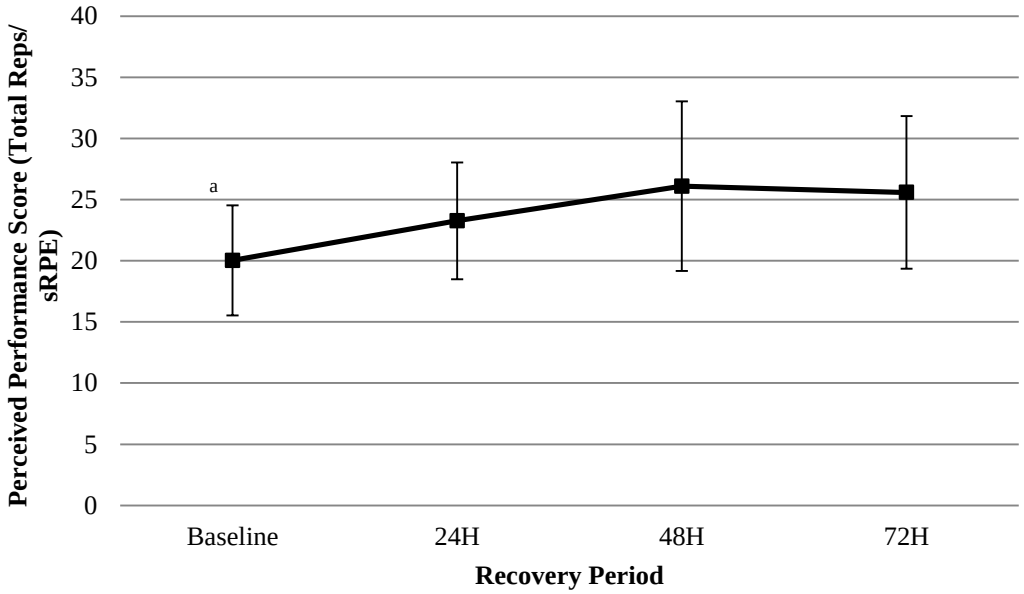

Figure 11. Mean PPS across baseline, 24H, 48H and 72H. [a] indicates significant difference from 24H, 48H and 72H ($p\leq0.05$).

Sex Differences

10RM

One-way ANOVA was conducted to compare male and female 10RMs. Male and female subjects were significantly different for 10RM with males being

significantly greater than females leg press ($p=0.006$), chest press ($p<0.001$), lat pulldown ($p<0.001$), shoulder press ($p<0.001$), knee extension ($p<0.001$), knee flexion ($p<0.001$), bicep curl ($p<0.001$) and triceps curl ($p<0.001$).

Repetitions

One-way ANOVA was performed to compare male and female exercise performance in terms of total repetitions. Male and females did not show a significant difference for total reps for baseline ($p=0.110$), 24H ($p=0.209$), 48H ($p=0.099$) or 72H ($p=0.313$).

CMJ

One-way ANOVAs were conducted to compare CMJ variables between male and females. Table 3 shows the differences between male and female CMJ variables for the lower body. Since only one female was able to do the upper body CMJ, there are no sex comparisons that were made. Overall, males were significantly greater than females for baseline PPr ($p<0.001$), ConMP ($p<0.001$), ConPF ($p=0.018$), ConMF ($p=0.001$), EccMF ($p=0.016$) and ConIMP ($p<0.001$) and did not differ for EccMP ($p=0.469$), EccPF ($p=0.191$) or ConRFD ($p=0.639$); 24H PPr ($p<0.001$), ConMP ($p<0.001$), ConMF ($p=0.001$), EccMF ($p=0.018$) and ConIMP ($p<0.001$) and no difference was seen for EccMP ($p=0.347$), ConPF ($p=0.165$), EccPF ($p=0.345$) or ConRFD ($p=0.607$); 48H PPr ($p<0.001$), ConMP ($p<0.001$), ConPF ($p=0.011$), ConMF ($p=0.001$), EccMF ($p=0.013$) and ConIMP ($p<0.001$) and no difference was seen for EccMP ($p=0.560$), EccPF ($p=0.078$) or ConRFD ($p=0.350$); 72H PPr ($p<0.001$), ConMP ($p<0.001$), ConMF ($p=0.003$), EccMF ($p=0.014$) and ConIMP ($p<0.001$) and no differences were seen for EccMP ($p=0.921$), ConPF ($p=0.110$), EccPF ($p=0.662$) or ConRFD ($p=0.952$).

Soreness

One-way ANOVA was done to compare male and female pressure pain thresholds with algometer and soreness ratings with VAS. Male and females were not significantly different for upper body algometer soreness measures during baseline (p=0.163), however males' upper body algometer measures were significantly greater than females for 24H (p=0.016), 48H (p=0.043) and 72H (p=0.039). Males reported significantly greater lower body algometer measures compare with females for baseline (p=0.031) and 24H (0.005). Male and females were not significantly different for lower body algometer measures for 48H (p=0.053) or 72H (p=0.128). Male and females were not significantly different for overall VAS for baseline (p=0.457), 24H (p=0.423), 48H (p=0.061) or 72H (p=0.757); upper body VAS for baseline (p=0.498), 24H (p=0.655), 48H (p=0.145) or 72H (p=0.914); or lower body VAS for baseline (p=0.450), 24H (p=0.479), 48H (p=0.190) or 72H (p=0.365).

sRPE, PRS, PPS

One-way ANOVA was performed to compare sRPE, PRS and PPS between male and females. Figure 12 describes mean sRPE for male and female across all time points. Male and females were not significantly different in sRPE for baseline (p=0.801), 24H (p=0.965), 48H (p=0.164) or 72H (p=0.586); PRS for baseline (p=0.855), 24H (p=0.902), 48H (p=0.920) or 72H (p=0.943); PPS for baseline (p=0.144), 24H (p=0.316), 48H (p=0.426) or 72H (p=0.627).

