WILLIAM PATERSON UNIVERSITY OF NEW JERSEY

Effects of Power Output Utilizing Post-Activation Potentiation versus Static Stretching on the Vertical Jump

A THESIS

Submitted in partial fulfillment of the requirements

for the degree of

MASTER OF SCIENCE

in Exercise and Sport Studies

By

Timothy A. Carpenter

Wayne, NJ

December 2014

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College/School: Science and Health

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ABSTRACT

Effects of Power Output Utilizing Post-Activation Potentiation versus Static Stretching on the Vertical Jump

The purpose of this study was to measure power output of the vertical jump after a static stretch versus post-activation potentiation without stretching. Six males (24.8 ± 4.3 years old) were tested using three different protocols; non-stretch (NS) with a 5RM back squat test, static stretch (SS), and post-activation potentiation (PAP). Mean and peak power output (W) were calculated using the Lewis, Sayers, Harman, and Johnson & Bahamonde formulas. An increase in jump height and power was observed in both the SS and PAP (1685.0 ± 260.4 W and 1713. 2 ± 257.4 W) protocols from the baseline NS (1647.2 ± 267.4 W) protocol. Stretch-induced impairments were not observed in the current study. PAP was shown to increase power output from baseline testing (p= 0.0001). It can be concluded that SS and PAP have a positive affect on athletic performance and should be studied further.

ACKNOWLEDGMENTS

I would like to acknowledge my parents and thank them for their support while I strive to reach one of my many life goals. I would like to acknowledge and thank my professors from William Paterson University. Dr. Manning for his continued guidance, patience, and wisdom, Dr. Schmidt for his enthusiasm and passion for exercise science. Dr. Figueroa for his advice, guidance, and motivation, Dr. Emmons for her guidance, Dr. Wicke for his ability to make students want to learn and guide students through their own endeavors, Dr. Gazillo Diaz for her guidance, Dr. Sullivan for her high insight in cardiac rehab, and Professor Mahady for opening my eyes to the world of strength and conditioning. It is because of these dedicated individuals that I have the knowledge base that is strong enough to succeed in this field. Thank you for always being available to inspire and lead.

I would like to acknowledge and thank William Paterson University and all others who have helped me along this journey. I would like to thank K-Strength Sports Training for allowing me more of a hands-on learning experience and allowing me to utilize your facility for this study. Finally, I would like to thank my classmates from the past few years who have helped me succeed and made this journey much more than just attending class. Thank you Valarie DiMartino, Hannah Greenberg, Alan Hsieh, Michael Cox, Keiran Halton, Steven Knezvic, Andrew Williams, Melony Monberger, Robert Boutote, Neeraja Nannapaneni, Kyla Rouse, Michael Ehlers, and Gina Campo.

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Chapter I

INTRODUCTION

The enhancement of athletic performance has long been deliberated on the best way to achieve the greatest training affect. Athletes today are more powerful and faster than the athletes of the past and require more effective training to reach their full potential. Stretching is very common among professional and collegiate athletes prior to training and competition and brings hope that there will be an increase in performance and decrease in skeletal muscle injuries (4,5). Stretching before exercise has been shown to decrease power output and therefore increase fatigue (6). Static stretching is a well-known technique that has been utilized for many years to increase flexibility and aid in recovery. For many athletes, power is a vital aspect of performance, and today this separates the good athletes from the best athletes. The vertical jump is an effective measure of power output and is used in many professional settings including basketball, football, volleyball, and track and field (4). At the opposite end, post-activation potentiation (PAP) has been shown to increase power output by increasing neuromuscular activity and has been suggested to be able to be manipulated to enhance acute performance and chronic adaptation (7,9). The purpose of this study was to measure power output of the vertical jump after a static stretch versus post-activation potentiation without stretching.

Statement of the Problem

Egan, et al. (2006) found that pre exercise static stretching had no impact on mean power output or peak torque in Division I women's basketball players during an isokinetic leg extension. Although the vertical jump was not used in this study, it shows that highly trained individuals may be less susceptible to a power decrement caused by stretching versus non-athletes (3). In a study to determine if muscle force and power were affected by four weeks of static and ballistic stretching, LaRoche et al. (2008) found that four weeks of training had little effect on muscular strength and power (5). Tennis is a sport in which power can become the leading factor in determining the winner of a match. Carvalho, et al. (2009) found that there was no significant change in jump height following a static and proprioceptive neuromuscular facilitation (PNF) stretch (2). However in a study done by Marek et al., static and PNF stretching elicited a decrease in peak torque and mean power output (6). Weber et al. (2008) found that heavy-load back squats, 85% of 1 repetition maximum (1RM), increased mean and peak jump height and ground reaction force. Showing that heavy squats can increase PAP, allow for a greater force production with less fatigue, and therefore increasing muscular strength and power (10). Being that there are conflicting results in different studies, this investigation needs to measure the overall affects of stretching and PAP.

