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The effectiveness of back squats and depth jumps on eliciting postactivation potentiation

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THE EFFECTIVENESS OF BACK SQUATS AND DEPTH JUMPS ON ELICITING POSTACTIVATION POTENTIATION

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CERTIFICATE OF APPROVAL

MASTER OF SCIENCE THESIS

This is to certify that the Thesis of

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Submitted in partial fulfillment of the requirements for the degree of Master of Science in The School of Health Sciences and Human Performance at Ithaca College has been approved.

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ABSTRACT

PURPOSE: Data show that heavy preload stimuli preceding a sprint can improve performance by eliciting postactivation potentiation (PAP), an increased intramuscular sensitivity to calcium that enhances cross-bridge cycling, thereby acutely enhancing force production and strength. The aim of this study was to compare depth jumps (DJ) to back squats (BS) as a means to elicit PAP in college aged female rowers. **METHODS:** Twenty Division III collegiate female athletes, whose mean ± SD for age, height, weight, and VO_2 Max were, respectively, 18.9 ± 0.9y, 1.5 ± 0.05m, 60.7 ± 21.4kg and 42.8 ± 4.44 $ml \cdot kg^{-1} \cdot min^{-1}$, completed a 40m sprint timed at 10m, 20m, and 40m with an electronic timing system. Subjects were randomly divided into either the DJ or BS group. Subsequently, their one repetition maximum (1 RM) for the BS or DJ was measured. One week later, subjects completed a 40m sprint, and then three repetitions at 90% of their 1RM for BS or three DJ; after 7 min of active rest, they completed a second 40m sprint. A dynamic warm-up and active cool down preceded and followed each testing session. Data were analyzed with three 2x2 repeated measures ANOVA with post hoc t-test performed where significance was found. **RESULTS:** Both conditions increased sprint time at 40m with DJ being significantly slower while BS only trended toward significance; DJ and BS 20m sprint time was also slower although not significantly. **CONCLUSION:** The data show that three repetitions at 90% of 1RM for BS or three DJ did not elicit PAP in female college rowers. These findings may be related to sex, load, training incompatibility, or sprinting proficiency in this subject population.

DEDICATION

This thesis is dedicated to all those who have made my education such a wonderful experience and to my parents who are my biggest supporters.

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Chapter 1

INTRODUCTION

Postactivation potentiation is a physiological phenomenon whereby previous muscular activity enhances ensuing force generation, thereby improving power and strength performance in certain types of athletes (Evetovich, Conley, & McCawley, 2015). Researchers believe PAP is caused by an increased calcium sensitivity in the muscle cell that causes myosin light chain phosphorlyation, thereby enhancing myosin cross-bridge activity (Byrne, Kenny, & O'Rourke, 2014; Robbins, 2005). Data show that PAP decreases running sprint time and 100m swim time, while increasing vertical and horizontal jump performance. Numerically, the changes are small, but in high level athletics, they may be the difference between winning and losing (Chiu et al., 2003; Hancock, Sparks, & Kullman, 2015; Matthews, Matthews, & Snook, 2004; Naclerio et al., 2015; Scott & Docherty, 2004; Wyland, Van Dorin, & Reyes, 2015).

To elicit PAP, some type of preconditioning activity is needed to provide the optimum balance between fatigue and potentiation in the desired muscles. Most studies have focused on determining which factors best elicit PAP, such as training experience, period of time between pre-conditioning stimulus and event, and load of conditioning activity (Rixon, Lamont, & Bemben, 2007; Wilson et al., 2013). The typical load used is three repetitions at 90% of the one repetition maximum (1RM) for the leg squat as the pre-conditioning stimulus (Bevan et al., 2010; Duncan, Thurgood, & Oxford, 2014; McBride, Nimphius, & Erickson, 2005). However, there are other protocols that have proven to be effective in eliciting PAP. Chatzopoulos et al. (2007), for example, had participants back squat to 90˚ of knee flexion for ten single trials at a load of 90% 1RM three minutes and five minutes before a 30m sprint. Other studies have used different techniques, like back squats and front squats, along with other types of interventions, different timing protocols, and different subject demographics to evaluate the mechanisms necessary for PAP (see Appendix A for a relevant list).

It appears as though the preload needs to be individualized not only for the athlete, but also for the activity or sport. Incorrectly applied preload stimuli or interventions such as too much weight or too many repetitions could decrease rather than enhance sport performance, perhaps causing unwanted pre event muscular fatigue (Wilson et al., 2013). This delicate and contextual balance between volume of weight, duration of activity, and length of rest needs to be further investigated to optimize the ability of PAP to improve performance; it is clear that a generalized approach for all athletes is inappropriate (Güllich & Sehmidtbleicher, 1996; Tillin & Bishop, 2009).

Most studies have used highly power-trained males as subjects. Data from these studies show that the higher the initial training status of the subject, the greater the PAP effect--leading to better experimental results (Bevan et al., 2010; Byrne et al., 2014; Chatzopoulos et al., 2007; Chiu et al., 2003; Duncan, Thurgood, & Oxford, 2014; Linder et al., 2010; Matthews et al., 2004; McBride, Nimphius, & Erickson, 2005; Yetter & Moir, 2008). Currently no one has reported the potential to elicit PAP in untrained individuals. In addition to training status, data show power-trained participants have a greater PAP effect than other types of athletes (Pääsuke et al., 2007). Data are inconclusive on whether or not PAP is elicited in highly trained endurance athletes. Further, data show the PAP effect is larger when the specific muscles trained are the ones tested (Hamada, Sale, & MacDougall, 2000; Pääsuke et al., 2007; Wilson et al., 2013).

Clearly, the means by which to elicit PAP, or in which athletes it's best induced, and the range of its ability to enhance performance warrants additional studies (Linder et al., 2010; Pääsuke et al., 2007; Wilson et al., 2013).

Female athletes can also experience PAP. Pääsuke et al (2007) examined how the knee extensor muscles in power trained, endurance trained, and untrained female participants reacted to electrically stimulated maximal voluntary contractions of the knee-extensors and found PAP in only power trained subjects. Linder et at (2010) also used females to determine if a 4RM back squat load could elicit PAP, and found a 1.2% decrease in 100m sprint time. Given that the majority of the studies on PAP have used males as subjects, additional research on its effects in females is warranted. Hence, one of the primary purposes of this paper is to determine if the back squat elicits PAP in females.