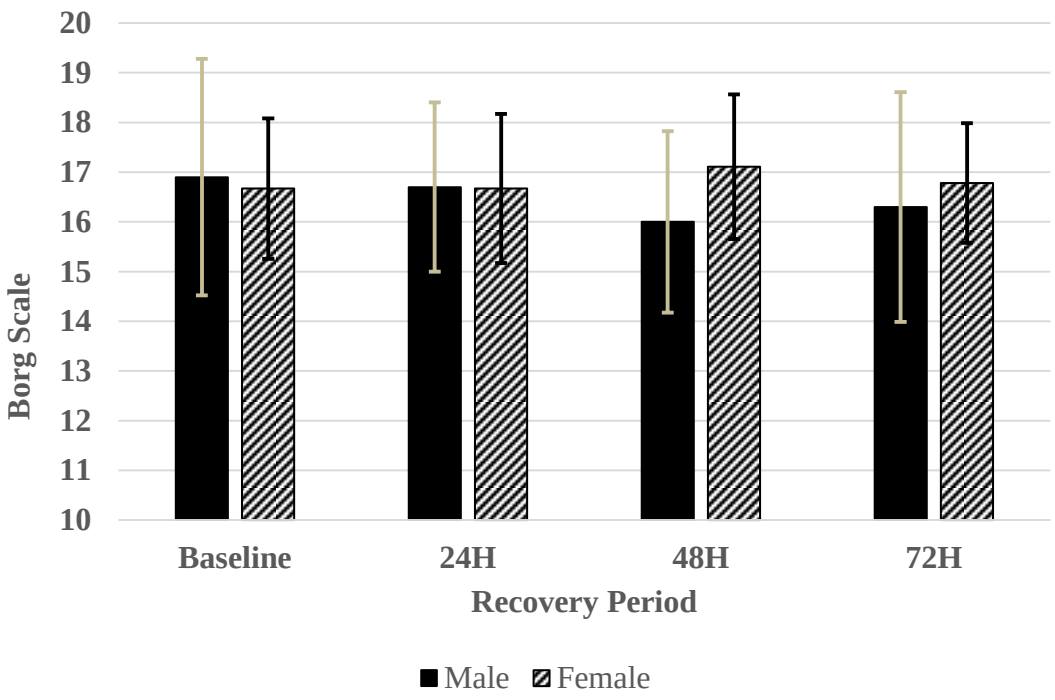

Figure 12. Mean sRPE across baseline, 24H, 48H and 72H. [a] indicates significant difference from male subjects ($p \leq 0.05$)

Chapter 5: Discussion

The purpose of this study was to determine the recovery pattern of ROTC cadets following a high intensity bout of resistance exercise while investigating any sex differences for measures related to recovery time, force production, soreness, perceived effort, and perceived recovery. It was hypothesized that 1) there would be a difference in recovery between male and female cadets, determined by the number of repetitions performed 2) changes in CMJ performance would match the pattern of change in exercise performance in ROTC cadets and 3) there would be differences in relative and absolute countermovement jump performance metrics between male and female ROTC cadets 4) there would be differences in DOMS related to EIMD between male and female ROTC cadets, 5) there would be a difference between male and female ROTC cadets in soreness ratings on a VAS and algometer measures and 6) there would be differences in the time course to reach peak soreness, as well as, to return to baseline in male and female ROTC cadets.

Exercise Performance

Results showed that mean delta scores for total repetitions were not significantly different between 24H, 48H and 72H regardless of the recovery scheme employed. Additionally, total repetitions during the initial exercise session (baseline) was lower than all time points (24, 48 and 72 hour recovery). This finding does not agree with past research[9, 22, 34, 44]. McLester et al. (2003), Judge & Burke (2010), Radaelli et al (2012) and Howatson et al. (2016) showed that baseline was not significantly lower than the recovery days, rather 24-hour recovery showed the lowest performance compared with all other exercise trials following resistance exercise. Due to the subjects not being

exposed to any type of muscle damage before the baseline exercise, it would not have been expected for total reps to be the lowest for baseline performance. This low baseline performance could have been due to the subjects not being exposed to a high intensity resistance workout prior to the study. The subjects may have experienced neural adaptations which could have aided in performance improvements throughout the study, despite 10RM being determined and verified on two separate occasions, respectively, prior to the start of baseline testing. In the current investigation, exercise performance, based on total reps performed, showed a gradual increase from baseline to 24 to 48-hour recovery followed by a slight decrease at 72 hour recovery. McLester et al (2003) found that healthy males were able to return to baseline performance within 48 hours of recovery while 24 hours of recovery was significantly lower than baseline performance. They also found a trend between 24, 48, 72 and 96-hour recovery that was similar to this study for baseline, 24, 48 and 72 hour recovery. Seventy-two hours of recovery was actually significantly greater than baseline total reps, similar to the relationship between 48 hour recovery and baseline performance in this study. They also found that 96 hour recovery was not significantly different from baseline, showing that total reps decreased following 72 hours. This is similar to our findings for 72-hour recovery. The subjects showed an improvement in performance over the course of the study indicating a training effect. These adaptations also suggest that this population was not as resistance trained as originally assumed.

CMJ

Lower body CMJ variables did not match the same pattern of change as exercise performance. The lower body CMJs were not different between baseline, 24, 48 or 72

hour recovery which does not match the pattern of baseline being the lowest performance and increasing performance in 24, 48 and 72 hour recovery. This unmatched pattern is similar to the findings of Howatson et al (2016). The authors found that CMJ jump height did not correlate with the decline in MVC performance. There was no difference in jump height between pre session, post session and 24-hour recovery. Baseline measures showed the only exercise trial where lower body CMJ variables declined was from pre to post exercise. The lack of decline from pre to post exercise during 24, 48 and 72-hour recovery may indicate that the exercise did not induce lower body muscle fatigue, this population of ROTC cadets was unable to generate a maximal force in CMJs which prevented a change from pre to post from being detected, or jump technique was altered in order to produce the same performance. Ronglan et al. (2006) and McLean et al. (2010) showed a decline in CMJ performance however, the CMJs were performed following high intensity handball and rugby matches, respectively, not a high intensity resistance exercise. This suggests that there still needs to be validation of using CMJ performance as an indicator of exercise performance following a bout high intensity resistance exercise.

Upper body CMJs did not decline from pre to post for baseline, 24, 48 or 72-hour recovery, again possibly indicating this exercise was unable to induce fatigue or this population was unable to produce a maximal force. The variables that increased between 24, 48 and 72-hour recovery indicate that the subjects were able to improve their upper body performance. Push up performance on a force plate following a resistance exercise has not been reported in previous literature. However, since lower body CMJ performance did not change from pre to post or between recovery days, it is

difficult to discuss if the push up test is reliable in testing changes in force production following a bout of high intensity resistance exercise in the upper body.

sRPE

No differences in sRPE were observed between baseline, 24, 48 and 72 hour recovery, indicating the subjects perceived the intensity of the exercise to be relatively the same across exercise trials. RPE after sets 1, 2 and 3 for each exercise was not different between baseline, 24, 48 and 72 hour recovery again, indicating the subjects perceived the intensity of three sets the same between each exercise trial.

RPE of set 1 was lower than set 2 and set 3 for all exercise trials showing that the subjects perceived the first set to be less intense than the second and third set. RPE for set 2 and 3 were not different, except during 72-hour recovery, indicating the subjects perceived the intensity to be relatively the same between set 2 and set 3. The increase in RPE between sets during resistance exercise is supported by Egan et al. (2006). They found that set 1 RPE was lower than the other sets of each of the exercises, possibly indicating the ability of an exerciser to detect accumulating levels of fatigue.