Egan et al. (2006) utilized the isokinetic knee extension to measure power output (3). Similarly, Marek et al. (2005) utilized an isokinetic leg extension along with electromyographic amplitude (EMG) of the vastus lateralis and rectus femoris muscles to measure power output and peak torque (9). A knee extension is not a primary movement in most athletics; in consequence it was not tested. The vertical jump is a measurement of power that requires an athlete to move into an athletic stance and move from that position.

Hypothesis

The following hypotheses were made for all conditions that were being tested:

1. There will be no difference between the three test conditions of non-stretching, static stretching, and post-activation potentiation.

2. Static stretching will show no difference in power output during the vertical jump versus non-stretching.

3. PAP without stretching will show no difference of power output during the vertical jump versus non-stretching.

4. PAP without stretching will show no difference of power output during the vertical jump versus static stretching.

Delimitations

The utilization of collegiate athletes or individuals who rely on or train for power, aged 19 to 29, will be recruited for this study. Being that the vertical jump is a power measurement, athletes that rely on power output will be utilized.

Limitations

As with any study, certain aspects will limit the outcome of the conditions being tested. Some limitations may include diet, level of fatigue, current training program, improper stretching techniques, and athletes not working to their full potential. Diet can affect the overall mood and the athlete's ability to perform. Although diet intervention will not be part of this study, athletes should understand the benefits of a proper diet and should adhere to a healthy lifestyle. Lack of sleep can affect the body's overall ability to perform and can alter results, therefore an adequate amount of sleep will be recommended during testing. The athlete's current training program may have an affect on the current study, but is not expected. All athletes will be chosen from the same team and training should be consistent within all groups. Improper stretching can alter results because of the hypothesis that not stretching will elicit a higher power output than a static stretch. Thus if the athlete does not stretch the proper way prior to testing, the results may be compromised. Finally, if the athletes are not willing to perform to their full potential during each test, then the results may show a different pattern than expected.

Definitions of Terms

The following definitions will be used:

1. A static stretch is defined as lengthening a muscle to the point of moderate discomfort for a minimum of thirty seconds. This time frame will allow the Golgi tendon organ (GTO) to relax the muscle and properly stretch.

2. PAP is known as the ability to enhance the neuromuscular state of the body immediately following heavy bouts of resistance exercise (8,10). Performing heavy back squats or deadlifts will elicit this effect.

Study Design

The study consisted of three conditions to be compared: stretching, non-stretching, and PAP. The study was quantitative in nature and utilized a one-way analysis of variance (ANOVA) to compare the groups. Statistical significance was set at $p \leq 0.05$. The subjects were athletes or individuals that rely on or train for the ability to produce maximal power. Subjects were non-smokers between the ages of 19 to 29 years. Five repetition maximum (5RM) was determined prior to testing following the National Strength and Conditioning Association (NSCA) 1RM testing protocol so proper measures can be taken (1). The study consisted of three trials. Day 1 consisted of a non-stretch vertical jump test, followed by a 5RM back squat test. Day 2 measured vertical jump height after the completion of the static stretch protocol. Day 3 measured vertical jump height after the completion of a 5RM back squat. Days 2 and 3 were randomized to reduce the chances of an order effect. Subjects signed an informed consent, PAR-Q, and adhered to all guidelines.

Chapter II

REVIEW OF RELATED LITERATURE

The vertical jump is a known evaluation of power output in athletes. Static stretching prior to exercise or athletic performance has been shown to decrease and maintain performance. Post-activation potentiation (PAP) has been shown to increase power output for athletes. Recent studies have found conflicting information on both types of pre-exercise warm-ups (3,4,7,8). This section has been divided into two subsections of static stretching and post-activation potentiation. The purpose of this study is to measure power output of the vertical jump after a static stretch versus post-activation potentiation without stretching.

Static Stretching

Egan et al. (2006) observed the acute affects of static stretching on peak torque and mean power output during a maximal voluntary isokinetic leg extension at 60 and 300 degrees per second in Division I women's basketball players. Eleven members of the women's basketball team were utilized in this study that used the Biodex System 3 dynamometer to measure peak torque and mean power output. Following baseline testing, subjects stretched using one unassisted and three assisted static stretching exercises prior to testing. Post-stretching assessments were taken at 5, 15, 30, and 45 minutes following static stretching. The results for this study indicated no changes in pre- to post-stretching for any interval, indicating no impact on peak torque or mean power by static stretching. Egan et al. (2006) suggests that trained athletes may be less susceptible to the stretching-induced force-decrement, whereas untrained and/or non-athletes may show to be more affected by static stretching prior to exercise (5).

Dalrymple et al. (2010) observed the effects of static and dynamic stretching on peak jump height of the vertical jump in collegiate women volleyball players. Each stretch, including no stretch, was performed immediately before the countermovement (CMJ) vertical jumps. Twelve women volunteered for this study that lasted a total of three weeks. Subject's performed one session per week, which consisted of a five-minute warm-up and random stretching protocol lasting eight minutes. Immediately following stretching, subjects were instructed to perform five maximal CMJ's, which were performed on a force platform, separated by one-minute of passive recovery. Results showed no significant difference for any of the stretching protocols (4).

