KINETIC AND KINEMATIC ANALYSIS OF THE SQUAT WITH AND WITHOUT SUPPORTIVE EQUIPMENT

A Thesis
by
JARED WAYNE SKINNER

Submitted to the Graduate School
Appalachian State University
In partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE

May 2011
Department of Health, Leisure, and Exercise Science

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May 2011

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ABSTRACT

KINETIC AND KINEMATIC ANALYSIS OF THE SQUAT WITH AND WITHOUT SUPPORTIVE EQUIPMENT

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The most common type of supportive equipment utilized in powerlifting is the squat suit (SS). The SS has the same fit and relative design of a singlet used in weightlifting, composed of various materials that stretch and then contract during the lift to possibly aid in increasing force, power and velocity. However, no previous investigation has examined the effect of a SS on squat performance. Thus, the purpose of this investigation was to investigate various kinetic and kinematic variables associated with squats with and without supportive equipment (i.e. SS). Participants were eight elite or professional level male powerlifters (height = 178.59 + 3.5 cm; body mass = 106.8 + 30.4 kg; age = 25 + 2.2 yrs; mean 1RM =197.7+53kg) with a minimum of four years of resistance training and powerlifting experience and displayed competent technique in the squat utilizing a SS. Subjects participated in three testing sessions, with the first session involving a one repetition maximum squat (1RM) without a SS. Session two and three involved a testing session completing two trials in the squat at three intensities (80, 90 and 100% of 1RM) either with (WSS) or without the squat suit (NSS). The session and order of the intensities were all randomized. Subjects were instructed not to perform lower body exercise 72 hours prior to each testing session and each session was separated by 1 week. Force-time, velocity-time and power-time graphs and horizontal and vertical displacement of the barbell during each lift were generated from data collected from a force plate under the lifter's feet and two linear position transducers attached to the barbell. Peak force, velocity and power were calculated for both the eccentric and concentric phase of the lift. Vertical and horizontal displacement were utilized to graph the bar path for both conditions. Statistical significance was chosen at $p \leq 0.05$. RESULTS: There were no significant differences in peak concentric force during WSS in comparison to NSS at all intensities (80%, 90% and 100% of 1RM). However, peak eccentric force was significantly higher during WSS at 100% of 1RM (NSS = 3222+427N, WSS = 3375+559N). Peak concentric velocity was significantly higher during WSS in comparison to NSS all intensities. There was no significant difference in peak eccentric velocity and peak eccentric power between the WSS and NSS. However, peak concentric power was significantly higher during WSS at 80% of 1RM (NSS=1441+410W; SS=1795+513W) and 90% of 1RM (NSS=1380+382W; SS=1647+525W). Significant differences in vertical bar path displacement were observed between WSS and NSS at 80%, 90% and 100% of 1RM. During NSS there was significantly greater vertical displacement. In conclusion, the current investigation has demonstrated significantly different kinetic and kinematic characteristics between squats with and without the SS. The SS altered bar displacement during the lift and improved peak eccentric force, peak concentric velocity and peak concentric power that would ultimately aid in enhancing squat performance.

ACKNOWLEDGEMENTS

This thesis was completed through the support of the *Office of Student Research* Grant, the Graduate Senate Association Senate Research Grant, and Inzer Advance Designs. I would like to thank my committee members, Jeffrey McBride, a mentor and friend over the many years I have been here. You have pushed me to become a better researcher and student. You helped inspire me to continue my education in Biomechanics, for which I will always be grateful. I would like to thank my friend Travis Triplett, the strongest women I have ever met. You seemed to always have time for advising me in school and life. I would also thank Kevin Zwetsloot; without your tutelage this thesis would not be possible. I would like to give a special thanks to all those who helped in the neuromuscular lab on this project, mainly Kim Fairbrother, James Snyder and Justin Blatnik. I would like to thank Megan Bryanton for her love and support and helping me through this year. Lastly, I would like to thank my family: Mom, Dad, Kyla and Mawmaw, whose support and love has and will continue to guide me through life.

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INTRODUCTION

The squat movement requires both lower body and trunk strength and is used in training programs of various types of athletes [1]. It also has been identified as an integral component of competitive Weightlifting and Powerlifting [2]. The sport of powerlifting, in particular, often involves the use of supportive equipment, the most common being a squat suit (SS). The SS has the same fit and design of a singlet used in weightlifting, composed of various materials that stretch and constrict during the movement to possibly aid in lifting more weight. However, no scientific data exists to substantiate this claim. Theoretically, the SS material stretches and stores elastic energy during the eccentric phase of the lift. The elastic energy may then be released during the concentric phase enhancing the ability to lift heavier weight via increasing force, velocity and power. In addition, due to the constrictive nature of the SS it is possible that the kinematics of the lift may be altered as reflected in varying bar paths.

Most activities of daily living require the coordinated contraction of several muscle groups at once, and squatting (a multi-joint movement) is one of the few strength training exercises that is able to effectively recruit multiple muscle groups in a single movement [3]. The lifter stands in an erect position with the feet usually placed shoulder-width apart. At the start of the lift the lifter will flex at the hip, knee and ankle while keeping his or her trunk erect, beginning the eccentric portion of the lift where the bar and the lifter will descend to where the top of the thigh becomes parallel with the floor. At this point the exercise becomes increasingly difficult due to the different lever systems involved in the movement pattern [1]. The knee and hips are considered third class levers, meaning that the resistance arm is greater than the moment arm and there is limited mechanical advantage during different phases of the movement [4]. When the desired depth is achieved the lifter will reverse the direction and begin ascending upward to their initial position. Mitetello et al. examined the kinematic variables between collegiate powerlifters, high school powerlifters and novice powerlifters and determined variation in concentric acceleration rates between the three groups during various points in the lift. Specifically, the data indicated that the more experienced powerlifters, who lifted more weight, achieved higher velocities in the concentric phase when compared to the novice and high school lifters [1]. The data suggest that if supportive equipment, such as the SS, could increase concentric velocity then this may increase the amount of weight lifted as well. While no investigations have looked specifically at the SS some studies have examined the effect of compression garments, such as shorts, on jumping performance. One investigation determined that with the use of a custom fitted compression garment increased power in the vertical jump. In addition, skin temperature increased at a faster rate during the warm-up protocol and increased flexion and torque rates during sprints and resulted in a reduction of impact forces by 27% in comparison to traditional athletic wear [5]. Another study suggests performance enhancement when wearing compression garments during simulated sporting events such as netball [6]. While the SS and compression garments are not the same they both consist of some similar characteristics allowing for speculation as to the benefit of a SS on squat performance. Considering the complexity of the squat and the number of muscles and joints it encompasses, understanding the biomechanics of the movement is necessary to optimize exercise and sport performance [2]. The squat exercise encompasses the ankle, knee, hips joints and spine. The squat is considered to be a closed kinetic chain (CKC) exercise [7]; meaning during the squat the load applied during the movement is on the body; however the force generated is applied to the ground, not the bar. Dependent of the load, the spine can be placed under an excessive amount of compression force. Research suggest that the absolute angle of the spine increased a nonsignificant six degrees from when subjects lifted a load up to 32% of their one repetition maximum [8]. However, when using a weight between 40–70% 1RM, a significant 16 degrees increase in forward inclination was noted [2]. These results were found performing squats without the use of a SS. Thus, the use of a SS may alter the amount of spine angle change or forward inclination to influence bar path as well possible influencing force, velocity and power. There has been no research performed on bar path during the squat while using a SS, however, a recent study examined bar path during a bench press in novice and elite lifters using a bench press shirt [9]. Difference in bar path between a bench press with and without a bench press shirt indicated that the bench press shirt created a more efficient movement pattern by minimizing horizontal displacement [9]. Fry et al. examined joint kinetics occurring when forward displacement of the knees is restricted vs. when such movement is not restricted in the squat. The results suggest that when performing a restricted squat where the knees are not permitted to move anteriorly past the toes, greater torque is generated at the hips and less torque at the knees than when performing an unrestricted squat in recreationally weight-trained men [10]. This may indicate that when using a SS, which might restrict motion, it would possibly influence the use of additional hip musculature thereby increasing force, velocity and power. A study examining national level powerlifters in comparison to recreationally trained lifters indicated that powerlifters moved their knees anteriorly to a lesser degree and generated more knee extensor torque [11]. Thus, restricted anterior motion of the knee, possibly as a result of utilizing a SS, might increase the generation of both knee and hip torque [12]. Decreased anterior motion of the knee would most likely be reflected by a increase in forward horizontal bar displacement. Based on previous investigations it appears that garment compression, such as that created by a SS, might increase performance characteristics of a given movement pattern. In addition, changes in bar path as a result of using a SS, might indicate changes in body or knee position which might allow for increased torque production around the knees and hips. As a result all of these factors might be represented by differences in eccentric or concentric levels of force, velocity or power. Therefore, the purpose of this investigation was to examine the effect of squatting with a SS on various kinetic and kinematic parameters.