Foster et al. (2011) discussed the use of sRPE following high intensity endurance exercise, cycling and basket training/ matches, and found that sRPE was a reliable measure and suggested that sRPE may be a valid approach to evaluating resistance exercise. They also discussed how resistance trained individuals were poor with rating aerobic exercise intensity due to them attending more to muscular tension rather than dyspnea. This may suggest that, since these cadets were endurance trained,

they may lack sensitivity in perceiving different levels of discomfort and fatigue associated with resistance exercise.

Pressure-Pain Threshold and Soreness

Algometer and VAS measures did not demonstrate the expected correlation, meaning that as algometer readings went up, VAS measures did not go down, which indicates that the subject experienced no soreness; or as algometer measures went down, the VAS measures did not go up, which demonstrates the subject experienced soreness. This relationship could suggest that pressure-pain threshold and soreness do not correlate in this population following a high-intensity interval resistance exercise.

The algometer measures showed that the upper body was consistently greater than the lower body for baseline, 24, 48 and 72-hour recovery, indicating it had a lower pressure-pain threshold. However, no differences were shown for either upper or lower body pressure-pain threshold levels over time.

VAS measures demonstrated higher soreness levels in the upper body compared with the lower body for baseline, 24 and 48-hour recovery. Upper and lower body soreness was not different for 72-hour recovery. Contrary to algometer measures, 24-hour recovery showed increased overall, upper and lower body soreness levels compared with baseline and 72 hours.

VAS was able to demonstrate a significant change in soreness levels between exercise trials contrary to algometer measures. Either the use of a digital algometer device or VAS measurements would be recommended in future investigations to measure soreness levels.

Despite the subjects showing a change in soreness levels, this change did not follow the pattern of exercise performance. Recovery for 24 hours showed the greatest soreness levels, but performance was still greater than baseline. This indicates that these subjects were able to improve performance regardless of a significant increase in muscle soreness. However, soreness and decrements in force production are not as comparable as the relationship between muscle damage and force loss.

PRS

The PRS scale showed that subjects felt less recovered after 24-hour recovery following baseline. Even though the subjects felt less recovered for 24-hour recovery, they were able to improve performance from baseline. This shows that the PRS scale may not be as useful in determining performance in ROTC cadets for a resistance exercise.

The PRS scale did correlate with VAS which demonstrates that as soreness levels increased, perceived recovery went down. The PRS scale may be better at determining for soreness levels than performance. This further demonstrates that soreness does not equal loss of force or decreased performance.

Perceived Performance Score (PPS)

The PPS was used to represent a person's performance capacity in regards to total repetitions and perceived exertion for the exercise. The greater the PPS, the higher the performance compared with perceived exertion and the lower the PPS, the lower performance compared with perceived exertion. The results showed that baseline had the lowest PPS when compared to 24, 48 and 72-hour recovery while there was no difference in PPS between 24, 48 and 72 hour recovery. This supports the findings that

baseline had the lowest performance, in terms of total reps, compared with 24, 48, and 72-hour recovery and 24, 48 and 72-hour recovery had no difference in performance. However, since the sRPE was not different between exercise sessions, further investigations should be conducted when the sRPE is difference between sessions.

Sex Differences

Males had greater 10RM loads than the females, meaning they were able to lift a greater amount of weight compared with the female subjects. The 10RM loads were divided by the subjects' body weight and the significant difference was still present for all exercise machines. Even though males were able to lift more, the performance did not differ between male and female, which opposes the findings in other studies that saw differences in performance[22]. Judge & Burke (2010) found that males were not able replicate baseline performance after 4 hours or 24 hours. However, the female participants in this study were able to repeat their baseline performance, indicating either an increased capacity to recover or a decreased level of muscle damage when performing similar exercise. There have been multiple studies that support the difference in performance between male and female following isometric exercises[18, 20]. However, due to the findings of this study, there still needs to be further investigation on sex differences in performance following resistance exercise.

Males outperformed females on the lower body CMJ across all trials. Only one female was able to perform the upper body CMJ, which was surprising considering the amount of push-ups typically utilized for training in the ROTC population based on Army fitness standards. This shows the differences in upper body strength between

male and female. Females should focus on increasing upper body exercise to improve upper body strength.

Males had greater algometer measures compared with females indicating that males were less sore than females. However, in regards to VAS measures, male and female subjects recorded similar soreness ratings for overall, upper and lower body, similar to the findings in Sewright et al. (2008). The VAS soreness measures match the pattern of exercise performance between male and female, unlike the algometer measures. Due to the discrepancy between algometer and VAS measures, these findings between male and female are not surprising. Males and females recorded similar sRPE, meaning the perceived exertion was similar for each group between baseline, 24, 48 and 72 hour recovery. PRS scale did not differ between male and female indicating both groups were similar in perceiving their recovery status between baseline, 24, 48 and 72 hour recovery. The fitness score also did not differ between male and female due to sRPE and repetitions not differing between the two groups.

This protocol was unable to show any differences in performance, recovery, soreness, sRPE, PRS or PPS between male and females. Even though males were lifting a greater amount of weight, they were able to recover the same as female and report soreness ratings similar to females. Future studies may want to consider incorporating a second baseline measure to eliminate the initial learning effect between baseline and 24 hour recovery, especially if those subjects are not resistance trained.

Chapter 6: Conclusion

Our findings indicate that ROTC cadets were able to complete a bout of high-intensity interval resistance exercise and maintain performance with as little as 24H of recovery. It was hypothesized that male and female cadets would differ in performance recovery; however they both recovered in the same pattern. It was hypothesized that CMJ variables would match the pattern of change of exercise performance; however CMJ variables did not match the pattern of change. This may have been due to the lack of fatigue from the resistance exercise. Regardless of the progression in performance, both male and female cadets showed an increase in soreness for 24H recovery. This shows that soreness does not affect performance in ROTC cadets following a bout of high-intensity interval resistance exercise. PRS may be more useful in determining soreness levels rather than performance in a high-intensity interval resistance exercise. More research needs to be done to investigate the utility of sRPE and PPS following a bout high intensity interval resistance exercise. The limitations of this study include 1) subjects were part of a convenience sample and therefore all findings can only be applied to male and female ROTC cadets, 2) there was no direct measure of changes in muscle force production and 3) there was no direct measure of changes in muscle damage. There needs to be further investigation over recovery patterns following a high-intensity interval resistance exercise in ROTC cadets and validating the CMJ as a surrogate in measuring fatigue and recovery. In conclusion, ROTC cadets recovered within 24H following a bout of high-intensity interval resistance exercise and this exercise protocol may be a good initial resistance program for cadets in order to improve performance in a short amount of time.