Aside from the back squat, it is likely that other modalities can serve as the pre-conditioning stimulus, such as the depth jump (Byrne et al., 2014). This is particularly interesting, as it is much more practical than a lift prior to an athletic competition. Byrne et al. showed that the depth jump elicited PAP in sprinting, improving sprint performance by 2.2%. The study did not examine females, and the timing of the jumps suggests it may have improved performance by enhancing the warm-up rather than eliciting PAP. Hence, a second purpose of this paper is to evaluate the effectiveness of a depth jump on eliciting PAP. To date, there has not been a study that compares a depth jump protocol to a squat protocol, so the present study will also compare the two interventions to determine the effectiveness in both methods in eliciting PAP and will use female athletes to broaden the knowledge base of PAP.

Statement of the Purpose

The purpose of this study is to evaluate whether depth jumps prior to sprinting will elicit postactivation potentiation in the leg muscles and furthermore decrease 40m sprint time of Division III female crew athletes.

Hypotheses

This study has three null hypotheses.

1. Performing depth jumps prior to performing a 40m sprint will have no effect on sprint time.
2. Performing squats prior to performing a 40m sprint will have no effect on sprint time.
3. There will be no difference between the depth jump and squat conditions.

Assumptions of the Study

For the purpose of this investigation certain assumptions are being made prior to the commencement of data collection.

1. The subjects will give their maximal effort in all trials.
2. The subjects will follow all instructions they have been given.
3. Subjects will provide honest answers about their health and workout history via questionnaires.

Definition of Terms

The following terms are operationally defined here for the purpose of this study.

1. Repetition maximum is the amount of weight that an individual can lift for only a predetermined amount of times. Commonly seen as 1RM, 4RM or 5RM in this paper.

2. A depth jump is a plyometric exercise in which the individual performing the exercise begins standing on a box and proceeds to step off the box and upon landing on the ground, immediately jumping maximally to touch the highest point they can.

Inclusion and Exclusion Criteria

1. Subjects were included if they were on the Ithaca College crew team and had been strength training for at least a year.
2. Subjects were excluded if they had any recent knee or back injuries as they could affect the results of the study.

Delimitations

The delimitations of this study include:

1. Only college age students with at least one year of strength training experience will be considered as participants.
2. This study will only use female crew athletes at Ithaca College.
3. This investigation will use similar protocols for the squat and depth jump conditions.

Limitations

This investigation will have a few limitations, which include:

1. The results of the study will be generalized to Division III female crew athletes with lifting experience from a relatively small institution in the northeast.
2. PAP is not elicited if athlete is fatigued or in a state of overreaching.

Chapter 2

REVIEW OF LITERATURE

Introduction

A physiological response currently being studied in human sport performance is postactivation potentiation (PAP). PAP is an acute or temporary increase in muscle force production due to maximal or near-maximal muscle contractile history. Subjects perform resistive exercises prior to beginning a sprinting bout to elicit PAP and improve performance (Evetovich et al., 2015; Turner, Bellhouse, Kilduff, & Russell, 2015).

According to Byrne, Kenny, and O'Rourke (2014), the principal mechanism leading to postactivation potentiation (PAP) is the phosphorlyation of myosin regulatory light chains, which increases myofibrillar Ca^{2+} sensitivity and thereby enhancing cross-bridge activity (Byrne et al., 2014). Other researchers describe PAP as increased twitch tension, increased rate of tension development, and decreased post-stimulus relaxation time (Robbins, 2005). Fiber type affects whether PAP or fatigue is present in the targeted muscle. It is possible for both mechanisms of potentiation and fatigue to coexist because both are caused by Ca^{2+} dependent mechanisms: PAP is increased Ca^{2+} sensitivity whereas muscle fatigue is caused by a decreased concentration of Ca^{2+} in the myoplasm, which decreases myofilaments Ca^{2+} sensitivity (Pääsuke et al., 2007; Sale, 2002). Regardless of the mechanism, researchers agree that an appropriate preload stimulus is necessary for PAP to be effective in athletic performance.

Given the various methods used to elicit PAP, it is difficult to compare studies. Nevertheless, recent studies have predominately focused on the ability of back squats to elicit PAP, which have served as the independent variable in all but one study in this literature review. Although the conditioning stimuli were similar, the studies used various sprint distances and preloads, as shown in Appendix A. This literature review will organize and analyze the studies according to the stimulus used, beginning with back squats and proceeding to depth jumps. For the purpose of this study, heavy back squats and back squats are synonymous, used interchangeably depending on reference wording.

Back Squats

Published research shows heavy preload stimuli elicit PAP, and back squatting is a common method used while the number of squats, the preload weight, and rest time before activity varies. For example, three of the studies used three repetitions at 90% or 91% of the individual's one repetition maximum (1RM), another study used ten sets of one repetition at 90% 1RM, and several others used a four-repetition maximum (4RM) or a five-repetition maximum (5RM) back squat. Lastly, one study used three progressively heavier sets of squats, five reps at 30% 1RM, four reps at 50% 1RM, and three reps at 70% 1RM prior to the sprint (Bevan et al., 2010; Chatzopoulos et al., 2007; Duncan et al., 2014; Linder et al., 2010; Matthews et al., 2004; McBride et al., 2005; Yetter & Moir, 2008).

Protocol: 1 x 3 @ 90% or 91%

These first sets of studies share similar stimuli yet differ in regards to sprint distance, sprint frequency, and pre-sprint rest time. Bevan, Cunningham, Tooley, et al. (2010) used a 10m-sprint distance in which 16 professional male rugby players completed a 10m baseline sprint, which was timed at 5m and 10m. Following a twenty minute recovery period subjects were required to complete one set of a preload stimulus: a back squat load of 91% 1RM for three repetitions. Subjects proceeded to sprint 10m every four minutes until (and including) 16 minutes had elapsed (Bevan et al., 2010). Treatment effects were individualized so researchers compared these performance sprints to ones measured in the lab. The lifting protocol decreased sprint times at both 5m and 10m by 5-8%; those subjects with the greater amount of strength training experience, had the largest gains in performance (Bevan et al., 2010).

In another study using male rugby players, researchers aimed to identify the effect of heavy resistance exercise on repeated 30m sprints with time splits at 5m and 10m (Duncan et al., 2014). The treatment session required subjects to warm up by lightly jogging for five minutes followed by dynamic stretching. Next, subjects completed three repetitions of a back squat at 90% 1RM and then had four minutes of walking recovery before repeating the sprint test. Seven sprints, on a field, separated by 25 seconds were performed and timed at 5m, 10m, and 30m. This design simulates rugby match play where players perform multiple sprints over time. Subjects were their own control in this cross over design. There was no significant change in performance at either 5m or 10m, although overall sprint times were significantly quicker for the fifth, sixth, and seventh sprints (Duncan et al., 2014). These last three sprints took place six to eight minutes after the preload stimulus suggesting a PAP effect in sustaining sprint speed since the 30m times were significantly lower than the non-PAP intervention (Duncan et al., 2014).