METHODS

Subjects

Eight elite or professional level male powerlifters who displayed competent technique in utilizing a SS and a minimum of 4 years of resistance training and powerlifting experience were utilized for this investigation. The subjects had a mean height of 178.59 ± 3.5 cm, a mean mass of 106.85 ± 30.4 kg, a mean age of 25 ± 2.2 years, and a mean 1RM squat of 197.7 ± 53 kg. Recruitment of subjects was limited to those who have had no prior injury or surgery of any kind within the last year. The participants were notified about the potential risks involved and given the opportunity to provide their written informed consent, approved by the Institutional Review Board at Appalachian State University.

Study Design

The testing was divided into three sessions, each session separated by at least one week. Participants were asked not to perform any lower body activity 72 hours pre-and post-testing to ensure minimal fatigue and adequate recovery between the multiple sessions. During session one, maximal strength was assessed through 1RM testing in the squat without the use of a squat suit. Session two and three were performed in a randomized order and involved performing two trials of a squat at 80%, 90% and 100% of 1RM either with (WSS) or without (NSS) a squat suit.

Maximal Strength Testing

A squat one repetition maximum (1RM) was assessed after an appropriate warm-up protocol. The warm-up protocol [13] will consist of multiple repetitions at loads equal to 30% (8-10 repetitions), 50% (4-6 repetitions), 70% (2-4 repetitions), and 90% (1 repetition) of the subject's estimated 1RM. During all attempts, subjects will be required to lower the bar to a point where the knee angle was 70° as measured by a goniometer. To ensure all squat attempts were performed to the same depth an adjustable box was placed at the level of the buttocks for each subject that was used for visual instruction in determining depth. Subjects were given up to four maximal attempts to achieve a 1RM. Subjects foot placement, bar position and rack height were recorded and used for the remaining testing sessions until the subject completed the study. It is important to note, that the subjects were instructed to perform the 1RM testing in the same style of foot placement and bar position as with if they were squatting in the SS. Rest periods of five minutes were allowed between trials. The maximal load successfully lifted was selected and used to determine the percentages for all subsequent testing sessions

Squat Performance Protocol

Session two and three involved, in a randomized order, squatting either with (WSS) or without (NSS) a squat suit. Two repetitions with five minutes of rest between each repetition were recorded for trials utilizing 80%, 90% and 100% of 1RM also in a randomized fashion. Each participant used a suit that was tailored to fit the subject by Advanced Inzer Design, Inc. (Longview, Texas) based on the subjects height and measurement of the waist, hip, chest and upper thigh. The suits utilized in testing were composed of two layers of canvas and two layers of polyester side panels.

Kinetic and Kinematic Data Collection & Analysis

All testing was performed with the subjects standing on a force plate (AMTI BP6001200; Watertown, MA) with the left and right side of the barbell attached to two linear position transducers (LPT) (Celesco PT5A-150; Chatsworth, CA). The data from the right side of the bar was used for analysis. Analog signals from the force place and two LPTs were collected for every trial at 1,000 Hz using a BNC-2010 interface box with an analog-to-digital card (National Instruments, NI PCI-6014, Austin, TX, USA). LabVIEW (National Instruments, Version 8.2, Austin, TX, USA) was used for recording and analyzing the data. Signals from the two LPTs and the force plate as well as data derived using double differentiation underwent rectangular smoothing with a moving average half-width of twelve. From laboratory calibrations, the LPTs and force plate voltage outputs was converted into displacement and vertical ground reaction force, respectively. Kinetic and kinematic variables were derived from displacement data through double differentiation processes. Bar displacement was measured using one of the three LPTs mounted directly above the subject on a custom power rack. The LPT produced a voltage signal representative of the degree at which the LPT was extended allowing for displacement–time data to be calculated [14] [15]. Subjects were fitted with an inline mechanical goniometer sensor (NORAXON U.S.A. Inc. Scottsdale, Arizona USA), to ensure that the appropriate knee angle was achieved during the various trials. The goniometer produced voltage outputs that were converted into knee angles found by a creating regression equation. If the squat did not meet the selected criteria for the trial, then it was discarded out and another squat was performed. The force plate methodology has been extensively examined throughout the literature to evaluate force and power produced during dynamic movements such as the squat [16].

Average Curve Analysis

Average curve analysis has been used previously to express performance during resistance exercise. Using a custom designed Lab VIEW program, this analysis technique permits the expression of all individual variable-time curves into 1 representative average variable-time curve. Typically, variable-time curves from different subjects cannot be added together and averaged because the time it takes each subject to complete the exercise in absolute time is different. However, through a resampling procedure that interpolates 501 samples of data from each of the original variable-time curves, all subjects' resampled variable-time curves can be expressed on the same relative time scale (0-100% normalized time). Subsequently, because all individual variable-time curves were on the same relative time scale, they can be added together and averaged to produce a single average curve for that group of subjects. In the current investigation, average curves were developed for the two squat conditions (WSS and NSS) for bar path.

Statistical Analyses

Descriptive data was summarized as mean+SD. Differences between kinetic and kinematic variables were determined through repeated measures two way ANOVA. A Post Hoc was used to reduce the chance of making a Type I error. The criterion alpha level for all statistics was set at $P \leq .05$. All statistical analyses was completed using a statistical software package (SPSS Version 17.0, SPSS Inc., Chicago, Illinois, USA).

RESULTS

Results indicate that peak concentric forces are similar between the squats with and without supportive equipment at all intensities. However, during the 100% trial, eccentric force was significantly higher with the SS (NSS = 3222+427N, SS = 3375+559N). Concentric velocity was significantly higher during squats at all intensities with the SS, when compared to NSS. There was no difference in eccentric velocity and power between the SS and NSS. However, concentric power was significantly higher with the SS during the 80% (NSS=1441+410W, SS=1795+513W) and 90% (NSS=1380+382W, SS=1647+525W) trials. Average curve analysis determined there was not a significant difference in horizontal displacement, but there was a significant difference in vertical displacement at all intensities.