Chaouachi et al. (2010) conducted a study that focused on the effects of static and dynamic stretching on agility, 30-m sprint, and jumping performance in trained individuals. The study looked at eight different stretching protocols relative to a control warm-up without stretching. The eight protocols were as follows: warm-up with a static stretch (SS) to point of discomfort (POD), warm-up with SS less than POD, warm-up with dynamic stretch (DS), warm-up with SS at POD combined with DS, warm-up with SS less than POD combined with DS, warm-up with DS combined with SS at POD, warm-up with DS combined with SS less than POD, and a control warm-up without stretching. The study utilized 22 highly trained male volunteer student athletes from the University of Sports of Tunisia. A downfall to this study is that a specific type of athlete was not tested, but a large array of student athletes competing in different sports. As a result, different types of training would elicit different types of results during the testing protocols. Results showed that the control, no stretch, had significantly faster times for the 30-m sprint than the DS and SS condition. Jumping performance did not show a significant difference between the groups. Researchers stated that results may be due to the conditioned state of the athletes. Sprinters could also benefit from the elastic recoil of the muscle resulting in a faster start (3).

Carvalho et al. (2009) conducted a study that looked at the acute effects of static stretching and proprioceptive neuromuscular facilitation (PNF) on the vertical jump in adolescent tennis players. Nine participants, four women and five men, were utilized in this study with an average age of 14.4 years. It was required that the subject's have at least two years of tennis practice and competed by the Tennis Federation of Rio de Janeiro. The Sargent Jump Test (SJT) was used to measure the height of the vertical jump. Two tests were performed 48 hours separate of each other at the same time of the day. Day one utilized static stretching, while day two utilized PNF. Both static stretching and PNF showed a decrease in height jumped, 0.7% in static stretching and 4.6% for PNF. Researchers stated that athletes who depend on power output might not benefit from static or PNF stretching prior to exercise (2). During this type of study, the age group would have an affect on the overall results. The age of the men and women indicates that their bodies are still developing and would not be a good candidate for this type of research. Looking in as an outsider, looking at the athlete's biological age would be a better choice to complete this type of study with adolescence.

In a similar study conducted by Marek et al, (2005), the study measured peak torque, mean power output, active range of motion, passive range of motion, electromyographic (EMG) amplitude, and mechanomyographic amplitude. During the study, the short-term effects of static stretching and PNF were examined. Nineteen healthy volunteer subjects, 10 women and 9 men, were utilized in a study that used a maximal concentric isokinetic leg extension at 60 and 300 degree per second. Range of motion (ROM) was determined prior to testing followed by four leg extensor stretching exercise of the dominant limb. Each subject performed both static stretching and PNF, not on the same day, on two random laboratory visits. Results indicated a reduction in peak torque, mean power output, and EMG amplitude while utilizing the static stretch and PNF. Deficits were seen in both static stretching and PNF at both velocities. Researchers stated a need to consider a risk-to-benefit ratio when incorporating both types of stretching prior to exercise or athletic performance (9).

Post-Activation Potentiation

Scott and Docherty (2004) observed the effects of heavy preloading on vertical and horizontal jump performance. The back squat was utilized for one set of a 5 repetition maximum (5RM) on 19 resistance-trained men who took part in four practice sessions and four testing sessions. During the testing sessions, subjects performed five minutes of cycling followed by 5 minutes of stretching. The subject then performed one set of four vertical jumps (VJ) and four horizontal jumps (HJ), followed by the 5RM back squat. After a five-minute rest period, subjects performed four VJ and four HJ. Results indicated that there were no significant differences between VJ and HJ due to preloading (12).

In a similar study conducted by Weber et al. (2008), the back squat was utilized with a one repetition maximum (1RM) on consecutive squat jump performance. This study used 12 men who were Division I track-and-field athletes with at least one year experience with training under a collegiate strength and conditioning program. Squat jumps were performed on a jump platform to measure peak and mean ground reaction force, and peak and mean jump height. The study consisted of two randomized testing conditions: a 5RM back squat at 85% of 1RM and five-repetition squat jump. Results showed a significant increase in peak jump height for back squat, whereas squat jump significantly decreased peak jump height. Mean jump height increased with the back squat and decreased with squat jumps. This study indicated that preloading back squat has a positive effect on squat jump performance (14).

Stieg et al. (2011) wanted to compare different depth jump as a warm-up to elicit the effects of PAP. The study consisted of 17 collegiate women soccer players who participated in five testing sessions separated by 48 hours. Subjects warmed up on the cycle ergometer and performed three pre-test countermovement jumps with arm swing. Immediately following the pre-test, subjects performed 0, 3, 6, 9, and 12 depth jumps in random order with a rest time of 10 seconds between jumps. Box jump heights were individualized at the level of the lateral femoral condyle. Results showed that vertical jump height during nine jumps were less than 0, 3, and 6 but no different than 12. This study showed an inefficiency to elicit PAP and overall decreased vertical jump performance (13).