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Appendix A: IRB Approval Letter

AUTHORIZATION TO USE or SHARE
HEALTH INFORMATION[1] THAT IDENTIFIES YOU FOR RESEARCH
An Informed Consent Document for Research Participation may also be required.

Title of Research Project: **Recovery Patterns from High-Intensity Interval Resistance Exercise in Male and Female ROTC Cadets**

IRB Number:

Leader of Research Team: **Dr. Jay Campbell**

Address: **1401 Asp Ave. Norman, OK 73019**

Phone Number: **(205) 435-1935**

If you decide to sign this document, University of Oklahoma (OU) researchers may use or share information that identifies you (protected health information) for their research. Protected health information will be called PHI in this document.

PHI To Be Used or Shared. Federal law requires that researchers get your permission (authorization) to use or share your PHI. If you give permission, the researchers may use or share with the people identified in this Authorization any PHI related to this research from your medical records and from any test results. Information used or shared may include all information relating to any tests, procedures, surveys, or interviews as outlined in the consent form; medical records and charts; name, address, telephone number, date of birth, race, government-issued identification numbers, and all information relating to test procedures as outlined in the protocol and informed consent document.

Purposes for Using or Sharing PHI. If you give permission, the researchers may use your PHI to determine recovery patterns following a bout of high-intensity interval resistance exercise, determine if there are any sex differences in recovery patterns following a bout of high-intensity interval resistance exercise and to validate the use of countermovement jumps as a measure to quantify fatigue and recovery.

Other Use and Sharing of PHI. If you give permission, the researchers may also use your PHI to develop new procedures or commercial products. They may share your PHI with other researchers, the research sponsor and its agents, the OU Institutional Review Board, auditors and inspectors who check the research, and government agencies such as the Department of Health and Human Services (HHS), and when required by law. The researchers may also share your PHI with future lab

[1] **Protected Health Information includes all identifiable information relating to any aspect of an individual's health whether past, present or future, created or maintained by a Covered Entity.**

members of the Sport and Military Performance Analytics Laboratory at the University of Oklahoma.

Confidentiality. Although the researchers may report their findings in scientific journals or meetings, they will not identify you in their reports. The researchers will try to keep your information confidential, but confidentiality is not guaranteed. The law does not require everyone receiving the information covered by this document to keep it confidential, so they could release it to others, and federal law may no longer protect it.

YOU UNDERSTAND THAT YOUR PROTECTED HEALTH INFORMATION MAY INCLUDE INFORMATION REGARDING A COMMUNICABLE OR NONCOMMUNICABLE DISEASE.

Voluntary Choice. The choice to give OU researchers permission to use or share your PHI for their research is voluntary. It is completely up to you. No one can force you to give permission. However, you must give permission for OU researchers to use or share your PHI if you want to participate in the research and, if you cancel your authorization, you can no longer participate in this study.

Refusing to give permission will not affect your ability to get routine treatment or health care unrelated to this study from OU.

Canceling Permission. If you give the OU researchers permission to use or share your PHI, you have a right to cancel your permission whenever you want. However, canceling your permission will not apply to information that the researchers have already used, relied on, or shared or to information necessary to maintain the reliability or integrity of this research.

End of Permission. Unless you cancel it, permission for OU researchers to use or share your PHI for their research will never end.

Contacting OU: You may find out if your PHI has been shared, get a copy of your PHI, or cancel your permission at any time by writing to:

Privacy Official University of Oklahoma PO Box 26901 Oklahoma City, OK 73190	or	Privacy Board University of Oklahoma 201 Stephenson Pkwy, Suite 4300A Norman, OK 73019
If you have questions, call: (405) 271-2511	or	(405) 325-8110

Access to Information. You have the right to access the medical information that has been collected about you as a part of this research study. However, you may not have access to this medical information until the entire research study is completely finished. You consent to this temporary restriction.

Giving Permission. By signing this form, you give OU and OU's researchers led by the Research Team Leader permission to share your PHI for the research project listed at the top of this form.

Participant Name (Print): _____

_____ _____
Signature of Participant Date
or Parent if Participant is a minor

Or

_____ _____
Signature of Legal Representative** Date

**If signed by a Legal Representative of the Participant, provide a description of the relationship to the Participant and the authority to act as Legal Representative:

_____
OU may ask you to produce evidence of your relationship.

A signed copy of this form must be given to the Participant or the Legal Representative at the time this signed form is provided to the researcher or his representative.

Appendix B: Informed Consent Form

701-A-1

Signed Consent to Participate in Research

Would you like to be involved in research at the University of Oklahoma?

I am Dr. Jay Campbell from the Department of Health and Exercise Science and I invite you to participate in my research project entitled Recovery Patterns from High-Intensity Interval Resistance Exercise in Male and Female ROTC Cadets. This research is being conducted at the Neuromuscular Laboratory in the S.J. Sarkey's Complex. You were selected as a possible participant because you are currently a member of the University of Oklahoma ROTC program and you are free musculoskeletal injuries that would prevent you from participating in high intensity exercise. You must be at least 18 years of age to participate in this study.

Please read this document and contact me to ask any questions that you may have BEFORE agreeing to take part in my research.

What is the purpose of this research? The purpose of this research is to determine the time course for recovery in Army ROTC cadets following a bout of high-intensity interval resistance exercise, examine if there are any sex differences for recovery following a bout of high-intensity interval resistance exercise and validate the use of counter movement jumps as a measure of fatigue following a bout of high-intensity interval resistance exercise.

How many participants will be in this research? About 40 people will take part in this research, which include 20 males and 20 females.

What will I be asked to do? If you agree to be in this research, you will be asked to complete 6 visits over a period of approximately 21 days.

Visit 1 (approximately 75 minutes): Informed Consent and Familiarization 1. The first will consist of each participant providing written consent, HIPAA information, PAR-Q, IPAQ and menstrual cycle information for the female subjects. Each subject will be given an overview of the protocol and once they give consent, their height, weight, age and academic grade (Freshman, Sophomore, Junior or Senior) will be recorded. Each subject will participate in a familiarization for the upper and lower body countermovement jump (CMJ) and with proper technique for each exercise and the exercise equipment itself. Each subject will become familiar with each of the 8 exercise machines used for the resistance exercise by determining their 10 repetition max (RM) for each machine. The exercises include leg press, chest press, lat pull down, shoulder press, knee extension, biceps curl, knee flexion and triceps extension. Each participant will be given a randomized exercise order.

Visit 2 (approximately 60 minutes): Familiarization 2. Each subject will be re-familiarized with the CMJ's and confirm their 10RM from visit 1. The participant will perform 5 upper body CMJ followed by 5 lower body CMJ's. Each participant will then go through each of the 8 exercise machines and confirm their 10RM. If the subject's 10RM changes, then the new 10RM will be determined and used for the remainder of testing.