DISSCUSSION

The primary findings in the investigation indicate squats with the SS elicits higher velocity and power during the concentric portion of the exercise as shown in Figure 5 and 6. There are currently no investigations that have reported on the biomechanical implications of using squat suit, examining the differences in peak force, velocity, power and bar path. It is theorized that this is due to the suits ability to store elastic energy during the eccentric phase of the squat and the release it in the concentric phase. The same effects are observed with squats that utilize the stretch shortening cycle [17]. The SS allows is designed to maintain a higher power output at lower intensities when compared to the squats without the suit. Previous research has shown that vertical velocity in squats has a direct relationship on the amount of muscle force exerted on the bar and vertical bar velocity was indicative of subject technique and therefore was considered the most meaningful parameter regarding performance [1]. The results indicate the SS allowed for a higher velocity at all intensities compared to the NSS condition. These results coincide with past research [11] as well as the initial hypothesis, that the suit would enhance these variables.

Although there was a difference in peak concentric force within the two conditions, there was no significance between the two conditions. This is surprising given the fact that most competitive powerlifters are able to increase their 1RM with the SS. It should be noted that the loads utilized in this investigation are typically lower than those used while training in the squat suit. Although not reported, greater absolute loads would likely result in altered kinetic and kinematic variables. Further study would be necessary to determine the role of different relative loads on the kinetic and kinematic variables measured. The increase in eccentric force could be due to the nature of the squat with the SS. During the eccentric phase, the lifter abducts the knees and allows the material of the suit to maximally stretch and build up this elastic energy, which explains the increase in concentric velocity and power. Previous literature has shown that the greatest amount of eccentric force during a jump is at the bottom or ammotorization phase of the movement [18]. The added force in the WSS group is due to the muscles of the thigh contracting and reversing the motion of the lift, as well as the force provided from the suit. These results suggest it is possible that the ability to lift a heavier load is more dependent on increasing velocity rather than force.

Another finding in the investigation indicates that there was no significant difference in horizontal displacement; however vertical displacement was significantly different between the SS and NSS. There was a greater vertical displacement in bar path during the NSS trials compared to the SS trial. It is important to note that subjects achieved the same depth between the two conditions and that most powerlifters will utilize a low bar positions and this could have had implications on the kinetic and kinematic variables examined. Wretenberg et al. examined at the differences associated with high and low bar squatters in powerlifters and weightlifters. Their results determined that powerlifters who utilized the low bar position put relatively more load on the hip joint, where as the weightlifters had the load disturbed equally between the hip and the knee. Another explanation as to why there was significantly more displacement in the NSS group was the suit allowed the lifters to remain more upright during the squat relative to their hip position. A posterior shift in the hips at the bottom of the squat would cause excess vertical displacement and a decrease in performance [19]. Although both groups both had a forward inclination in bar path in the eccentric phase, it is speculated that there was a forward inclination of the knee in the NSS group and was a determining factor in the squat kinematics. In Figures 1 and 3, the concentric phase of the squat was different in the WSS compared to the NSS. This trend follows the initial thought that that SS did allow the lifter to maintain their trunk in a more upright position. McLaughlin et al. found similar results when examining highly trained powerlifter: they found that trunk, hip and knee horizontal displacements were greater in the less skilled group and could elicit a decrease in performance [11]. This suggests that the SS helps to minimize these variables and help increase squatting performance. These results may not be typical when using novice lifters or powerlifters that compete without the use of the squat suit in training and competition. Further study would be necessary to determine the role of relative experience lifters had on the kinetic and kinematic variables measured. Although not reported in the current investigation, the material and structure of the suit could have implications on the different kinetic and kinematic variables. This being the first investigation comparing the different variables of the squat exercise with and without the use of the SS, future research will help to best delineate how to use the SS during the course of an athlete's training program and competition, in order to maximize performance.

PRACTICAL APPLICATIONS

The most appropriate application of the SS would be used in the sport of equipped powerlifting. The increase in kinetic variables does suggest that there is an increase in the potential to lift heavier weight when using the SS. From this investigation one can assume that the ability to lift a heavier load is more dependent on increasing velocity rather than force. Training maximal strength compared to velocity has long been debated in the lifting community since the beginning of the sport. This investigation may prove as a resource for lifters trying to increase their competitive squat. Training velocity and power in the SS may be more beneficial in increasing the amount of weight lifted in competition then training with higher loads. It is unclear whether incorporating the SS into training would positively augment raw strength since there is no data reporting on training implications with the SS. However it is important to note, the suits that were under investigation are designed for high-level experienced lifters and should always practice safe lifting technique and practice while training to reduce the risk of injury.

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Table 1: *Subject Anthropometrics and Strength Measurements* (Mean +SD)

	Males n =8
Age, years	25.1+2.2
Height, cm	178.59+3.5
Body Mass, kg	106.8+ 30.4
Squat 1 RM (NSS), kg	197.7+53

Table 1: Subjects Mean± SD anthropometric and strength measurements.

Table 2: *Peak Values (NSS) and (WSS)*

NSS	80%	90%	100%
Peak Eccentric Force, N	2974.68±413	3066.87±430	3222.84±430
Peak Concentric Force, N	3458.936±477	3621.82±470	3759.59±430
Peak Eccentric Velocity, m/s	.05±.01	.03±.01	.03±.01
Peak Concentric Velocity, m/s	.49±.11	.46±.1	.38±.12
Peak Eccentric Power, W	64.79±46.23	52.01±23.3	3.51±26.78
Peak Concentric Power, W	1441.37±337	1380.52±362	1252.69±420

WSS	80%	90%	100%
Peak Eccentric Force, N	3044.61±580	3140.44±573	3375.96±535
Peak Concentric Force, N	3600.91±590	3756.08±583	3813.34±462
Peak Eccentric Velocity, m/s	.035±.01	.035±.02	.033±.01
Peak Concentric Velocity, m/s	.59±.13	.53±.15	.44±.13
Peak Eccentric Power, W	67.13±31	57.11±40	63.12±39
Peak Concentric Power, W	1795.73±490	1647.81±519	1374.27±351

Table 2: Peak+SD Force, Velocity and Power values.