The third study to use this preload used Division III football players as their subjects. They completed heavy squat (HS), loaded countermovement jumps (LCMJ), and a control condition (McBride et al., 2005). All sessions began with a five minute warm-up on a cycle ergometer followed by four minutes of walking. Subjects then performed three repetitions of a squat at 90% 1RM or jump squats on a Smith machine using 30% of their HS 1RM. The jump squats needed to be at least 90% of their maximal jump squat height to be valid for LCMJ protocol. Only the warm up took place prior to sprinting for the control condition. After the preload subjects walked four minutes before sprinting 40m, with times taken by electronic timers at 10m, 30m, and 40m (McBride et al., 2005). Data show that only the squat protocol improved sprint performance, which increased by 1.39%; suggesting that only this exercise elicits PAP. Since the authors did not measure electromyography (EMG) in the subjects, this hypothesis is unconfirmed (McBride et al., 2005).

Protocol: 10 x 1 @ 90% 1RM

One study required subjects to perform multiple sets of single repetition squats. The first of three sessions was used to familiarize subjects with the lift as well as to find their 1RM for back squat. In the second session the subjects' baseline 30m sprint time was recorded. The fastest of the three trials was selected as the baseline (Chatzopoulos et al., 2007). Ten single repetitions with a load of 90% 1RM squats to 90˚ of knee flexion were then completed prior to a rest period of three minutes. Subjects then performed the 30m sprint. This protocol was repeated in a third session where subjects rested five minutes post-stimulus instead of three. This method was used to analyze the difference between the two post-tests as a way to identify when fatigue ended and PAP became more prevalent. Results show that heavy squats five minutes prior to sprinting elicited PAP and improved sprint performance by 1-3%. Researchers suggested that fatigue was still dominant to PAP at the three minute post-test, thereby negating a PAP effect (Chatzopoulos et al., 2007).

Protocol: 4 Repetition Maximum

The use of female subjects in PAP research is uncommon, although in one study resistance trained collegiate women served as subjects (Linder et al., 2010). Participants completed a control and intervention condition; the latter included a four repetition maximum (4RM) back squat. Subjects engaged in a four minute warm up protocol on a cycle ergometer followed by a four-minute rest period for both control and intervention conditions. In the control session, following the warm up, the subjects sprinted 100m twice with four minutes of active walking between them. All subjects performed the trials individually to attenuate the effects competition or motivation. The experimental condition had the same warm up, but also included two sets of squats, where subjects reached a predetermined 4RM; sets were separated by two minutes of rest. The subjects then rested nine minutes before completing the 100m sprint (Linder et al., 2010). This protocol significantly improved sprint performance by approximately 1.2% with an average decrease in sprint time of 0.19 seconds. Findings suggest sprinters should complete a set of back half squats around ten minutes before a race, as the nine minute rest interval is appropriate to obtain PAP effects (Linder et al., 2010).

Protocol: 5 Repetition Maximum

Using a crossover design, Matthews, Matthews, and Snook (2004) looked at the effect of a five repetition maximum (5RM) back squat protocol to improve 20m sprint performance. The control trial included a warm up, 20m sprint, ten-minute rest, and a second 20m sprint. In the experimental condition subjects warmed up and completed a 20m sprint, rested for five minutes, performed a 5RM back squat, and then completed a second 20m sprint when a total of ten minutes had elapsed from the completion of the first sprint (Matthews et al., 2004). The experimental protocol decreased sprint time by 3.3%, approximately 0.98 seconds. Results suggest the 5RM elicited PAP thereby improving performance (Matthews et al., 2004).

Protocol: Progressive Weight Increase

Heavy back squats (HBS) were compared to heavy front squats (HFS) to determine which method was more effective at eliciting PAP (Yetter & Moir, 2008). Researchers had subjects perform the intervention in a random order to adjust for any treatment order effects. The HBS testing session began with a five-minute cycle and four-minute walk, but then required subjects to complete five repetitions at 30% 1RM, four reps at 50% 1RM, and three reps at 70% 1RM with a two-minutes rest between sets. Four minutes of walking post-squatting preceded the three 40m sprints. The HFS condition followed the same protocol with the 1RM weight equal to 80% of the HBS 1RM. The control in this study required subjects to cycle, walk, and then sprint. The HBS intervention had significantly faster sprints compared to the control by 2.3% at 40m. Whereas no significant difference was found between HBS and HFS for the 10m-20m interval, HBS was significantly faster, 0.24s, than HFS at 30m-40m. Yetter and Moir attributed the decrease in sprint time at 30m to 40m interval to better velocity maintenance. A limitation of the study was that the HFS was calculated and not measured so it may have not been a sufficient load to elicit PAP (Yetter & Moir, 2008).

Depth Jump

In contrast to the traditional stimulus, other researchers have begun to determine if other stimuli could be more practical, effective, and possibly safer, while still using sprinting as the dependent variable. Rather than use a squat independent variable, they used a dynamic stretching and depth jump (DJ) protocol (Byrne et al., 2014). Depth jumping is a plyometric activity in which the athlete steps off a box and immediately jumps as quickly and as high as possible typically spending less than one quarter of a second on the floor. This is done to “enhance the reactive strength of the stretch-shortening cycle” to increase speed and vertical jump capacity (Byrne, Moran, Rankin, & Kinsella, 2010, p. 2050). Depth jumps are a neuromuscular activity, so it is important to find each person’s optimal drop height, which allows them to jump the highest in a subsequent work bout. In their 2010 study, two DJ methods were compared; the maximum jump height (MJH) and the reactive strength index (RSI) (Byrne et al., 2010). The MJH progresses each subject incrementally until peak jump height is achieved and the RSI measures the time that is spent on the ground prior to the jump. Since subjects attempted each method, it was a crossover design. The MJH method optimized depth jump performance, increasing jump height by at least 0.10m. No sprinting was performed during this study since the purpose was to identify which depth jumping method was best (Byrne et al., 2010).