Visit 3 (approximately 75 minutes): Baseline Measures. Each participant will examine soreness levels and recovery using a visual analog scale (VAS) and a perceived recovery scale (PRS). Each participant will perform a dynamic warm-up, 5 upper body and 5 lower body CMJs, resistance exercise warm-up, resistance exercise protocol and 5 upper body and 5 lower body CMJs post exercise. The exercise protocol consists of 3 rounds of the 8 exercise machines performed with the 10RM load. 30 minutes post-exercise session, the participant will be asked to record their session rate of perceived exertion (sRPE) using the Borg scale of 6-20.

Visit 4, 5 and 6 (approximately 75 minutes): Recovery Measure 1, 2 and 3. Each participant will be randomized to a recovery scheme (24, 48, 72 hrs; 48, 72, 24 hrs; etc) post-baseline measures. Participants will be asked to perform the same tasks as defined in visit 3 for all recovery measures.

10 RM Determinations: A 10 RM will be established for each of the 8 exercises. Subjects will begin with a light load that will allow them to perform about 15-18 repetitions. The load will increase by 5-10 lbs. for upper body and 15-20 lbs. for lower body for the next set depending on the level of difficulty. If the subject is able to produce more than 10 repetitions with this load, it will increase again by 5-10 lbs. or 15-20 lbs. until the subject can only produce 10 repetitions maximum. Between each set, the subject will rest for 2-4 minutes to ensure recovery. The 10 RM for each exercise machine will be recorded on the subject's data sheet and this load will be used for all resistance exercises including both baseline measures and post-baseline recovery measures.

Resistance Exercise Protocol: The 8 exercises in the resistance exercise protocol will include the leg press, chest press, shoulder press, lat pulldown, knee extension, triceps extension, knee flexion and bicep curl. The order at which each subject will perform these exercises will be randomized. All exercise sessions will occur in the Neuromuscular Laboratory in the S.J. Sarkeys Complex in the Department of Health and Exercise Science at the University of Oklahoma. The subject will have 60 seconds to produce as many repetitions until failure using their 10RM load. Once 60 seconds is complete, there will be 60 seconds of rest until the next set of repetitions on the next machine. This will be repeated until all 8 exercises are complete. The completion of the 8th exercise machine will represent the first round of the exercise. There will be 2 minutes of rest before starting the next round and the subject's RPE for the first round will be recorded during this 2-minute recovery period. This cycle will continue for the second and third round of exercise.

Force Platform & CMJ: The bilateral force plate system and accompanying software will be used to evaluate the subject's fatigue and recovery before and after performing the resistance exercise by performing CMJ's. The data collector will zero the force plate scale and ask the subject to step onto the force plate by evenly distributing the subject's weight on both the right and left force plate. Once weight is evenly distributed, the collector saved the subject's weight. The data collector will then instruct the subject to perform the CMJ's by giving a verbal cue "ready, set, go". Each participant will perform 5 CMJ's with 3-5 seconds in between each jump. This will be done for both upper and lower body CMJ's. In each case, the 3 CMJ's with the highest peak force will be retained and averaged for statistical analysis.

Soreness Assessments: Soreness rating will be evaluated using a 100-mm VAS. The VAS will be anchored at 1and 10 with 1 relating to "no soreness" and 10 relating to "extreme soreness". Participants will be asked to take each joint through a full range of motion and will be palpated using a palpation tool known as an algometer. Once each participant has gone through the range of motion for each joint and each major muscle group has been palpated, the participant will mark on the VAS the soreness level and that will be recorded on the participant's data sheet.

Perceived Recovery Scale (PRS): The PRS will be used to investigate how well each participant perceives their recovery. The scale will range from 0-10 with 0 indicating "very poorly recovered/ extremely tired" and 10 indicating "very well recovered/ highly energetic". The participants will provide the PRS value once they have arrived for the testing session and it will be recorded on the participant's data sheet.

sRPE: Thirty-minutes post-exercise following the three recovery days, the participants will be asked to provide the sRPE for that bout of exercise. The scale used will be the Borg scale which ranges from 6-20 where 6 indicate "no exertion at all" and 20 indicate "maximal exertion.

How long will this take? Your participation will take 6 visits (each ~60-75 minutes) for a total of 21 days.

What are the risks and/or benefits if I participate? The risk for participating in this study is muscle damage and injury. However, due to the participants being active and have been participating in physical training with the ROTC, risk for injury is minimal.

What do I do if I am injured? If you are injured during your participation, report this to a researcher immediately. Emergency medical treatment is available. However, you or your insurance company will be expected to pay the usual charge from this treatment. The University of Oklahoma Norman Campus has set aside no funds to compensate you in the event of injury.

Will I be compensated for participating? You will not be reimbursed for your time and participation in this research.

Who will see my information? In research reports, there will be no information that will make it possible to identify you. Research records will be stored securely and only approved researchers and the OU Institutional Review Board will have access to the records.

You have the right to access the research data that has been collected about you as a part of this research. However, you may not have access to this information until the entire research has completely finished and you consent to this temporary restriction.

Do I have to participate? No. If you do not participate, you will not be penalized or lose benefits or services unrelated to the research. If you decide to participate, you don't have to answer any question and can stop participating at any time.

Will my identity be anonymous or confidential? Your name will not be retained or linked with your responses unless you specifically agree to be identified. The data you provide will be retained in anonymous form unless you specifically agree for data retention or retention of contact information at the end of the research. Please check all of the options that you agree to:

I agree for the researcher to use my data in future studies. ___Yes ___ No

Video Recording of Research Activities To assist with accurate recording of your jump performance, observations may be recorded on a video recording device. The video recording will be retained for up to two years. You have the right to refuse to allow such recording. Please select one of the following options:

I consent to video recording. ___ Yes ___ No

Will I be contacted again? The researcher would like to contact you again to recruit you into this research or to gather additional information.

_____ I give my permission for the researcher to contact me in the future.

_____ I do not wish to be contacted by the researcher again.

Who do I contact with questions, concerns or complaints? If you have questions, concerns or complaints about the research or have experienced a research-related injury, contact me at jcampbell21@ou.edu or Nicole McGuire at n.mcguire@ou.edu

You can also contact the University of Oklahoma – Norman Campus Institutional Review Board (OU-NC IRB) at 405-325-8110 or irb@ou.edu if you have questions about your rights as a research participant, concerns, or complaints about the research and wish to talk to someone other than the researcher(s) or if you cannot reach the researcher(s).

You will be given a copy of this document for your records. By providing information to the researcher(s), I am agreeing to participate in this research.

Participant Signature	Print Name	Date
Signature of Researcher Obtaining Consent	Print Name	Date

Appendix C: HIPAA

AUTHORIZATION TO USE or SHARE
HEALTH INFORMATION[1] THAT IDENTIFIES YOU FOR RESEARCH
An Informed Consent Document for Research Participation may also be required.