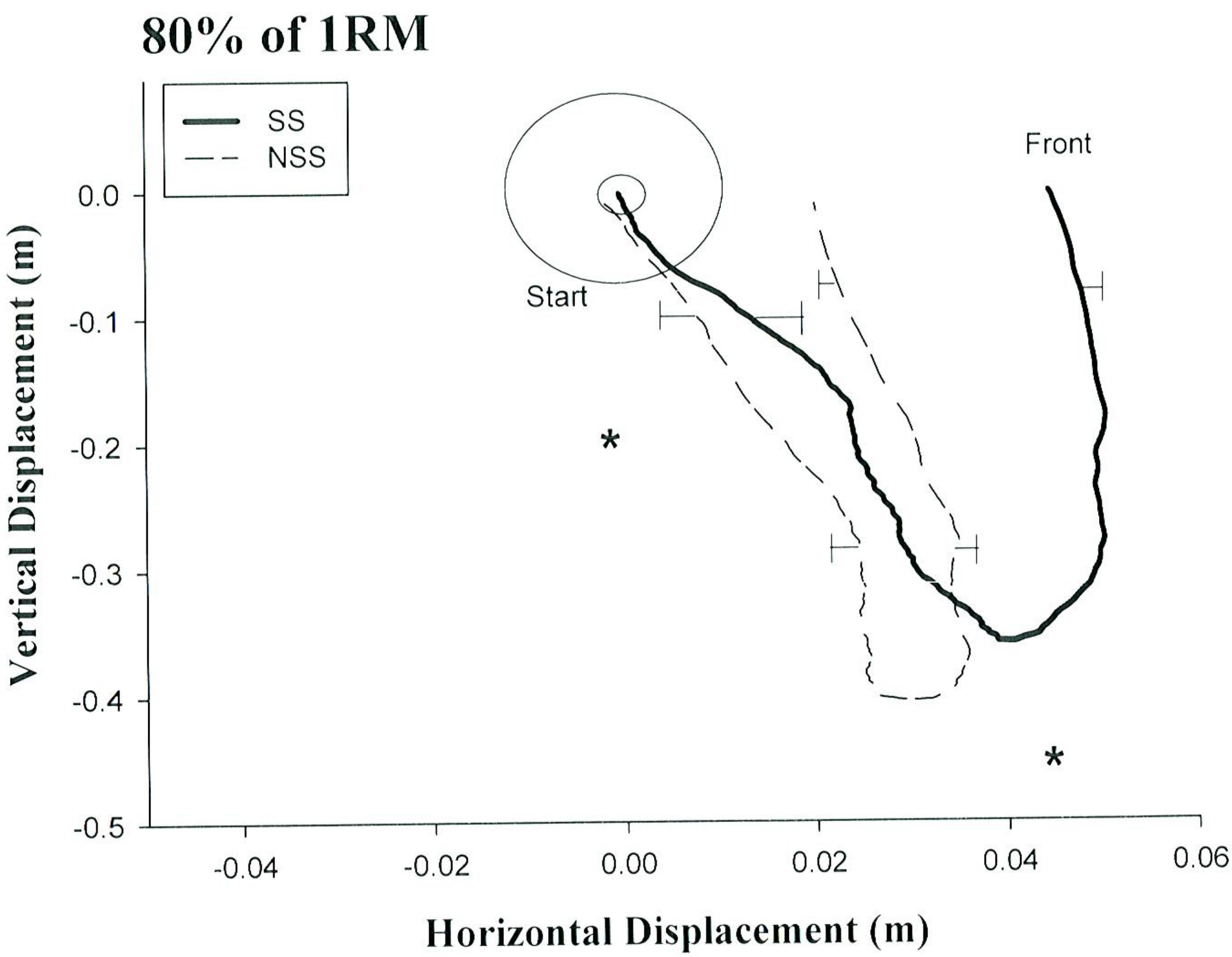

Figure 1. Average bar path with SS vs. NSS at 80% of 1RM. *Significant difference ($p \leq .05$) between SS and NSS in vertical displacement.

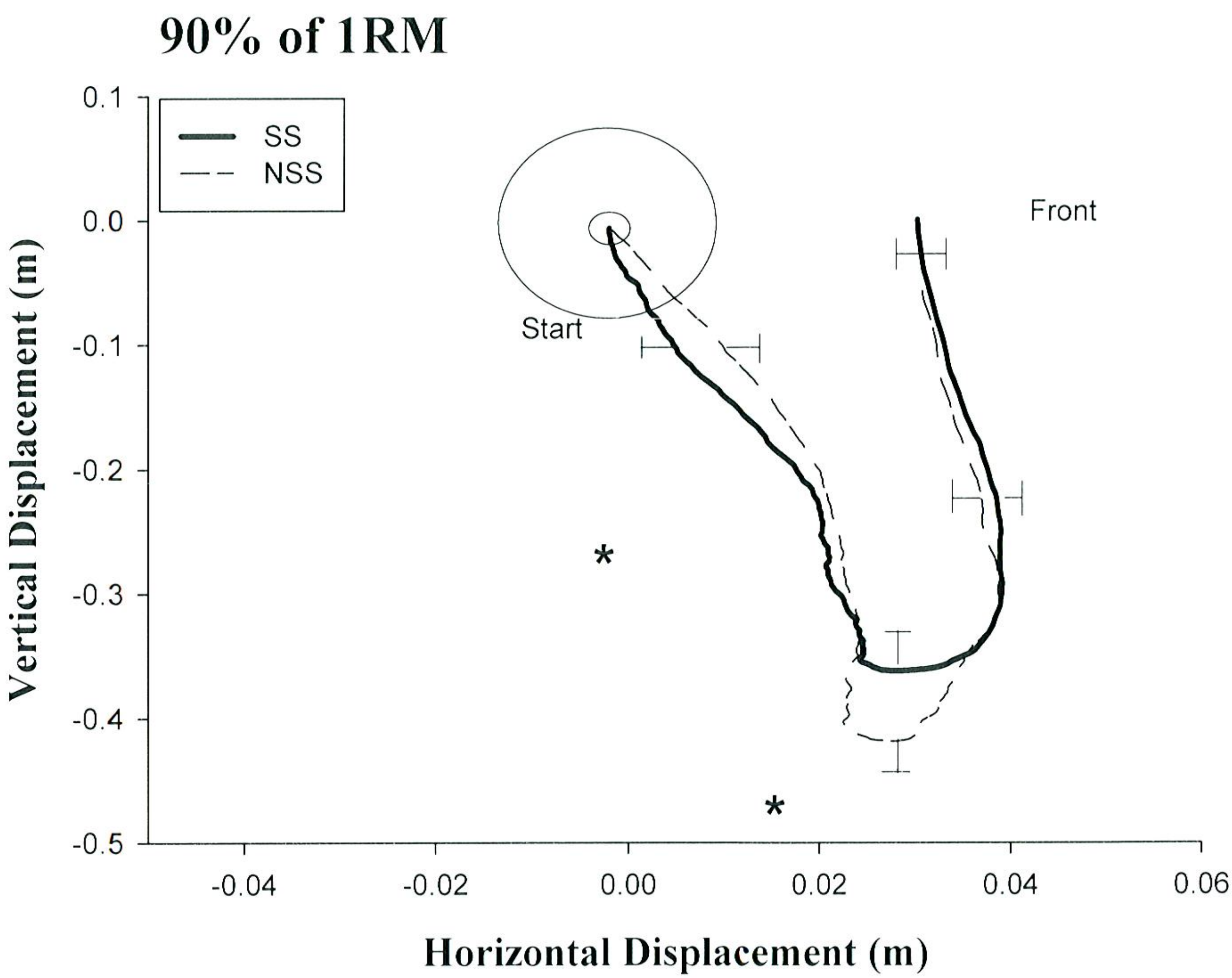

Figure 2. Average bar path with SS vs. NSS at 90% of 1RM. *Significant difference (p.≤.05) between SS and NSS in vertical displacement.