As a follow up study, Byrne et al (2014) had subjects complete a dynamic warm-up and then determined if the MJH depth jump method (DYNDJ) improved 20m sprint time. Researchers compared this to dynamic warm up only (DYN) and a control condition (Byrne et al., 2014). Each subject performed all three conditions, separated by one week; hence, they served as their own controls in this repeated measures design. Each testing session began with the subjects jogging for five minutes. The control intervention required subjects to rest for one minute before the 20m sprint. In the DYN intervention, subjects performed ten dynamic stretches after their five minutes of jogging, rested for one minute, and then completed the 20m sprint. Lastly, the DYNDJ intervention consisted of five minutes of jogging, ten dynamic stretches and three DJ, followed by a minute of rest and then the 20m sprint. Depth jumping significantly decreased 20m sprint time by 2.2% relative to other conditions (Byrne et al., 2014).

Summary

Both the squat and depth jump independent variables significantly improve sprint time although nearly all studies used the back squat. While squat protocols are effective, they are not the most practical in competition settings, such as at a track meet, as weight racks are not readily available. Squatting is also a more dangerous activity and requires a higher training status than plyometric activities. Depth jumping is an understudied, more practical method for PAP and is safer for athletes. For example, a track athlete would be able to depth jump off of a bleacher or chair at a competition. More research is needed using depth jumping as the independent variable for evaluating PAP in sprinting performance. Nearly all studies except Linder et al. (2010) used males as subjects, but Linder also found that PAP is elicited in female subjects. Additional study on the ability of various preconditioning stimuli to elicit PAP in females and therefore improve sprint performance is warranted.

In the present study, subjects performed a baseline sprint, and then either heavy back squats or depth jumps prior to sprinting. Sprint distance was 40m with time splits at 10m and 20m. Female collegiate crew athletes, who were resistance trained with some sprint training experience, were subjects. Results were expected to show depth jumps elicit PAP to increase sprint performance in equal or greater amounts than back squats. Results would provide coaches and athletes with a safer and more practical option to optimize performance during training and competitions. Depth jumps require less teaching and training than squats for an individual to become proficient. This would allow athletes of all ages to use this modality to improve their performance.

Chapter 3

METHODS

Subjects

Subjects were actively recruited from the women's crew team at Ithaca College. The crew team was chosen for this investigation because it took place at a small division III institution with a smaller selection of athletes who are in a continual lifting program. The team was available during the time of data collection, as they were not in competition season and were enthusiastic about participating. Twenty division III collegiate female athletes, whose mean and standard deviation for age, height, weight, and VO_2 Max were 18.89 ± 0.88 y, 1.50 ± 0.52 m, 60.68 ± 21.44 kg and 42.47 ± 4.44 $ml \cdot kg^{-1} \cdot min^{-1}$, respectively, volunteered as subjects. None had recent orthopedic injury, musculoskeletal injury, or pathologies that affected the results. Each subject had been resistance training for at least a year, as research shows higher training levels increase PAP response; it also helps minimize injury risk.

Design

In the first meeting, subjects filled out a health history form (Appendix B) and signed an informed consent (Appendix C) and were familiarized with the aspects of the study. Subjects completed a three-week training period of study specific exercises to prepare their bodies for testing. This three-week strength and conditioning program was part of the normal strength and conditioning program for the team. All workouts and testing sessions began the same with a five minute jogging warm up, followed by dynamic stretching. The dynamic stretches in this study were the same as those used at the beginning of their routine training sessions. The warm up included a knee hug lunge, high skips swinging the opposite arm, high knees, butt kicks, single leg RDLs (Romanian dead lifts), long stride backwards run, short stride backwards run, a high knee march, and an inchworm. During this three-week training, the baseline 40m sprint time was measured with a Fusion Sport Smart Speed Photocell Timing System (Fusion Sport, Australia) and time was recorded at 10m, 20m and 40m. The one repetition maximum (1RM) for the squat and the optimal drop height for the depth jump were also measured during training. A 1RM for the squat lift is defined as the maximum amount of weight that can be lifted once with proper exercise technique. The 1RM testing protocol from the National Strength and Conditioning Association (NSCA) was used in this investigation (Baechile, 2000). During the three-week training period, subjects were familiarized with the test protocol. Subjects were stratified into groups based on baseline sprint times so that there was not a significant difference between group average baseline sprint times.

The depth jump height was determined using the methods of Byrne, Moran, Rankin, and Kinsella (2010). The height of the jump was measured using a SPRI Vertec Jump Training System (SPRI, Libertyville, IL). Subjects began on an 8” box and completed two depth jumps before the height of the box was incrementally increased by 3” to 5”. The optimal drop height was found when the height of the jump reached its peak.

After the three-week training program, subjects warmed up as described and then completed the pre-condition sprint. Two minutes later, subjects then completed either the back squat or depth jump intervention as previously assigned. Subjects then actively rested by walking for seven minutes. Proctors assured no other warm up took place, especially stretching since it could lead to a reduction of PAP (Güllich & Sehmidtbleicher, 1996). At the end of seven minutes, subjects completed the post-test 40m sprint.

The predicted outcomes of this study were that sprint times would be significantly quicker in both conditions. This increase in performance was expected to show both conditions elicit PAP equally, allowing greater flexibility and preference for using either method in competition.

Statistical Analysis

T-tests were run in the beginning of the study to ensure there was no significant difference between the baseline sprint times of each group. Three repeated measures analysis of variance (ANOVA), $\alpha = 0.05$, were performed for each of the three distance checkpoints. Paired t-tests were run post hoc to determine where the significance lay. Since this was a preliminary study, the decision was made to not use a corrected alpha.

Chapter 4

RESULTS

Back squats and depth jumps as a heavy stimulus prior to sprinting did not improve performance in this population of female crew athletes. Indeed, there was a main effect for time for all subjects, showing that the intervention decreased sprint performance at 20m and 40m, F (1, 18) = 7.63, p = 0.01, η^2 = 0.30; F (1, 18) = 9.40, $p <$ 0.01, η^2 = 0.34. In addition, there was no main effect for group. Hence, traditional post hoc analyses were not warranted. Nevertheless, given the nature of this study, paired t-tests were calculated for within group differences to gain a better understanding of the data. Table 1 includes mean pre and post stimulus sprint times for both depth jump and squat. The tests show that there was not a significant difference between pre and post sprint times at 10m for both the depth jump and back squat, F (1, 18) = 1.44, p = 0.25, η^2 = 0.07. Post sprint times at 10m did not differ between the two groups, F (1, 18) = 0.36, p = 0.56, η^2 = 0.02.