McCann and Flanagan (2010) conducted a study to determine if a power exercise would lead to greater PAP than a strength exercise, if a four to five minute rest interval led to greater PAP, the extent to which PAP was an individual phenomenon, and the effect of PAP on the ground reaction force during a vertical jump. Sixteen volleyball players, eight men and eight women, were utilized in this study. The study consisted of four groups: groups A and B completed the back squat on day 1 and hang clean on day 2, groups C and D completed the hang clean on day 1 and back squat on day 2, groups A and C had a rest interval of 4 minutes followed by 5 minutes on the first day, and groups B and D had a rest interval of 5 minutes followed by 4 minutes on the first day. Exercise and order were reversed for the second day. Subject's performed tow sets of five vertical jumps as a warm up. Subject's 5RM back squat was determined, performed, and vertical jumps were completed four-minutes following the completion of the back squat. Results did not show a consistent rest interval or exercise that increased vertical jump height. Researchers suggest that individualized training will increase vertical jump height, thus enhancing sports performance (10).

Hanson et al. (2007) examined PAP differently than other researchers. The study examined acute performance enhancing effects of a single light-load of high-velocity or heavy-load of low-velocity squat intervention set (SIS). Thirty subjects, 24 men and 6 women, were utilized from collegiate weight training classes with at least one year of resistance training experience. Subjects attended three separate sessions with a minimum of three days and maximum of seven days between each session. Warm-up consisted of riding a stationary bike for five-minutes followed by light stretching of the lower extremities. Squat exercises were performed on a standard smith machine. During the testing sessions, subjects performed two countermovement jump sets, followed by a single SIS that was a different intensity for each session, and a final countermovement jump set. Results showed that there was no significant difference in either SIS condition. Researchers believe that PAP may have dissipated by the time post-testing took place which could have attributed to the results (6).

Chapter III

PROCEDURES

Subjects

Subjects were athletes or individuals that rely on or train for explosive power and were comprised of six men (N=6) with a mean age of 24.8 ± 4.3 years. The average height of the subjects was 1.82 ± 0.05 meters, the average weight of the subjects was 99.2 ± 11.5 kg, and the average Body Mass Index (BMI) was 30.0 ± 3.6 kg shown in Table 1. Subjects did not perform any lower body exercise 48 hours prior to testing.

Table 1. Subject's descriptive statistics.

	Age (yrs)	Height (m)	Weight (kg)	BMI
Men (n=6)	24.8 ± 4.3	1.82 ± 0.05	99.2 ± 11.5	30.0 ± 3.6

Laboratory Procedures

The study was comparing three conditions: static stretching (SS), non-stretching (NS), and post-activation potentiation (PAP). Standing height and height jumped were measured using the Vertical Jump Measuring Device (Tandem Sport Vertical Challenger, Louisville, KY). Testing was conducted at K-Strength Sports Training in Fairfield, New Jersey. Data was collected over a period of three weeks among a total of three sessions, one session for each testing condition. Testing times were the same on each day and were based on the availability of the subject. Each subject performed each condition that was being tested with no more than one-week separation. Mean and peak power and force were measured.

Testing Protocol

Session 1: Session 1 consisted of the NS protocol and the 5RM back squat. Each testing session began with the following standardized dynamic lower body warm-up consisting of the following: 40 yard jog, 20 yard skip, 20 yard shuffle, 20 yard walking leg swing, 20 yard walking lunge, 20 yard walking side lunge with body weight squat, 20 yard high knee run, and 5 jump squats. Subjects completed the standardized warm-up, had a 5-minute rest, and proceeded directly to the vertical jump. The subjects performed a total of 5 countermovement jumps. Following each jump, the subject would reset before attempting the next jump. The subjects would then proceed to squat to achieve a 5RM, following the NSCA 1RM testing protocol (1). Additional assistance was provided to anyone requiring further explanation. After all jumps were completed, the subject's would cool down with the method of choice. Subsequent sessions 2 and 3 were given in random order to minimize an "order" effect.

Session 2: Session 2 consisted of the SS protocol. Subjects completed the standardized warm-up followed by the static stretching protocol. The stretches were the seated hamstring stretch (figure 1), seated gluteal stretch (figure 2), standing quadriceps stretch (figure 3), and standing calf stretch (figure 4) (12). Each stretch was held for 30 seconds with a 30 second rest period in between and conducted 3 times per stretch. Additional assistance was provided to anyone requiring further explanation. Following SS the subjects had a 5-minute rest and then performed 5 countermovement jumps. Following each jump, the subject would reset before attempting the next jump. After all jumps have been completed, the subject's would cool down with the method of choice.