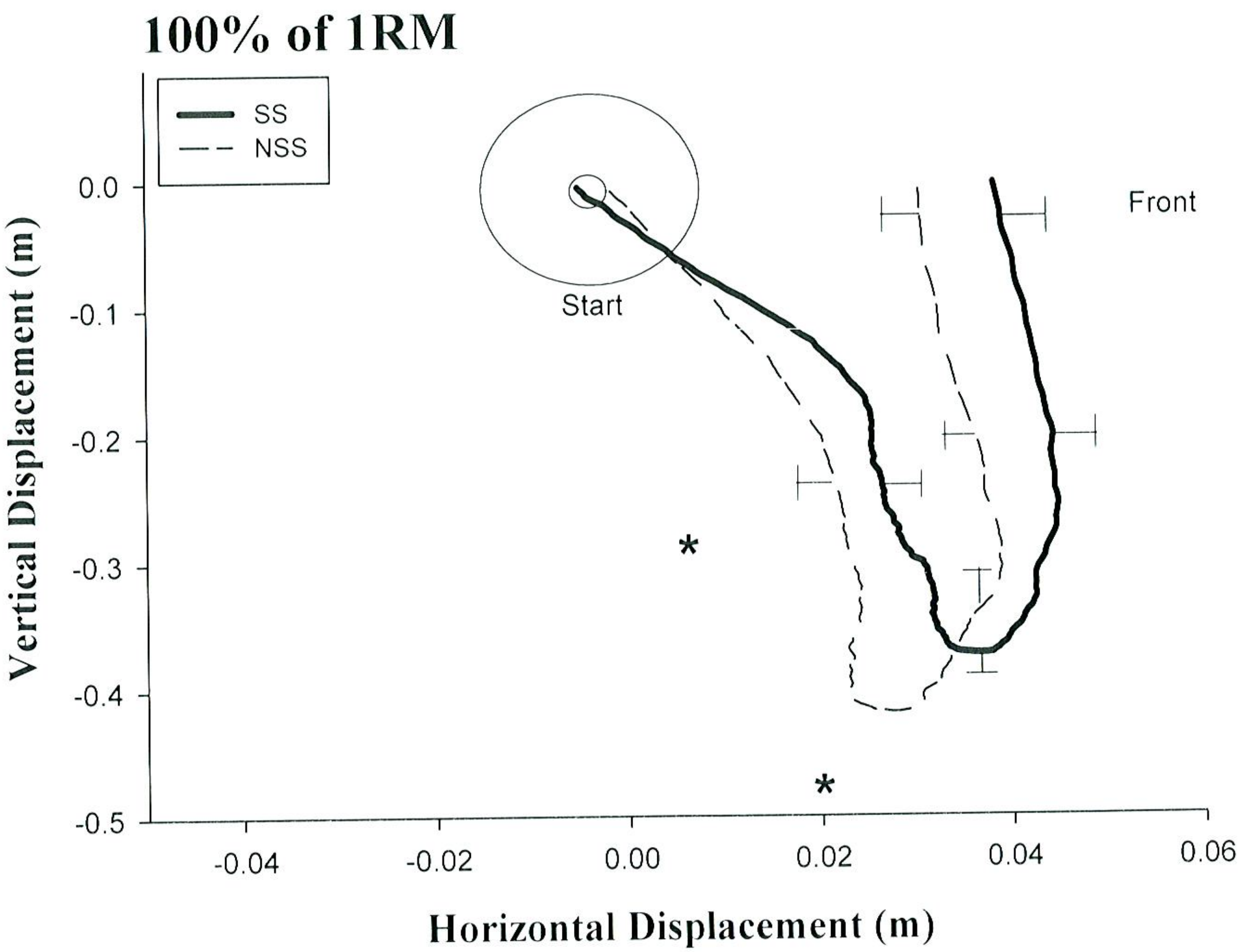

Figure 3. Average bar path with SS vs. NSS at 100% of 1RM. *Significant difference ($p \leq .05$) between SS and NSS in vertical displacement.

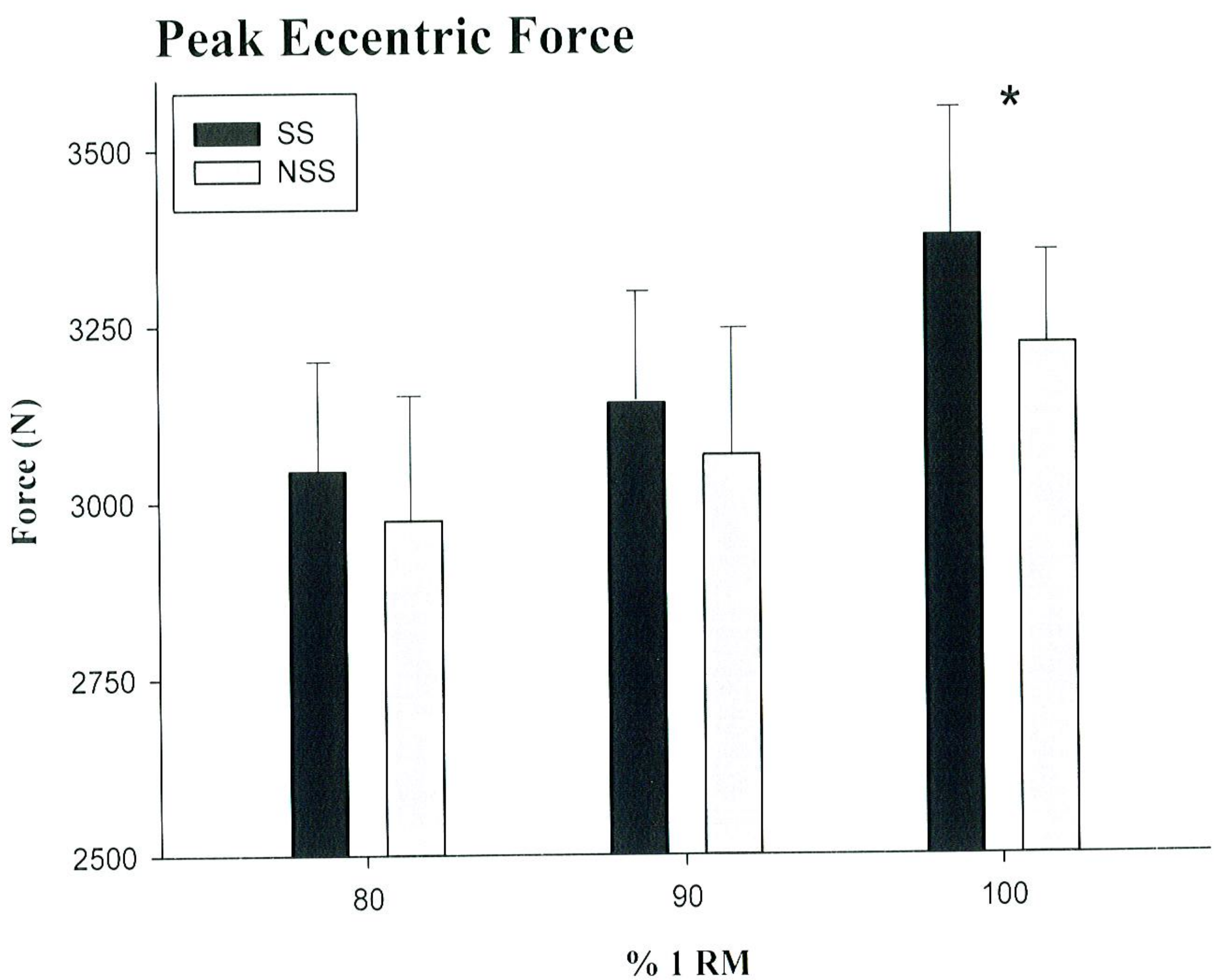

Figure 4. Differences in peak eccentric force between SS and NSS. *Significant difference (p.≤.05) between SS and NSS.