In contrast, sprint times at 20m significantly decreased from pre to post for back squat by 1.10%, and for the depth jump, F (1, 18) = 7.63, p = 0.01, η^2 = 0.30. There was no significant difference between depth jump and back squat post sprint times at 20m, F (1, 18) = 0.09, p = 0.77, η^2 = 0.01. Post hoc paired t-tests showed that both back squat (p = 0.075) and depth jump (p = 0.079) were close to trending toward significance. The small sample size affects these values, suggesting a larger sample size could yield significant post hoc results.

Similarly to 10m and 20m, post sprint times did not differ significantly at 40m between depth jump and back squat F (1, 18) = 0.03, p = 0.86, $\eta^2 <$ 0.01, but sprint performance decreased 1.68% for the depth jump and 0.91% for the back squat F (1, 18) = 9.40, $p < 0.01$, $\eta^2 = 0.34$. While post hoc t-tests revealed no significant differences between the two groups, data show that back squat pre-post 40m time difference trended toward significance ($p = 0.07$), while depth jump was significantly slower (p = 0.045) using an uncorrected alpha ($\alpha = 0.05$). An uncorrected alpha was used in this analysis since there was a significant main effect, but low power due to a small sample size after the participants were divided into groups.

Figure 1 shows the average 40m sprint time pre and post stimulus for both interventions. The significantly higher sprint times at the 20m and 40m suggest there was no PAP effect in either the depth jump or squat condition.

Table 1.

Mean Pre- and Post-Stimulus Sprint Times by Condition

	Depth Jump (n=10)			Squat (n= 10)		
	10m	20m	40m	10m	20m	40m
Pre mean (s)	2.06	3.62	6.55	2.10	3.62	6.61
SD	0.09	0.12	0.27	0.09	0.14	0.32
Post mean (s)	2.09	3.68	6.66	2.10	3.66	6.67
SD	0.11	0.13	0.27*	0.09	0.17†	0.36†

Note. * p < 0.05 significant differences pre-post stimulus, † p = 0.07 trend toward significance pre-post stimulus, data (mean ± standard deviation), distances in meters (m), and time in seconds (s).

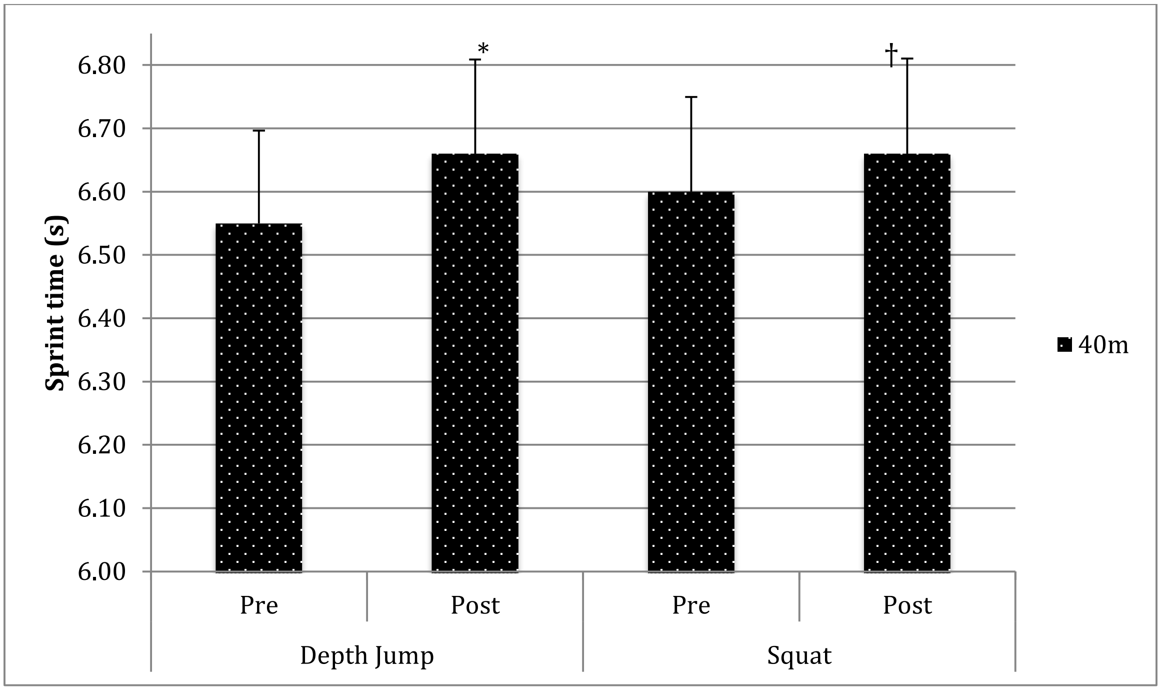

Figure 1. Comparison of pre and post 40m sprint times by condition. Post times show a significantly slower main effect than pre times. Post hoc paired t-tests show differences between groups, $*p < 0.05$, † $p = 0.07$.

Chapter 5

DISCUSSION

The aim of this study was to compare the ability of different heavy preload stimuli to elicit postactivation potentiation (PAP) and therefore improve 40m sprint performance in female division III rowers. The main purposes were to evaluate whether female athletes would have the same response to the squat condition as supported by the literature, and determine if the depth jump condition was an effective way to elicit PAP. With the back squat being widely researched in the literature, its purpose was to serve as a control to the less popular depth jump when evaluating performance of female subjects. The principle findings were that PAP was not observed in the subjects after either the depth jump or the squat condition and rather than improve performance, the interventions decreased sprint performance. These results are inconsistent with the literature, which showed that depth jumps and squats elicit PAP and improve performance by up to 8% (Bevan et al., 2010; Byrne et al., 2014; Chatzopoulos et al., 2007; Duncan et al., 2014; Linder et al., 2010; Matthews et al., 2004; McBride et al., 2005; Yetter & Moir, 2008).

There are many possible explanations for why the results did not coincide with the literature and why sprint performance decreased. One hypothesis for why sprint performance decreased is that my subjects were more endurance trained than power trained. Training leads to many adaptations at the cellular level. Power training and aerobic training both influence myofiber type, myofiber size, and myofiber contractile properties (Tanaka & Swensen, 1998). For example, any type of training alters myosin heavy chain (MHC) expression, which leads to a change in myosin ATPase speed. Difference in ATPase speed influences the rate at which ATP is broken down to ADP +

Pi thereby effecting muscle contractile rate. Both endurance and weight training cause a myofiber transformation, whereby the type of fiber is converted from type IIx to type IIa, resulting in a slower myosin ATPase speed. Additionally, endurance training down regulates the MLC in type II fibers, decreasing the maximal shortening velocity (Vmax) (Fitts & Widrick, 1996; Tanaka & Swensen, 1998). Concurrent training potentially attenuates increases in myofiber diameter that occur during strength and sprint training, thereby decreasing anaerobic power output (Babcock et al., 2012). Collectively the aforementioned changes decrease power output and hence slow sprint speed. Aside from contributing to a decrease in sprint speed, the changes in type II fiber Vmax also could attenuate the PAP effect by interfering with the ability of the conditioning stimulus to increase Ca^{2+} sensitivity, and therefore enhance cross-bridge cycling.