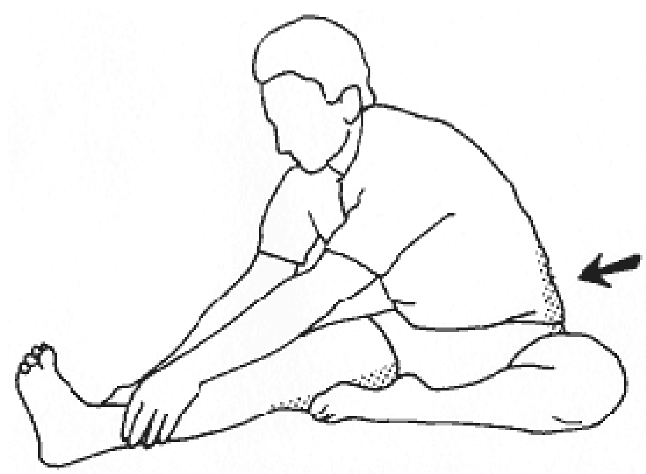

Figure 1. Seated hamstring stretch.

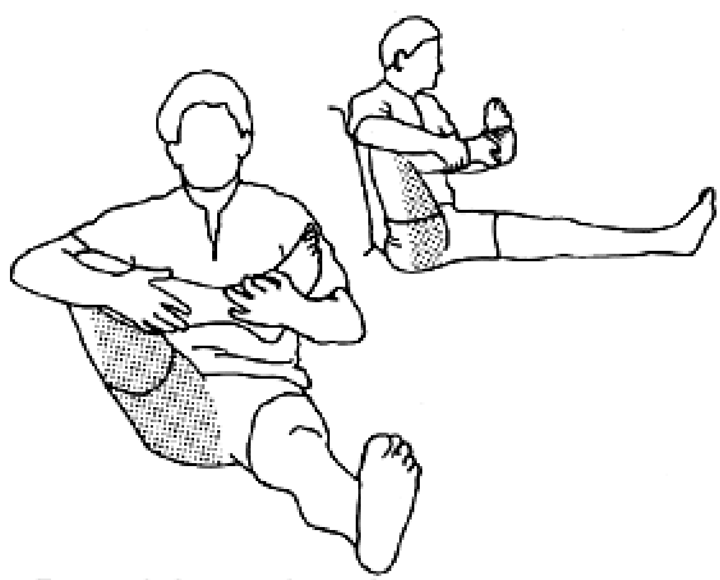

Figure 2. Seated gluteal stretch.

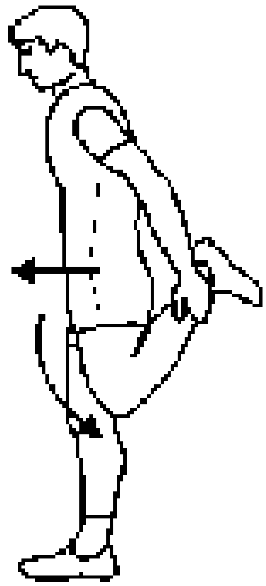

Figure 3. Standing quadriceps stretch.

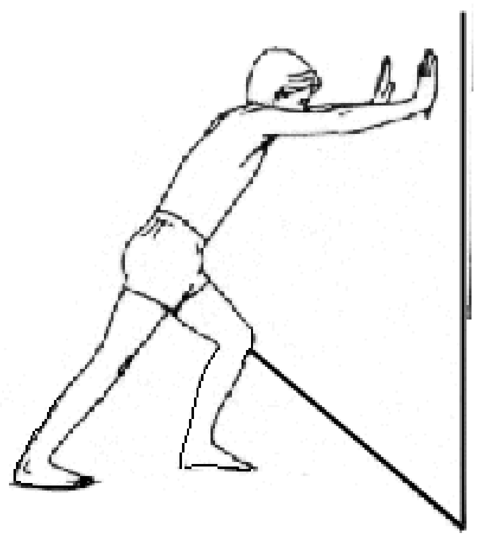

Figure 4. Standing calf stretch.

Session 3: Session 3 consisted of the PAP protocol. Subjects completed the standardized dynamic warm-up and proceeded to the weight room where they would complete 3 warm up sets at 65%, 75%, and 85% of their estimated 1RM based on the previously tested 5RM weight. The subjects completed a 5RM, had a 5-minute rest, and proceeded to the vertical jump where 5 countermovement jumps will be completed. Following each jump, the subject would reset before attempting the next jump. After all jumps were completed, the subject's would cool down with the method of choice.

Statistical Procedures

The study was quantitative in nature and utilized a one-way analysis of variance (ANOVA) to compare the three testing conditions. Statistical significance was set at $p \leq 0.05$. The study compared mean and peak power output (Watts) from the following formulas: Lewis formula, Sayers formula, Harman formula, and the Johnson & Bahamonde formula.

Chapter IV

RESULTS

Results indicated that jump height had increased for both the SS protocol and the PAP protocol from the baseline, NS, testing. The subject's mean jump height for the NS protocol was 23.3 ± 5.0 inches (in), mean jump height for the SS protocol was 24.4 ± 5.3 in, and mean jump height for the PAP protocol was 25.2 ± 5.5 in shown in Figure 1. Results also suggested that the subject's peak height was attained during the fourth jump of each protocol also shown in Figure 5.