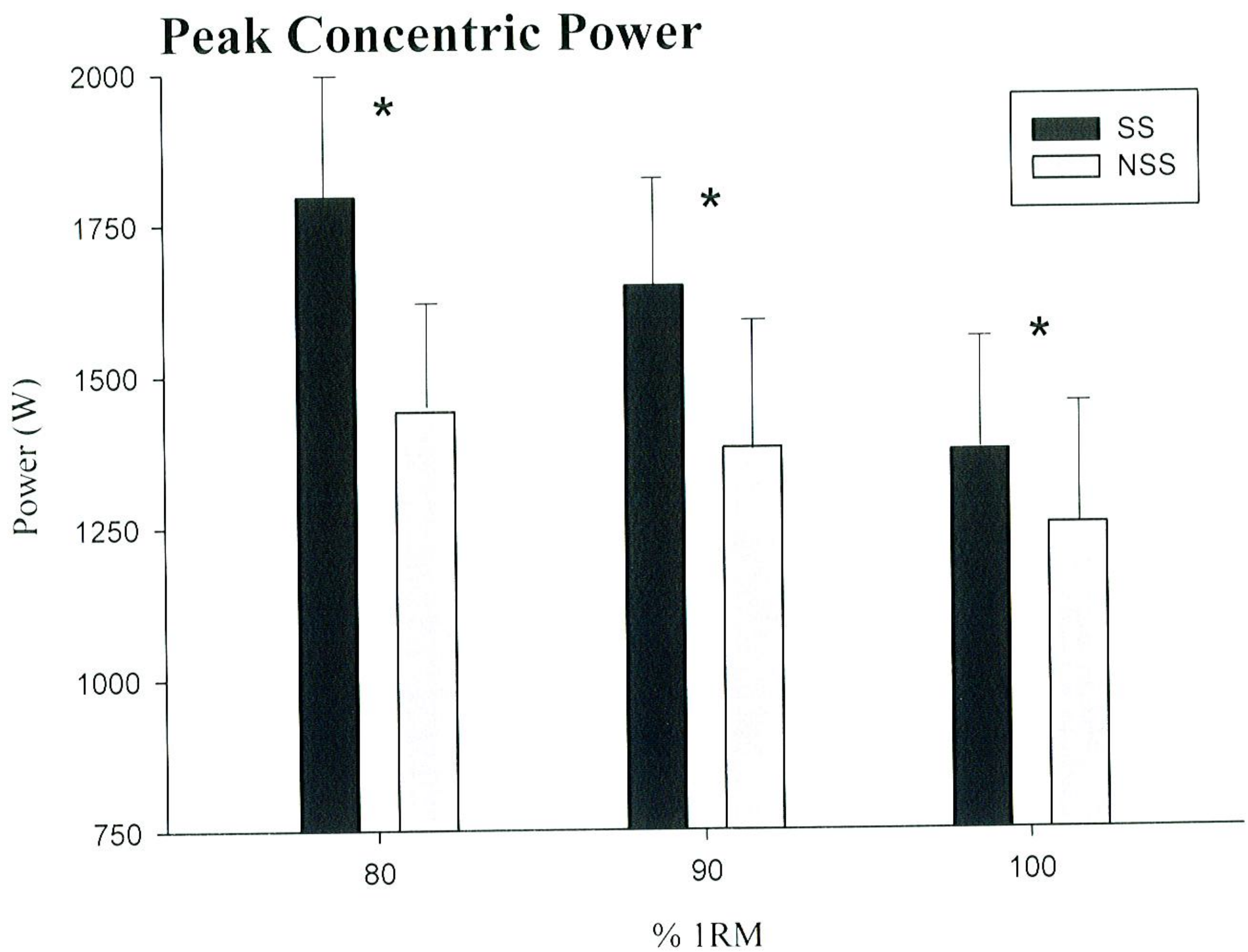

Figure 5. Differences in peak concentric power between SS and NSS. *Significant difference (p.≤.05) between SS and NSS. **Significant difference (p.≤.05) between trials.

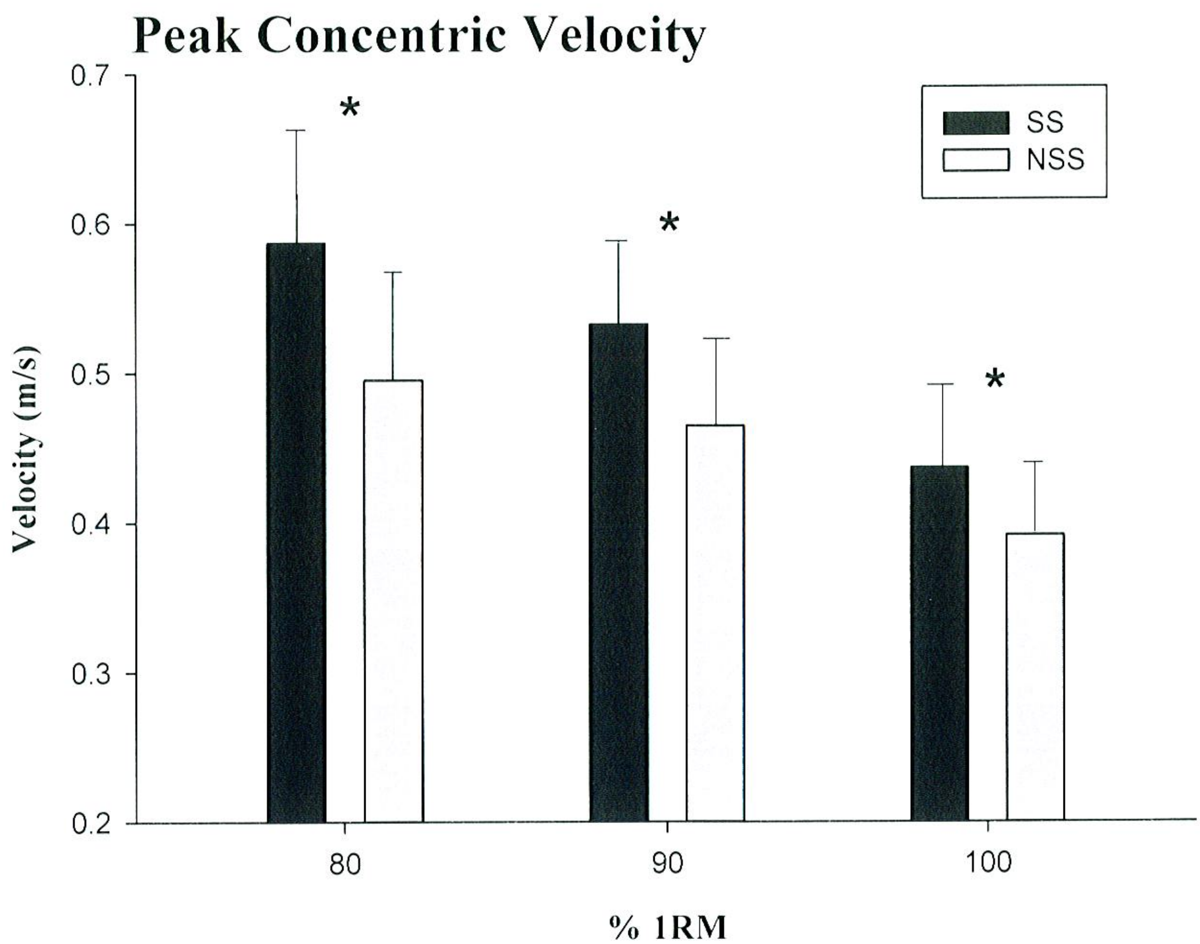

Figure 6. Differences in peak concentric velocity between SS and NSS. *Significant difference (p.≤.05) between SS and NSS. **Significant difference (p.≤.05) between trials.