An alternative explanation of the lack of PAP effect was that the subjects were not familiar enough with the exercises they performed. As shown in Appendix A, most studies show that squatting before a sprint improves performance, whereas it did not in this study (Chatzopoulos et al., 2007; Linder et al., 2010; Matthews et al., 2004; McBride et al., 2005). The current subjects normally performed front squats in their training except for the three weeks leading up to this investigation where they back squatted. The switch was made because the front squat does not elicit PAP as effectively as back squats (Yetter & Moir, 2008). Perhaps if more familiarization training had occurred, the subjects could have performed the back squat more comfortably and confidently thereby enabling it to elicit PAP.

The load used in the back squat may have influenced the results as well. Linder et al (2010) used a 4RM, which is approximately 82.5% of 1RM, as opposed to the current methods that used three repetitions at 90% of the 1RM. The literature, however, clearly supports the use of the load used in this study, as shown in Appendix A. The major difference between Linder and the other studies is subject sex. Most studies used males, whereas Linder et al. (2010) studied females, as in the current study. Perhaps the load needed to elicit PAP is lower in females than it is in males. Data show that untrained males have a higher percentage of fast-twitch muscle fibers than untrained women (Wilson et al., 2013). This sex difference may exist after training; consequently, the load needed to elicit PAP may be lower in females than males. By extension, perhaps PAP will be lower in females than males, since fast-twitch fibers are more responsive to preconditioning stimuli (Fitts & Widrick, 1996; Rixon et al., 2007).

Load optimization may also have been affected by the endurance training in this study. Endurance training allows muscles to maintain isometric torque longer compared to power athletes. Thus, it is possible that a lower load with more repetitions would have elicited PAP in the subjects. Subjects may have also been fatigued by the load being too heavy and may have needed a longer recovery time. Indeed, PAP may be best elicited with individualized pre-conditioning stimuli based on different neuromuscular responses across individuals (Pääsuke et al., 2007).

The depth jump was unfamiliar to the subjects as they only performed this exercise in the weeks prior to data collection. The subjects did, however, complete other plyometric activities, so the depth jump was not fully novel. Previous research shows that depth jumps improve sprint performance (Byrne et al., 2014). As shown in Table 2 and Figure 1, the current data did not support this finding. A main difference in the protocols between the studies is the length of the rest time between the depth jump and sprint. The rest period was seven minutes compared to one minute in the other study. The seven minute rest period in this study complied with the consensus in the literature that shows there must be five to 10 minutes of rest after the preload stimulus (Rixon et al., 2007; Wilson et al., 2013). The difference in rest time suggests that including the depth jump in the warm up simply extends and possibly optimizes the warm up rather than elicit PAP. A potentially more accurate way to investigate depth jumps on PAP as reported in the study by Byrne et al. (2014) would have been to replace the dynamic stretches with the depth jumps in the third condition instead of having the third protocol be a combination of dynamic stretches and depth jumps.

The aforementioned explanations are all possibilities for the lack of PAP in the subjects. Cellular level adaptations that influence myofiber type and size potentially affect the mechanisms necessary for PAP leading to a diminished response. Alternative loads and modalities could potentially be more effective at eliciting PAP in a variety of athletic populations. In summary, this study determined that neither three depth jumps nor three squats prior to sprinting improved performance.

Chapter 6

SUMMARY, CONCLUSIONS, RECOMMENDATIONS

Summary

The purpose of this investigation was to evaluate the effectiveness of back squat and depth jump protocols to elicit PAP in female crew athletes. Previous literature shows back squats are effective at eliciting PAP in both males and females, but there is little support for the depth jump. The subjects in this investigation completed either the three repetitions of a back squat load of 90% 1RM protocol or the three depth jumps protocol in between 40m pre and post sprints. Results showed a significant increase in 40m sprint times across both conditions, which was inconsistent with the literature. The decreased performance suggested there was no PAP.

Conclusions

Neither protocol elicited PAP in this population of Division III female crew athletes, and in fact made them slower. Potential reasons for this could be the sprint distance used, an inappropriate load, a difference in training methods, the effects of concurrent training, lack of intense sprint training, or the subjects' sex. It appears that the primary reason for a lack of PAP is related to the load. In theory, once the load is determined, rest time and other factors should fall into place.

Research Suggestions

Further research is warranted and should focus on female subjects to determine what an appropriate load is and in what capacity PAP could be elicited. This could be done through a study using different stimulus loads and different active rest times. Specifically, female subjects should complete the same lifting protocol, beginning with a back squat protocol, with each session having a different active rest period. A study design like this would be able to better determine when fatigue ends and PAP begins. A second study of female subjects should test different loads with each session testing different repetition maximums, e.g. 4RM, 5RM, etc. This would aid in finding the optimal load for females. The same principle should be used to find the range of distance in which there is a PAP effect. For example, allowing for track athletes specifically to determine if a PAP stimulus would be effective for their race. The training status of the individual should be considered when determining optimal PAP preload since fiber type composition greatly affects how muscles respond to preload stimulus. The depth jump variable should also be studied since there is little literature about its effectiveness in both sexes. Future research should begin with highly trained male athletes since previous literature shows that PAP is effectively elicited. Subjects should perform three depth jumps, following protocol set by Byrne et al. (2014), prior to different length rest periods. Again, this would better determine when fatigue ends and PAP begins. After optimal methods are determined using male athletes, research should continue with highly trained female athletes. Depth jumping is safer than any Olympic lift and is more feasible in a pre-competition setting for both sexes of athletes. If the research supporting maximal or near maximal stimulus elicits PAP increases in both males and females, it could change the way warm ups are conducted prior to competition.

REFERENCES

Baechile, T.R., & Earle, R.W. (2000). *Essentials of strength training and conditioning* (2nd ed.). Champaign, IL: Human Kinetics.

Babcock, L., Escano, M., D'Lugos, A., Todd, K., Murach, K., & Luden, N. (2012). Concurrent aerobic exercise interferes with the satellite cell response to acute resistance exercise. *American Journal of Physiology: Regulatory, Integrative and Comparative Physiology, 302*(12), R1458–R1465.