Title of Research Project: **Recovery Patterns from High-Intensity Interval Resistance Exercise in Male and Female ROTC Cadets**

IRB Number: 8682

Leader of Research Team: **Dr. Jay Campbell**

Address: **1401 Asp Ave. Norman, OK 73019**

Phone Number: **(205) 435-1935**

If you decide to sign this document, University of Oklahoma (OU) researchers may use or share information that identifies you (protected health information) for their research. Protected health information will be called PHI in this document.

PHI To Be Used or Shared. Federal law requires that researchers get your permission (authorization) to use or share your PHI. If you give permission, the researchers may use or share with the people identified in this Authorization any PHI related to this research from your medical records and from any test results. Information used or shared may include all information relating to any tests, procedures, surveys, or interviews as outlined in the consent form; medical records and charts; name, address, telephone number, date of birth, race, government-issued identification numbers, and all information relating to test procedures as outlined in the protocol and informed consent document.

Purposes for Using or Sharing PHI. If you give permission, the researchers may use your PHI to determine recovery patterns following a bout of high-intensity interval resistance exercise, determine if there are any sex differences in recovery patterns following a bout of high-intensity interval resistance exercise and to validate the use of countermovement jumps as a measure to quantify fatigue and recovery.

Other Use and Sharing of PHI. If you give permission, the researchers may also use your PHI to develop new procedures or commercial products. They may share your PHI with other researchers, the research sponsor and its agents, the OU Institutional Review Board, auditors and inspectors who check the research, and government agencies such as the Department of Health and Human Services (HHS), and when required by law. The researchers may also share your PHI with future lab

[1] **Protected Health Information includes all identifiable information relating to any aspect of an individual's health whether past, present or future, created or maintained by a Covered Entity.**

members of the Sport and Military Performance Analytics Laboratory at the University of Oklahoma.

Confidentiality. Although the researchers may report their findings in scientific journals or meetings, they will not identify you in their reports. The researchers will try to keep your information confidential, but confidentiality is not guaranteed. The law does not require everyone receiving the information covered by this document to keep it confidential, so they could release it to others, and federal law may no longer protect it.

YOU UNDERSTAND THAT YOUR PROTECTED HEALTH INFORMATION MAY INCLUDE INFORMATION REGARDING A COMMUNICABLE OR NONCOMMUNICABLE DISEASE.

Voluntary Choice. The choice to give OU researchers permission to use or share your PHI for their research is voluntary. It is completely up to you. No one can force you to give permission. However, you must give permission for OU researchers to use or share your PHI if you want to participate in the research and, if you cancel your authorization, you can no longer participate in this study.

Refusing to give permission will not affect your ability to get routine treatment or health care unrelated to this study from OU.

Canceling Permission. If you give the OU researchers permission to use or share your PHI, you have a right to cancel your permission whenever you want. However, canceling your permission will not apply to information that the researchers have already used, relied on, or shared or to information necessary to maintain the reliability or integrity of this research.

End of Permission. Unless you cancel it, permission for OU researchers to use or share your PHI for their research will never end.

Contacting OU: You may find out if your PHI has been shared, get a copy of your PHI, or cancel your permission at any time by writing to:

Privacy Official
University of Oklahoma
PO Box 26901
Oklahoma City, OK 73190

or Privacy Board
University of Oklahoma
201 Stephenson Pkwy, Suite 4300A
Norman, OK 73019

If you have questions, call: (405) 271-2511 or (405) 325-8110

Access to Information. You have the right to access the medical information that has been collected about you as a part of this research study. However, you may not have access to this medical information until the entire research study is completely finished. You consent to this temporary restriction.

Giving Permission. By signing this form, you give OU and OU's researchers led by the Research Team Leader permission to share your PHI for the research project listed at the top of this form.

Participant Name (Print): _____

_____ _____
Signature of Participant Date
or Parent if Participant is a minor

Or

_____ _____
Signature of Legal Representative** Date

**If signed by a Legal Representative of the Participant, provide a description of the relationship to the Participant and the authority to act as Legal Representative:

_____
OU may ask you to produce evidence of your relationship.

A signed copy of this form must be given to the Participant or the Legal Representative at the time this signed form is provided to the researcher or his representative.

Appendix D: Health Status Questionnaire

Sport and Military Performance Analytics Laboratory

OU Department of Health and Exercise Science

Health Status Questionnaire

Instructions. Complete each question accurately. All information provided is confidential.

(NOTE: The following codes are for office use only: RF; MC; SLA; SEP)

Part 1. Information about the individual

1._____
Date

2. _____
Legal name Nickname

3._____
Mailing address

_____
Home phone Business phone

4.Gender (circle one): Female Male (RF)

5. Year of birth: _____ Age _____

6. Number of hours worked per week: Less than 20 20-40 41-60 Over 60

(SLA) More than 25% of time spent on job (circle all that apply)

Sitting at desk Lifting or carrying loads Standing Walking Driving

Part 2. Medical history

7. (RF) Circle any who died of heart attack before age 50:

Father Mother Brother Sister Grandparent

8.Date of: Last medical physical exam: _____Last physical fitness test: _____
Year Year

IRB NUMBER: 8682
IRB APPROVAL DATE: 11/28/2017

9. Circle operations you have had:

Back (SLA)	Heart (MC)	Kidney (SLA)	Eyes (SLA)	Joint (SLA)	Neck (SLA)
Ears (SLA)	Hernia (SLA)	Lung (SLA)	Other----------		

10. Please circle any of the following for which you have been diagnosed or treated by a physician or health professional:

Alcoholism (SEP)	Diabetes (SEP)	Kidney problem (MC)
Anemia, sickle cell (SEP)	Emphysema (SEP)	Mental illness (SEP)
Anemia, other (SEP)	Epilepsy (SEP)	Neck strain (SLA)
Asthma (SEP)	Eye problems (SLA)	Obesity (RF)
Back strain (SLA)	Gout (SLA)	Osteoporosis
Bleeding trait (SEP)	Hearing loss (SLA)	Phlebitis (MC)
Bronchitis, chronic (SEP)	Heart problems (SLA)	Rheumatoid arthritis (SLA)
Cancer (SEP)	High blood pressure (RF)	Stroke (MC)
Cirrhosis, liver (MC)	Hypoglycemia (SEP)	Thyroid problem (SEP)
Concussion (MC)	Hyperlipidemia (RF)	Ulcer (SEP)
Congenital defect (SEP)	Infectious mononucleosis (MC)	Other----------