APPENDIX A

Institutional Review Board Documentation

APPALACHIAN STATE UNIVERSITY

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REQUEST FOR REVIEW OF HUMAN PARTICIPANTS RESEARCH

Please complete and send the form electronically to irb@appstate.edu. The first page with signatures must be submitted to IRB, Research & Graduate Studies, John E. Thomas Building.

1. Date: 08 / 03 /2010

2. Project Title: Evaluation of Maximal Squat Strength and Power in Trained Males using Supportive Equipment

3. Principal Investigator(s): Jared Skinner

4. Phone: 704-221-1635 Email: JS69732@appstate.edu

5. Academic Department/Unit: Health, Leisure, and Exercise Science

6. ASU Status: Faculty/Staff______ Graduate Student __X___ Undergraduate Student Other__

7. If student, name of faculty mentor: Jeffrey M. McBride

8. Faculty mentor's e-mail address: mcbridejm@appstate.edu Phone: 828-264-2571

9. This is: Honors or Master's Thesis __X___ Capstone or Project of Learning Dissertation ___

Faculty Research _____ Other ____________________

10. Project Support: __X_____ Non-Sponsored ___________ Sponsored: Sponsor___________ Proposal # ________________ Pending ________ Funded _____

11. Plan to publish or present off-campus: Yes __X___ No_____________

12. Projected data collection dates: 08 / 23 / 2010 to 10 / 31 /2010

13. Does this research involve any out-of-country travel? Yes _____ No___X_____

Proposals cannot be considered until the researchers have completed the online CITI Training (http://www.citiprogram.org/default.asp?language=english) required for human subject research.

I have read Appalachian State University's Policy and Procedures on Human Subjects Research and agree to abide them. I also agree to report any significant and relevant changes in procedures and instruments as they relate to participants to the Chairperson of the Institutional Review Board.

__Jared Skinner____	_08/03/2010_	__Kim Fairbrother_	__08/03/2010_
PI	Date	Co-investigator	Date
_Jeffrey M. McBride	_08/03/2010_	__N. Travis Triplett	__08/03/2010_
If PI is student, Faculty Mentor	Date	Co-investigator	Date

CHECKLIST FOR RESEARCH INVOLVING HUMAN PARTICIPANTS

1. **Purpose of proposed research:**

This investigation attempts to fill the gap in the literature, examining the powerlifting suit and its applications. This is the first investigation of its kind. There is no evidence as to how much the suit assist the lifter during the squat and how it affects the mechanics of the squat. Therefore, the purpose of this study is to compare muscle activity, peak force, and maximal Strength in equipped squats to unequipped squats in trained athletes and how it could ultimately improve performance.

2. **Briefly describe your subject population. Will any individuals be excluded solely on the basis of gender, race, color, or any other demographic characteristic? If so, please explain.**

Subjects will include 10 resistance-trained athletes between the ages of 18 and 30. Subjects will have at least 3 years of experience performing the back squat exercise and have no prior injuries within the last year. Subjects will be recruited primarily through local and regional strength and conditioning facilities and will not be excluded solely on the basis of race, color, or any other demographic characteristic. Women will not be involved in the study in order to maintain a homogeneous subject population and to avoid hormonal influences of the menstrual cycle on exercise and recovery. We will only include the first 10 responses from recruitment for the study; all other responses will be notified that their participation will not be needed.

3. **Give a brief description of your research procedures as they relate to the use of human participants. This description should include, at least, the following:**

Participants in this investigation will visit the Holmes Convocation Center's Neuromuscular Laboratory for three testing sessions. Subjects will be asked to refrain from performing any type of resistance exercise or strenuous activity 48 hours prior to each of the three testing sessions. All testing sessions will be preceded by a brief bicycle ergometer warm-up. The first testing session for all subjects will consist of collecting anthropometric measurements, as well as a one repetition maximum (1RM) in the squat; this session will last 30 minutes. The second testing session will be randomized and involve the subjects performing squats using 80, 90 and 100% of their raw 1RM using supportive equipment or not. The second testing session will last 90 minutes. The third session will consist of the subject performing the remaining portion of 80, 90 and 100% of their raw 1RM using supportive equipment or not. During all repetitions the downward portion of the lift will be performed using a three second tempo. A one second tempo will be used for the upward portion of the lift. All squats will be performed on a force plate using a Texas squat barbell attached to two linear position transducers (LPTs) for measurement of force, power, velocity and bar path during the lift. Additionally, muscle activity will be monitored through electromyography (EMG) for all squats for the vastus lateralis (VL), vastus medialis (VM), and biceps femoris (BF). There is no privacy needed for the preparation and placement of EMG. During all testing sessions, a certified strength and conditioning specialist will be present to ensure proper lifting technique and safety.

Equipment to be used:

Force Plate (AMTI)
Linear Position Transducers (Celesco Transducer Products)
Noraxon TeleMyo 2440T G2 Electromyography
Custom programs designed using LabVIEW (Version 8.2, National Instruments)

4. Is deception involved? YES _____ NO __X___

If yes, please describe.

Subjects will be informed of their individual strength and power levels and have access to a complete analysis of their squat technique. Subjects will learn the benefits of various squatting techniques and how it can increase overall leg strength. Subjects will be informed of how their participation increases the body of knowledge in exercise science for athletic and general populations.

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

YES_____ NO__X___

If yes, please explain.

6. **The benefits of this activity to the participants must outweigh the potential risks. To this end, please:**

a. Describe the benefits to the individual participants and to society.

Subjects will be informed of their individual strength and power levels and have access to a complete analysis of their squat technique. Subjects will learn the benefits of various squatting techniques and how it can increase overall leg strength. Subjects will be informed of how their participation increases the body of knowledge in exercise science for athletic and general populations.

b. **Describe the potential risks to any individual participating in this project. Please explain any possible risks of psychological, legal, physical, or social harm. What provisions have been made to insure that appropriate facilities and professional attention necessary for the health and safety of the participants are available and will be utilized?**

There are no inherent risks involved with this investigation except for the potential of muscle pulls or strains associated with the testing common to any type of physical activity. Preparation for electromyography may result in some minor skin irritation and/or discomfort. The spot for EMG placement will require hair to be removed by shaving, the area will also need to be cleaned and sterilized by rubbing a small piece of sand paper across the area to remove dirt and debris and then rubbing an alcohol swap over the area after. Testing will be monitored by qualified personnel (Certified Strength and Conditioning Specialist) with first aid and CPR certification. All procedures for the physical performances tests are previously published and are outlined in the standards for the field of Strength and Conditioning as supported by the National Strength and Conditioning Association.