Bevan, H. R., Cunningham, D. J., Tooley, E. P., Owen, N. J., Cook, C. J., & Kilduff, L. P. (2010). Influence of postactivation potentiation on sprinting performance in professional rugby players. *Journal of Strength and Conditioning Research, 24*(3), 701–705.

Byrne, P. J., Kenny, J., & O'Rourke, B. (2014). Acute potentiating effect of depth jumps on sprint performance. *Journal of Strength and Conditioning Research*, *28*(3), 610–615.

Byrne, P. J., Moran, K., Rankin, P., & Kinsella, S. (2010). A comparison of methods used to identify "optimal" drop height for early phase adaptations in depth jump training. *Journal of Strength and Conditioning Research*, *24*(8), 2050–2055.

Chatzopoulos, D. E., Michailidis, C. J., Giannakos, A. K., Alexiou, K. C., Patikas, D. A., Antonopoulos, C. B., & Kotzamanidis, C. M. (2007). Postactivation potentiation effects after heavy resistance exercise on running speed. *Journal of Strength and Conditioning Research, 21*(4), 1278–1281.

Chiu, L. Z. F., Fry, A. C., Weiss, L. W., Schilling, B. K., Brown, L. E., & Smith, S. L. (2003). Postactivation potentiation response in athletic and recreationally trained individuals. *Journal of Strength and Conditioning Research*, *17*(4), 671–677.

Duncan, M. J., Thurgood, G., & Oxford, S. W. (2014). Effect of heavy back squats on repeated sprint performance in trained men. *The Journal of Sports Medicine and Physical Fitness*, *54*(2), 238–243.

Evetovich, T. K., Conley, D. S., & McCawley, P. F. (2015). Postactivation potentiation enhances upper- and lower-body athletic performance in collegiate male and female athletes. *Journal of Strength and Conditioning Research*, *29*(2), 336–342.

Fitts, R. H., & Widrick, J. J. (1996). Muscle mechanics: Adaptations with exercise-training. *Exercise and Sport Sciences Reviews*, *24*, 427–273.

Güllich, A., & Sehmidtbleicher, D. (1996). MVC-induced short-term potentiation of explosive force. *New Studies in Athletics*, *4*, 67–80.

Hamada, T., Sale, D. G., & MacDougall, J. D. (2000). Postactivation potentiation in endurance-trained male athletes. *Medicine and Science in Sports and Exercise*, *32*(2), 403–411.

Hancock, A. P., Sparks, K. E., & Kullman, E. L. (2015). Postactivation potentiation enhances swim performance in collegiate swimmers. *Journal of Strength and Conditioning Research*, *29*(4), 912–917.

Linder, E. E., Prins, J. H., Murata, N. M., Derenne, C., Morgan, C. F., & Solomon, J. R. (2010). Effects of preload 4 repetition maximum on 100-m sprint times in collegiate women. *Journal of Strength and Conditioning Research*, *24*(5), 1184–1190.

Matthews, M. J., Matthews, H. P., & Snook, B. (2004). The acute effects of a resistance training warmup on sprint performance. *Research in Sports Medicine*, *12*(2), 151–159.

McBride, J. M., Nimphius, S., & Erickson, T. M. (2005). The acute effects of heavy-load squats and loaded countermovement jumps on sprint performance. *Journal of Strength and Conditioning Research*, *19*(4), 893–897.

Naclerio, F., Chapman, M., Larumbe-Zabala, E., Massey, B., Neil, A., & Triplett, T. N. (2015). Effects of three different conditioning activity volumes on the optimal recovery time for potentiation in college athletes. *Journal of Strength and Conditioning Research*, *29*(9), 2579–2585.

Pääsuke, M., Saapar, L., Ereline, J., Gapeyeva, H., Requena, B., & Ööpik, V. (2007). Postactivation potentiation of knee extensor muscles in power- and endurance-trained, and untrained women. *European Journal of Applied Physiology*, *101*(5), 577–585.

Rixon, K. P., Lamont, H. S., & Bemben, M. G. (2007). Influence of type of muscle contraction, gender, and lifting experience on postactivation potentiation performance. *Journal of Strength and Conditioning Research*, *21*(2), 500–505.

Robbins, D. W. (2005). Postactivation potentiation and its practical applicability: A brief review. *Journal of Strength and Conditioning Research*, *19*(2), 453–458.

Sale, D. G. (2002). Postactivation potentiation: Role in human performance. *Exercise and Sport Sciences Reviews*, *30*(3), 138–143.

Scott, S. L., & Docherty, D. (2004). Acute effects Of heavy preloading on vertical and horizontal jump performance. *Journal of Strength and Conditioning Research*, *18*(2), 201–205.

Tanaka, H., & Swensen, T. (1998). Impact of resistance training on endurance performance. A new form of cross-training? *Sports Medicine*, *25*(3), 191–200.

Tillin, N. A., & Bishop, D. (2009). Factors modulating post-activation potentiation and its effect on performance of subsequent explosive activities. *Sports Medicine*, *39*(2), 147–166.

Turner, A. P., Bellhouse, S., Kilduff, L. P., & Russell, M. (2015). Postactivation potentiation of sprint acceleration performance using plyometric exercise. *Journal of Strength and Conditioning Research*, *29*(2), 343–350.

Wilson, J. M., Duncan, N. M., Marin, P. J., Brown, L. E., Loenneke, J. P., Wilson, S. M. C., … Ugrinowitsch, C. (2013). Meta-analysis of postactivation potentiation and power: Effects of conditioning activity, volume, gender, rest periods, and training status. *Journal of Strength and Conditioning Research*, *27*(3), 854–859.

Wyland, T. P., Van Dorin, J. D., & Reyes, G. F. “Cisco.” (2015). Post-activation potentiation effects from accommodating resistance combined with heavy back squats on short sprint performance. *The Journal of Strength & Conditioning Research*, *29*(11), 3115-3123.

Yetter, M., & Moir, G. L. (2008). The acute effects of heavy back and front squats on speed during forty-meter sprint trials. *Journal of Strength and Conditioning Research*, *22*(1), 159–165.