11. Circle all medicine taken in last 6 months:

Blood thinner (MC)	Epilepsy medication (SEP)	Nitroglycerin (MC)
Diabetic pill (SEP)	Heart-rhythm medication (MC)	Estrogen
Digitalis (MC)	High-blood-pressure medication (MC)	Thyroid
Diuretic (MC)	Insulin (MC)	Corticosteroids
Asthma	Other ----------	

12. Any of these health symptoms that occurs frequently is the basis for medical attention. Circle the number indicating how often you have each of the following:

0 = Never 1 = Practically never 2 = Infrequently 3 = Sometimes 4 = Fairly often 5 = Very often

a. Cough up blood (MC)
0 1 2 3 4 5

b. Abdominal pain (MC)
0 1 2 3 4 5

c. Low back pain (SLA)
0 1 2 3 4 5

d. Leg pain (MC)
0 1 2 3 4 5

e. Arm or shoulder pain (MC)
0 1 2 3 4 5

f. Chest pain (RF) (MC)
0 1 2 3 4 5

g. Swollen joints (MC)
0 1 2 3 4 5

h. Feel faint (MC)
0 1 2 3 4 5

I. Dizziness (MC)
0 1 2 3 4 5

j. Breathless with slight exertion (MC)
0 1 2 3 4 5

Part 3. Health-related behavior

13. (RF) Do you now smoke? Yes No

14. If you are a smoker, indicate number smoked per day:

Cigarettes:	40 or more	20-39	10-19	1-9
Cigars or pipes only:	5 or more or any inhaled		Less than 5, none inhaled	

15. Weight now: _____lb. One year ago: _____lb..

16. Thinking about the things you do at work, how would you rate yourself as to the amount of physical activity you get compared with others of your age and sex?

1. Much more active
2. Somewhat more active
3. About the same
4. Somewhat less active
5. Much less active
6. Not applicable

17. Now, thinking about the things you do outside of work, how would you rate yourself as to the amount of physical activity you get compared with others of your age and sex?

1. Much more active
2. Somewhat more active
3. About the same
4. Somewhat less active
5. Much less active
6. Not applicable

18. Do you regularly engage in strenuous exercise or hard physical labor?

1. Yes (answer question # 19) 2. No (stop)

19. Do you exercise or labor at least three times a week?

1. Yes 2. No

Appendix E: International Physical Activity Questionnaire

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE (October 2002)

LONG LAST 7 DAYS SELF-ADMINISTERED FORMAT

FOR USE WITH YOUNG AND MIDDLE-AGED ADULTS (15-69 years)

The International Physical Activity Questionnaires (IPAQ) comprises a set of 4 questionnaires. Long (5 activity domains asked independently) and short (4 generic items) versions for use by either telephone or self-administered methods are available. The purpose of the questionnaires is to provide common instruments that can be used to obtain internationally comparable data on health–related physical activity.

Background on IPAQ

The development of an international measure for physical activity commenced in Geneva in 1998 and was followed by extensive reliability and validity testing undertaken across 12 countries (14 sites) during 2000. The final results suggest that these measures have acceptable measurement properties for use in many settings and in different languages, and are suitable for national population-based prevalence studies of participation in physical activity.

Using IPAQ

Use of the IPAQ instruments for monitoring and research purposes is encouraged. It is recommended that no changes be made to the order or wording of the questions as this will affect the psychometric properties of the instruments.

Translation from English and Cultural Adaptation

Translation from English is encouraged to facilitate worldwide use of IPAQ. Information on the availability of IPAQ in different languages can be obtained at www.ipaq.ki.se. If a new translation is undertaken we highly recommend using the prescribed back translation methods available on the IPAQ website. If possible please consider making your translated version of IPAQ available to others by contributing it to the IPAQ website. Further details on translation and cultural adaptation can be downloaded from the website.

Further Developments of IPAQ

International collaboration on IPAQ is on-going and an ***International Physical Activity Prevalence Study*** is in progress. For further information see the IPAQ website.

More Information

More detailed information on the IPAQ process and the research methods used in the development of IPAQ instruments is available at www.ipaq.ki.se and Booth, M.L. (2000). *Assessment of Physical Activity: An International Perspective.* Research Quarterly for Exercise and Sport, 71 (2): s114-20. Other scientific publications and presentations on the use of IPAQ are summarized on the website.

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the **vigorous** and **moderate** activities that you did in the **last 7 days**. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal.

PART 1: JOB-RELATED PHYSICAL ACTIVITY

The first section is about your work. This includes paid jobs, farming, volunteer work, course work, and any other unpaid work that you did outside your home. Do not include unpaid work you might do around your home, like housework, yard work, general maintenance, and caring for your family. These are asked in Part 3.

1. Do you currently have a job or do any unpaid work outside your home?

   ☐ Yes

   ☐ No → ***Skip to PART 2: TRANSPORTATION***

The next questions are about all the physical activity you did in the **last 7 days** as part of your paid or unpaid work. This does not include traveling to and from work.

2. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, heavy construction, or climbing up stairs **as part of your work**? Think about only those physical activities that you did for at least 10 minutes at a time.

   _____ **days per week**

   ☐ No vigorous job-related physical activity → ***Skip to question 4***

3. How much time did you usually spend on one of those days doing **vigorous** physical activities as part of your work?

   _____ **hours per day**
   _____ **minutes per day**

4. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads **as part of your work**? Please do not include walking.

   _____ **days per week**

   ☐ No moderate job-related physical activity → ***Skip to question 6***

5. How much time did you usually spend on one of those days doing **moderate** physical activities as part of your work?

_____ **hours per day**
_____ **minutes per day**

6. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time **as part of your work**? Please do not count any walking you did to travel to or from work.

_____ **days per week**

☐ No job-related walking → ***Skip to PART 2: TRANSPORTATION***

7. How much time did you usually spend on one of those days **walking** as part of your work?

_____ **hours per day**
_____ **minutes per day**

PART 2: TRANSPORTATION PHYSICAL ACTIVITY

These questions are about how you traveled from place to place, including to places like work, stores, movies, and so on.

8. During the **last 7 days**, on how many days did you **travel in a motor vehicle** like a train, bus, car, or tram?

_____ **days per week**

☐ No traveling in a motor vehicle → ***Skip to question 10***

9. How much time did you usually spend on one of those days **traveling** in a train, bus, car, tram, or other kind of motor vehicle?

_____ **hours per day**
_____ **minutes per day**

Now think only about the **bicycling** and **walking** you might have done to travel to and from work, to do errands, or to go from place to place.

10. During the **last 7 days**, on how many days did you **bicycle** for at least 10 minutes at a time to go **from place to place**?

_____ **days per week**

☐ No bicycling from place to place → ***Skip to question 12***

11. How much time did you usually spend on one of those days to **bicycle** from place to place?

_____ **hours per day**
_____ **minutes per day**

12. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time to go **from place to place**?