7. **Please describe how participants will be informed of their rights and how informed consent will be obtained and documented. Attach a copy of the consent form and any materials used in the recruitment of participants.**

The study will be thoroughly explained to the subjects by the investigators and the subjects will be given the opportunity to demonstrate their clear understanding of their involvement in the investigation and to ask questions. A copy of the consent form will then be reviewed with each subject and once voluntary consent is given through a signature, the forms will be kept in a locked file cabinet in the Neuromuscular Laboratory.

8. **The confidentiality of all participants must be maintained. To this end, please respond to the following.**

a. **How will the confidentiality of participants be maintained?**

Subject identity will not be disclosed in any published documents or shared with anyone but the experimenters. All information collected will be kept confidential and disguised so that no personal identification can be made and all experimental data will be identified by number only. Confidentiality of all subjects will be maintained by keeping subject files under lock and key. Individual data will not be reported in results of final publication.

b. **How will confidentiality of data be maintained?**

All data analysis and results will be conducted/maintained using identification numbers and all subject data files will be locked in the Neuromuscular Laboratory until all final dissemination of the data, after which subject files will be destroyed.

c. **Describe the process of final disposition of the data. How long will the data be stored and how will they be destroyed?**

Data will be analyzed and be presented and reported in manuscript format and submitted to a peer-reviewed journal for publication. Papers will be shredded and data files deleted after 5 years.

d. **How are participants protected from the future harmful use of the data collected in this protocol?**

Study results will be kept confidential and disguised so that no personal identification can be made. Subjects will be protected by avoiding the use of personal names and/or photographs (unless consent is given) and also through the use of identification numbers.

Appalachian State University

Informed Consent for Participants

Title of Project: Evaluation of Maximal Squat Strength and Power in Trained Males using Supportive Equipment

Primary Investigator: Jared Skinner

Faculty Advisor: Jeffery M. McBride

I. Purpose of this Research/Project

Many sports rely on training for maximal leg strength to increase athletic performance. This investigation attempts to fill the gap in the literature, examining the powerlifting suit and its applications. This is the first investigation of its kind. There is no evidence as to how much the suit assist the lifter during the squat and how it affects the mechanics of the squat. Therefore, the purpose of this study is to compare muscle activity, peak force, and maximal Strength in equipped squats to unequipped squats in trained athletes and how it could ultimately improve performance.

II. Procedures

Participants in this investigation will visit the Holmes Convocation Center's Neuromuscular Laboratory for two testing sessions. Subjects will be asked to refrain from performing any type of resistance exercise or strenuous activity 48 hours prior to each of the two testing sessions. All testing sessions will be preceded by a brief bicycle ergometer and perform 0 to 75% of 1 RM squat for a warm-up. The first testing session for all subjects will consist of collecting anthropometric measurements, as well as a one repetition maximum (1RM) in the squat; this session will last 30 minutes. The second testing session will be randomized and involve the subjects performing squats using 80, 90 and 100% of their raw 1RM using supportive equipment or not. The second testing session will last 90 minutes. The third session will consist of the subject performing the remaining portion of 80, 90 and 100% of their raw 1RM using supportive equipment. During all repetitions the downward portion of the lift will be performed using a three second tempo. A one second tempo will be used for the upward portion of the lift. All squats will be performed on a force plate using a Texas squat barbell attached to two linear position transducers (LPTs) for measurement of force, power, velocity and bar path during the lift. Additionally, muscle activity will be monitored through electromyography (EMG) for all squats for the vastus lateralis (VL), vastus medialis (VM), and biceps femoris (BF). There is no privacy needed for the preparation and placement of EMG. During all testing sessions, a certified strength and conditioning specialist will be present to ensure proper lifting technique and safety.

III. Risks

There are no inherent risks involved with this investigation except for the potential of muscle pulls or strains associated with the testing common to any type of physical activity. Preparation for electromyography may result in some minor skin irritation and/or discomfort. The spot for EMG placement will require hair to be removed by shaving, the area will also need to be cleaned and sterilized by rubbing a small piece of sand paper across the area to remove dirt and debris and then rubbing an alcohol swap over the area after. Testing will be monitored by qualified personnel (Certified Strength and Conditioning Specialist) with first aid and CPR certification. All procedures for the physical performances tests are previously published and are outlined in the standards for the field of Strength and Conditioning as supported by the National Strength and Conditioning Association.

IV. Benefits

Participants will be informed of their individual strength and power levels and have access to a complete analysis of their squat technique. Participants will learn the benefits of various squatting techniques and how it can increase leg strength. In addition, the subjects will be informed of how their participation increases the body of knowledge in exercise science with application to athletic and general populations.

V. Extent of Anonymity and Confidentiality

Participants identity will not be disclosed in any published documents or shared with anyone but the experimenters. All information collected will be kept confidential and disguised so that no personal identification can be made and all experimental data will be identified by number only. Confidentiality of all subjects will be maintained by keeping files under lock and key for a period of 5 years.

VI. Compensation

Participation is strictly voluntary for all testing procedures for this project. There is no charge for participation in this study, nor is there any financial compensation for participating. While the likelihood of sustaining any type of injury from participating in this study is extremely low, Appalachian State University or the Neuromuscular Laboratory and it's researchers have no method of compensation for medical care resulting from injuries occurring while participating. Should an injury occur, you should seek immediate medical attention from your health care provider.

VII. Freedom to Withdraw

Your participation in this investigation is completely voluntary. The refusal to participate or the decision to discontinue participation at any time will involve no penalty. We reserve the right to terminate your participation for any reason. Specific reasons as to why your participation was terminated may include that this investigation will pose an unreasonable risk to your health, or we as investigators, conclude that you are not performing the requirements of the investigation.

VIII. Approval of Research

This research project has been approved, as required by the Institutional Review Board of Appalachian State University.

__________________ ______________________

IRB Approval Date Approval Expiration Date

IX. Subject's Responsibilities

I voluntarily agree to participate in this study.

- Have three years of resistance training experience. No use of ergogenic aids in the previous three months. No prescription drugs that impair physical performance.
- Arrive at the testing site without having engaged in strenuous activity for 48 hours prior to my scheduled test time.
- Complete a single 30 minute testing session involving maximum lifting and physical performance testing, and some basic body size measurements.
- Complete two 90 minute testing session involving physical performance testing.

X. Subject's Permission

I have read and understand the Informed Consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent.

____ ________________

Subject Signature (I am at least 18 years of age.)
Date

Should you have any questions about this research or its conduct, you may contact

Jared Skinner 704-221-1635 js69732@appstate.edu

Investigator Telephone E-mail

Jeffrey M. McBride 828-262-6333 mcbridejm@appstate.edu

Faculty Advisor Telephone E-mail

Dr. Tim Ludwig 828-262-2712 irb@appstate.edu

Chair, IRB Telephone E-mail

Graduate Studies and Research
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VITA

Jared Wayne Skinner was born on April 17, 1987 in Marshville, North Carolina. After graduating from Forest Hills High School, he attended Appalachian State University in Boone, NC and graduated with honors with a Bachelor of Science in Exercise Science in May of 2009. He accepted a Graduate Assistantship Position at Appalachian State University and was awarded his Masters of Science in Exercise Science in May 2011. Jared plans to pursue a doctorate degree in Biomechanics at the University of Florida. Jared's parents are Wayne and Tammy Skinner of Marshville, North Carolina.