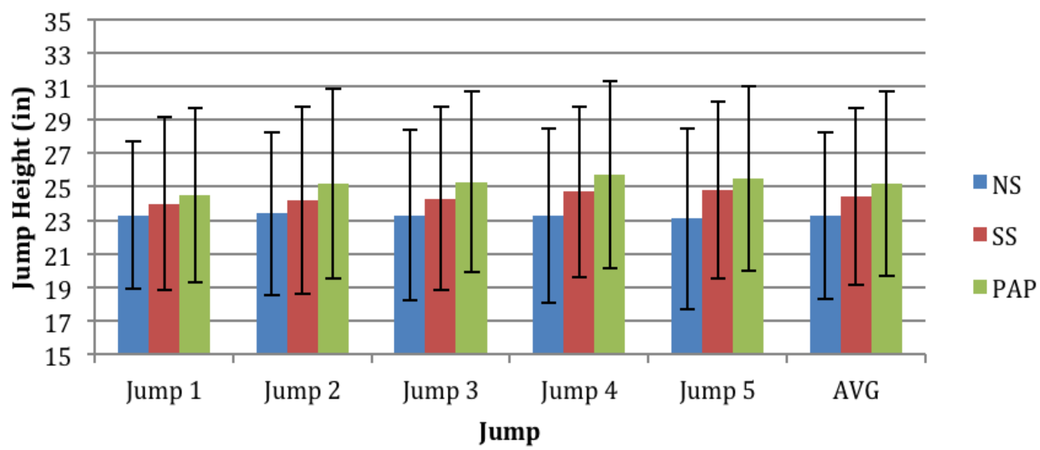

Figure 5. Subject's jump height for each testing protocol.

The subjects' mean peak jump height for the NS protocol was 24.0 ± 4.8 in, mean peak jump height for the SS protocol was 25.0 ± 4.9 in, mean peak jump height for the PAP protocol was 25.8 ± 5.7, and overall mean peak height of 24.9 ± 5.1 in shown in Table 2.

Table 2. Subject's peak jump height for each protocol.

	NS	SS	PAP	AVG
Jump Height (in)	24.0 ± 4.8	25.0 ± 4.9	25.8 ± 5.7	24.9 ± 5.1

Power Output

Subjects showed an increase in power output from baseline testing in the Lewis and Sayers Formulas, which relates to the increase in jump height. However, the Harman Formula showed a decrease in power output from baseline testing as shown in Table 3. The Lewis Formula (LF) showed a mean power output for the NS protocol of 1647.2 ± 267.4 W, a mean power output for the SS protocol of 1685.0 ± 260.4 W, and a mean power output for the PAP protocol of 1713.2 ± 257.4 W. The Sayers Formula (SF) showed a peak power output for the NS protocol of 1478.3 ± 767.1 W, a peak power output for the SS protocol of 1653.1 ± 818.0 W, and a peak power output for the PAP protocol of 1781.5 ± 843.0 W. The Harman Formula (HF) showed a peak power output for the NS protocol of 1761.6 ± 17.0 W, a peak power output for the SS protocol of 1758.7 ± 16.8 W, and a peak power output for the PAP protocol of 1756.6 ± 16.8 W shown in Table 3.

Table 3. Power output for each formula.

	Lewis Formula Avg. Power (W)	**Harman Formula Peak Power (W)**	**Sayers Formula Peak Power (W)**
NS*	1647.2 ± 267.4	1761.6 ± 17.0	1478.3 ± 767.1
SS*	1685.0 ± 260.4	1758.7 ± 16.8	1653.1 ± 818.0
PAP*	1713.2 ± 257.4	1756.6 ± 16.8	1781.5 ± 843.0

* Indicates a significant difference between each condition of each formula.

The LF showed a mean peak power output for the NS protocol of 1674.4 ± 262.0 W, a mean peak power output for the SS protocol of 1708.6 ± 261.5 W, a mean peak power output for the PAP protocol of 1733.4 ± 262.4 W, and a overall mean peak power output of 1705.5 ± 261.9 W. The SF showed a mean peak power output for the NS protocol of 1591.4 ± 763.3 W, a mean peak power output for the SS protocol of 1745.6 ± 762.0 W, a mean peak power output for the PAP protocol of 1874.0 ± 876.0 W, and a overall mean peak power output of 1737.0 ± 791.5 W. The HF showed a mean peak power output for the NS protocol of 1759.8 ± 16.7 W, a mean peak power output for the SS protocol of 1757.2 ± 16.8 W, a mean peak power output for the PAP protocol of 1755.1 ± 17.2 W, and a overall mean peak power output of 1757.4 ± 16.9 W shown in Figure 6.