_____ **days per week**

☐ No walking from place to place → ***Skip to PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY***

13. How much time did you usually spend on one of those days **walking** from place to place?

_____ **hours per day**
_____ **minutes per day**

PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY

This section is about some of the physical activities you might have done in the **last 7 days** in and around your home, like housework, gardening, yard work, general maintenance work, and caring for your family.

14. Think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, chopping wood, shoveling snow, or digging **in the garden or yard**?

_____ **days per week**

☐ No vigorous activity in garden or yard → ***Skip to question 16***

15. How much time did you usually spend on one of those days doing **vigorous** physical activities in the garden or yard?

_____ **hours per day**
_____ **minutes per day**

16. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** activities like carrying light loads, sweeping, washing windows, and raking **in the garden or yard**?

_____ **days per week**

☐ No moderate activity in garden or yard → ***Skip to question 18***

17. How much time did you usually spend on one of those days doing **moderate** physical activities in the garden or yard?

_____ **hours per day**
_____ **minutes per day**

18. Once again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** activities like carrying light loads, washing windows, scrubbing floors and sweeping **inside your home**?

_____ **days per week**

☐ No moderate activity inside home → ***Skip to PART 4: RECREATION, SPORT AND LEISURE-TIME PHYSICAL ACTIVITY***

19. How much time did you usually spend on one of those days doing **moderate** physical activities inside your home?

_____ **hours per day**
_____ **minutes per day**

PART 4: RECREATION, SPORT, AND LEISURE-TIME PHYSICAL ACTIVITY

This section is about all the physical activities that you did in the **last 7 days** solely for recreation, sport, exercise or leisure. Please do not include any activities you have already mentioned.

20. Not counting any walking you have already mentioned, during the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time **in your leisure time**?

_____ **days per week**

☐ No walking in leisure time → ***Skip to question 22***

21. How much time did you usually spend on one of those days **walking** in your leisure time?

_____ **hours per day**
_____ **minutes per day**

22. Think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **vigorous** physical activities like aerobics, running, fast bicycling, or fast swimming **in your leisure time**?

_____ **days per week**

☐ No vigorous activity in leisure time → ***Skip to question 24***

23. How much time did you usually spend on one of those days doing **vigorous** physical activities in your leisure time?

_____ **hours per day**
_____ **minutes per day**

24. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** physical activities like bicycling at a regular pace, swimming at a regular pace, and doubles tennis **in your leisure time**?

_____ **days per week**

☐ No moderate activity in leisure time → ***Skip to PART 5: TIME SPENT SITTING***

25. How much time did you usually spend on one of those days doing **moderate** physical activities in your leisure time?
_____ **hours per day**
_____ **minutes per day**

PART 5: TIME SPENT SITTING

The last questions are about the time you spend sitting while at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting or lying down to watch television. Do not include any time spent sitting in a motor vehicle that you have already told me about.

26. During the **last 7 days**, how much time did you usually spend **sitting** on a **weekday**?

_____ **hours per day**
_____ **minutes per day**

27. During the **last 7 days**, how much time did you usually spend **sitting** on a **weekend day**?

_____ **hours per day**
_____ **minutes per day**

This is the end of the questionnaire, thank you for participating.

Appendix F: Physical Activity Readiness Questionnaire

Physical Activity Readiness Questionnaire - PAR-Q (revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO	
☐	☐	**1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?**
☐	☐	**2. Do you feel pain in your chest when you do physical activity?**
☐	☐	**3. In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	**4. Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	**5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
☐	☐	**6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	**7. Do you know of any other reason why you should not do physical activity?**

If you answered YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME _____

SIGNATURE _____ DATE _____

SIGNATURE OF PARENT or GUARDIAN (for participants under the age of majority) _____ WITNESS _____

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

Supported by: Health Canada / Santé Canada

continued on other side...

Appendix G: Menstrual History Questionnaire

Menstrual History Questionnaire

1. **How old were you when you started having menstrual periods?**
   Age: _____ 1a. If you cannot remember your exact age, were you:
   - ☐ Younger than 10
   - ☐ 10-12 yrs old
   - ☐ 13-15 yrs old
   - ☐ 16 or older
   - ☐ Don't Know

2. **At present which statement best describes your menstrual cycle?**

   - ☐ I'm still having regular periods: The date of my last period was: ___/___/_____
   - ☐ My periods are irregular: The date of my last period was: ___/___/_____
   - ☐ I'm pregnant, or my last pregnancy ended within the past 2 months, or I'm breast feeding

   - ☐ My periods have stopped on their own. (I've had menopause.)
   - ☐ I've had menopause, but now have periods because I am taking hormones.
   - ☐ I've had an operation (surgery) which stopped my periods.
     If your menstrual periods ceased because of surgery, what did you have removed?
     - ☐ One ovary only
     - ☐ Both ovaries
     - ☐ Uterus only
     - ☐ Uterus and one ovary
     - ☐ Uterus and both ovaries
     - ☐ Don't know
   - ☐ I've taken medication which has stopped my periods.
     If your periods stopped because of medication, which medication were you taking? Medication name: _____

   - ☐ I"ve had chemotherapy which has stopped my periods.
   - ☐ I've had radiation therapy which has stopped my periods.
   - ☐ Other: _____

3. **If your menstrual periods have stopped, how old were you when your menstrual periods stopped?** (Please provide us with the age at which your menstrual periods stopped regardless of why they have stopped – naturally, due to surgery, medication, chemotherapy, or radiation therapy. If your periods have stopped, but you now have periods because of taking hormones, answer with the age at which your periods first stopped.)
   Were you:
   - ☐ Younger than 20
   - ☐ 20-29 yrs old
   - ☐ 30-39 yrs old
   - ☐ 40-44 yrs old
   - ☐ 45-49 yrs old
   - ☐ 50-54 yrs old
   - ☐ 55 – 59 yrs old
   - ☐ 60 or older

   OR ☐ **My menstrual periods have not stopped.**

4. **If your menstrual periods have stopped, how old were you when you first experienced symptoms of menopause such as hot flashes or night sweats?**
   _____ Years old
   - ☐ Did not experience symptoms
   - ☐ Don't Know

   OR ☐ **My menstrual periods have not stopped.**

All women should answer the next two questions, whether they currently have menstrual periods or not.

5. When you are (were) having regular menstrual cycles, how many days are (were) there between periods? _____ Days between periods

For how many days do (did) you have your period? _____ Days

6. Between the ages of 18 and 40, excluding times when you may have been on the pill, pregnant, or nursing, which of the following statements BEST describes your menstrual periods? They are (were)…

- ☐ Nearly always regular, that is, you could usually predict when you would start bleeding to within two or three days
- ☐ Fairly Regular
- ☐ Irregular
- ☐ Don't Know