Appendix A

Summary of the Literature

Authors and Year	Stimulus		Participants	Distance	Outcome (improve)
Bevan et al (2010)	BS	1x3 at 90%	16 pro rugby (M)	5-, 10m	5-8%
Duncan et al (2014)	BS	1x3 at 90%	10 pro rugby (M)	5-, 10-, 30m x 7	Sustain sprints
McBride et al (2005)	BS & LCMJ	1x3 at 90%	15 NCAA football (M)	10-, 20-, 40m	1.39%
Chatzopoulos et al (2007)	BS	10x1 at 90%	15 healthy males	10-, 30m	1-3%
Linder et al (2010)	BS	4RM	12 college females	100m	1.2%
Matthews et al (2004)	BS	5RM	20 pro rugby (M)	20m	3.3%
Yetter and Moir (2008)	BS & FS	Progressive increase	10 male athletes	40m x 3	2.3%
Byrne et al (2014)	DJ & DYN	3 DJs	29 male athletes	20m	2.2%

Note. BS means back squat, FS means front squat, LCMJ is lower countermovement jump, DJ is depth jump & DYN is dynamic warm-up

Appendix B

Medical History and Health Habit and 24-hour Recall Questionnaire

Name: _______________________

Age: _______

Weight: __________

Height: ___________

Sex: _______

1. Medical/Health History: Check if you ever had?

Heart Disease/ Stroke	
Heart Murmur	
Skipped, rapid beats, or irregular heart rhythms	
High Blood Pressure	
High Cholesterol	
Rheumatic Fever	
Lung Disease	
Diabetes	
Epilepsy	
Injuries to back, hips, knees, ankles or feet	

Other conditions/comments

Present Symptoms: Check within the box if you have you had these symptoms within the last 6 months?

Chest Pain	
Shortness of Breath	
Light Headedness	
Heart Palpitations	
Loss of Consciousness	
Illness, surgery, or hospitalization	
Ankle/Leg swelling	
Joint/muscle injury requiring medical treatment -ex) ACL, rower's knee	
Allergies (if yes please lift under comments)	

Other conditions/comments:

List all medications presently taking:

2. Exercise habits:

Do you presently engage in physical activity? (circle one)

Yes **No**

What kind of exercise do you do? (circle one)

Aerobic **Strength Training** **Both**

How hard do you exercise? (circle one)

Easy **Moderate (can carry on conversation)** **Hard (can't carry on conversation)**

How many times a day do your work out?

How many days a week do you work out?

Did you ever have or do you currently have discomfort, shortness of breath, or pain when exercising? (circle one)

Yes **No**

3. Have you consumed alcohol in the past 24 hours? (circle one)

Yes **No**

4. Have you used caffeine (e.g., coffee) or nicotine (e.g., cigarettes) in the last 3 hours? (circle one)

Yes **No**

5. Did you eat any food in the last 3 hours? (circle one)

Yes **No**

6. Did you exercise in the last 24 hours? (circle one)

Yes **No**

7. Have you ever torn your ACL (fully or partially)? (circle one)

Yes **No**

8. When was your last menstrual cycle? Are you menstruating now?

Appendix C

INFORMED CONSENT FORM

The Effectiveness of Back Squats and Depth Jumps on Eliciting Postactivation Potentiation

1. Purpose of the Study
   Our purpose is to examine the effects of heavy preload stimuli on subsequent 40-meter sprint trials.

2. Benefits of the Study
   For the subjects- You may benefit from participating in this study because you will learn what your one repetition maximum is for the squat lift (1RM) as well as identify your optimal depth jump start height. This information will be beneficial to have if you plan on continuing your lifting regimen after college graduation. You will also complete a 3-week supervised training program that will be beneficial for reconditioning your body for the spring season of crew team. All participants will see first hand how scientific data are collected and will greatly assist the graduate students who are conducting this study as they learn how to do scientific research. Your participation will also assist one graduate student in the collection of data for a thesis project. Lastly, it is hoped that your contributions will provide data that can be useful to not only the scientific community, but also athletes and coaches who could potentially use the findings in their pre-competition workouts.

3. What You Will Be Asked to Do
   The entire study including the 3-week training program is expected to take no more than 6 weeks. Participation requires you to be at least 18 years old and have at least two years of resistance training experience. This is because previous research has shown that the effects of postactivation potentiation are greater in those who are more resistance trained. Participants may not have any past or current orthopedic or musculoskeletal injury or pathology. At the first session you will be familiarized with the proper lifting techniques and have time to practice and feel comfortable performing the lifts and sprints. During this training time is when the 1RM of the squat and the optimal depth jump height will be found. Each testing session will begin with a warm up of jogging and dynamic stretching before moving on to the heavy lifting. The squat protocol will consist of a warm up of increasing weights until the muscles are warm enough to perform the 3 repetitions at 90% of the 1RM. Once these have been completed you, as the subject, will be expected to perform a 40-meter sprint at maximal effort. A second day of testing will begin with the same warm up, stretching and slow progression to optimal depth jump height. You will then perform three depth jumps and the 40-meter sprint.

4. Risks of Participation
   The risks associated with this study, the squatting, depth jumping and sprinting include musculoskeletal or orthopedic injury as well as a possible cardiac event which could be fatal, although for your age group this is very unlikely. Sore muscles are also a potential risk for 24 to 48 hours after each training or testing session. To minimize these risks a warm up and cool down will be included in every session and research technicians involved with data collection are either CPR or First Aid certified, with the some holding both. There will be plenty of research technicians present during data collection who are able to both assist you in the event of an injury as well as activate an emergency action plan to seek additional assistance if warranted.

5. Compensation for Injury
   If you suffer an injury that requires any treatment or hospitalization as a direct result of this study, the cost for such care will be charged to you. If you have insurance, you may bill your insurance company. You will be responsible to pay all costs not covered by your insurance. Ithaca College will not pay for any care, lost wages, or provide other financial compensation.

6. If You Would Like More Information about the Study
   If you would like more information about this study at any point prior to, during, or after data collection, you may contact Tom Swensen at tswensen@ithaca.edu or 607.274.3114 or Julie Landrigan at jlandrigan@ithaca.edu or 518.210.5150.

7. Withdraw from the Study
   Participation in this study is voluntary and you may withdraw at any time if you choose to do so. No penalty will be held against you.

8. How the Data will be Maintained in Confidence
   Information gathered during this study will be maintained in complete confidence. Only the researchers will have access to this information, which will be stored in a locked cabinet in room 320 in the Center for Health Sciences at Ithaca College or on password protected computer. You and your name will never be associated with this information in any future disclosures. To further insure confidentiality, all files will be number coded and data collection instruments will be kept separately from Informed Consent Forms and sign-up sheets.

I have read the above and I understand its contents. I agree to participate in the study. I acknowledge that I am 18 years of age or older.

____

Print or Type Name

____ ____________________

Signature Date

I give my permission to be videotaped.

____

Signature Date