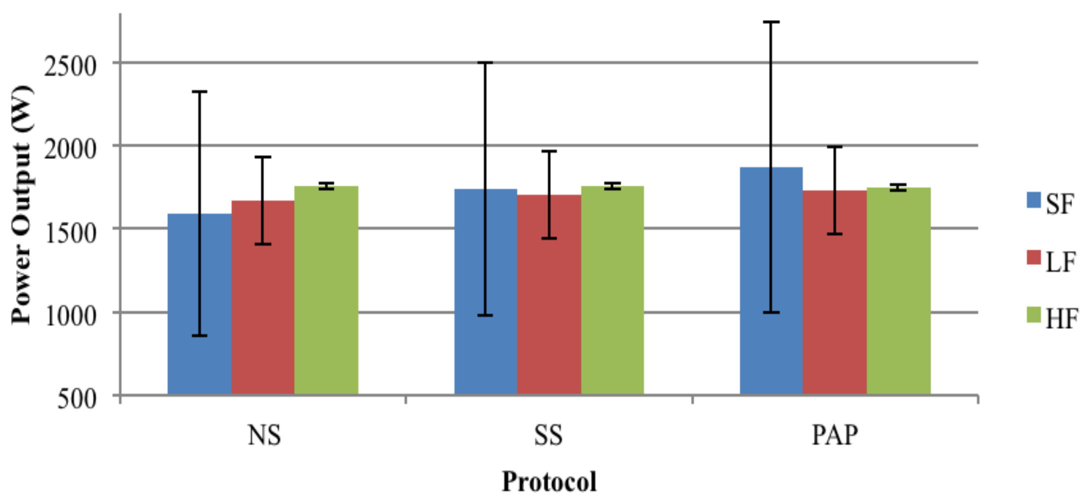

Figure 6. Mean peak power output for each testing protocol, each formula and protocol being significantly difference from each other.

Results also showed an inconsistency's between formulas that were not used in the current study. Two of the six formulas used in the current study gave a negative figure for measure of power. Johnson and Bahamonde peak power formula and the Harman formula for average power showed negative power output for each of the testing conditions. The Johnson and Bahamonde average power formula gave significantly lower numbers than that of the three formulas utilized in the study shown in Table 4.

Table 4. Power output for each inconsistent formula.

	Harman Formula Avg. Power (W)	J & B Formula Peak Power (W)	J & B Formula Avg. Power (W)
NS	-1507.1 ± 17.0	-1524.7 ± 17.7	150.4 ± 17.7
SS	-1510.0 ± 16.8	-1527.6 ± 17.5	147.5 ± 17.5
PAP	-1512.1 ± 16.8	-1529.7 ± 17.4	145.4 ± 17.4

Statistical Analysis

Statistical analysis utilizing an ANOVA revealed that there is a significant difference, $p \leq 0.05$, between the Lewis, Sayers, and Harman formulas ($p = 0.0001$). Dependent variables of power (W) showed that there was a significant difference in the formulas between testing conditions. In the Lewis formula, NS, 1647.2 ± 267.4 W, was shown to be significantly different than SS ($p = 0.001$), and PAP ($p = 0.0001$), SS, 1685.0 ± 260.4 W, was shown to be significantly different than NS ($p = 0.001$) and PAP ($p = 0.008$), and PAP, 1713.2 ± 257.4 W, was shown to be significantly different than NS ($p = 0.0001$) and SS ($p = 0.008$).

In the Sayers formula, NS, 1478.3 ± 767.1 W, was shown to be significantly different than SS ($p = 0.0001$) and PAP ($p = 0.0001$), SS, 1653.1 ± 818.0 W, was shown to be significantly different than NS ($p = 0.0001$) and PAP ($p = 0.005$), and PAP, 1781.5 ± 843.0 W, was shown to be significantly different than NS ($p = 0.0001$) and SS ($p = 0.005$).

In the Harman formula, NS, 1761.6 ± 17.0 W, was shown to be significantly different than SS ($p = 0.001$) and PAP ($p = 0.0001$), SS, 1758.7 ± 16.8 W, was shown to be significantly different than NS ($p = 0.001$) and PAP ($p = 0.006$), and PAP, 1756.6 ± 16.8 W, was shown to be significantly different than NS ($p = 0.0001$) and SS ($p = 0.006$).

DISCUSSION

Previous research has indicated that power output can be increased by PAP and decreased by SS. The current study found an increase in power output in both the SS, 1685.0 ±260.4 W, and PAP, 1713.2 ± 257.4 W, protocol from the baseline NS, 1647.2 ± 267.4 W, protocol. Statistical analysis showed a significant difference in all conditions and formulas ($p = 0.0001$), concluding that the protocols offered a greater advantage over the other. It was observed that SS and PAP both increased in overall jump height, SS (24.4 ± 5.3 in) PAP (25.2 ± 5.5 in), from the baseline NS (23.3 ± 5.0 in) protocol concluded that there were added benefits from the SS and PAP protocols. A variety of factors could have influenced the results of the current study both positively and negatively. Training status, subject age, subjects sleep cycle, and individual differences can have an effect on the results.

Static Stretching

Stretching is very common among athletes prior to training and competition and brings hope that there will be an increase in performance and decrease in skeletal muscle injuries (4,5). The current study shows that there was an increase in performance from the baseline testing when performing the SS protocol (Table 3). Carvalho et al. (2009) found that there was no significant change in jump height after conducting a flexibility regime (2). Dalrymple et al. (2010) had similar results, stating that there were no significant differences between static, dynamic, and no stretching groups (4). The current findings suggest that static stretching can have a positive effect on athletic performance. The stretch-induced impairments that were observed in the current study may have been due to the trained state of the subjects, which is in agreement with the findings of other researchers (3,5). Lesser-trained individuals may show different results when stretch-induced.

LaRoche et al. (2008) suggests that athletes should avoid stretching prior to any activity that requires high levels of muscle force (8). The current study does not show any results indicating that stretching prior to exercises that require high levels of muscle force would be affected by a stretching regime. In fact, the results of the current study would recommend stretching prior to high force activities in highly trained individuals. Egan, et al. (2006) found that pre exercise static stretching had no impact on mean power output or peak torque in Division I women's basketball players showing that the current findings relate to the fact that highly trained individuals may be less susceptible to stretching induced vulnerabilities (3,5). Participants in the current study, although trained for power, were not as highly trained as Division I athletes, but showed that power athletes were less susceptible to stretching induce vulnerabilities. It should be noted that the standardized dynamic warm-up might have had an effect on the overall effectiveness of the protocols overriding the added advantages and/or disadvantages of the NS, SS, and PAP protocols.

Stretching is a tool used by many professional and collegiate sports teams as well as many small businesses such as K-Strength Sports Training and others, to promote flexibility, skeletal muscle health, and a healthy lifestyle (7). Researchers have found that static stretching prior to engaging in high force activities has been shown to decrease the amount of power that one can produce (4,5,6,7). The current findings suggest that stretching prior to high force activity compliments an athlete's power output and reflected an ability of the subjects to benefit from stretching prior to exercise.

Post-Activation Potentiation

Post-activation potentiation (PAP) is not practiced as much as stretching, however, PAP can have great effects on athletic performance. PAP has been shown to increase power output by increasing neuromuscular activity (7,9). The current study has shown an increase in power output from baseline testing for the PAP protocol. Scott and Docherty (2004) utilized a 5RM for preloading a vertical jump and observed no significant differences between VJ and HJ due to preloading (12). A similar study conducted by Weber et al. (2008) observed conflicting results, stating that preloading has a positive effect on vertical jump performance. Researchers saw a significant increase in peak jump height when preloading with a back squat (14). The current study used a 5RM for preloading and observed an increase in power output from the baseline similar to that of other researchers (14).

Previous researchers have found there is no consistency in results showing an increase in power output (10,13). The current study suggests that PAP can increase the amount of power produced by an individual. Training effects and learning effects can also have an effect on the increase in vertical jump height. Stieg et al. (2011) found an inefficiency to elicit PAP, which overall decreased vertical jump performance (13). Other research suggests that PAP effects have worn off by the time of post testing affecting the results (6).

Resistance training and preloading has a positive affect on the central nervous system (CNS) allowing an increased excitation to working muscle allowing for increased power. The current study shows that this theory can increase the amount of power an athlete can produce when preloading with a back squat for a 5RM. Each of the formulas used in the current study have a shown significant differences between each of the testing protocols suggesting that SS and PAP can have a positive effect on athletic performance.

There are many different formulas used to measure power output. The current study utilized the Lewis, Sayers, Harman, and Johnson and Bahamonde formulas; however, inconsistencies were seen in some of the formulas. Previous research has not considered the effects of different formulas on power output and thus has not observed these inconsistencies. Formulas showing negative power outputs were not considered in this study. Further research will be needed to observe the differences in power formulas.

Chapter V

Conclusion

It can be concluded that SS and PAP have a positive effect on athletic performance and has been shown to increase power output. The study suggests that pre-exercise stretching and preloading may also be dependent on training status, thus SS or PAP may not affect professional or collegiate athletes. All participants utilized in the current study were individuals that train or rely on power. Training status and environmental condition can have an effect on the outcome of a study. Power athletes can see the benefits of stretching prior and/or post exercise. Although a larger sample size was desired, the results show that an increase in power was revealed during each of the testing conditions.

Suggestions for future research

Conflicting information has been found in much of the research. A similar study to the current one should be conducted with a greater sample size in order to see the primary differences in each testing protocol. Subjects should be taken from a specific team and tested for a specific sport in order to avoid specific training differences. As noted, the dynamic warm-up added to each of the testing conditions could have affected the overall outcome of the study. Future research should be limited to testing only the conditions without any outside interferences. Lifestyle habits should be noted (i.e. smoking, drinking, recreational or prescription drug use) because of the effect it could have on the results. This study could also be done with different rest intervals. It has been suggested that once PAP is induced, it can last up to 30 minutes. Future research should test this hypothesis and test a vertical jump at

5-minute intervals to test the peak of PAP. The formulas utilized in the current study could be tested under different condition to observe any inconsistencies.

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APPENDIX A

INFORMED CONSENT

William Paterson University

Project Title: The Affects of Power Output Utilizing Post-Activation Potentiation versus Static Stretching on the Vertical Jump

Principal Investigator: Timothy Carpenter

Faculty Sponsor: Dr. Michael Figueroa

Faculty Sponsor Phone Number: 973-720-3950

Department: Kinesiology

Course Name and Number: EXSC 7800-02 Thesis Exercise Science

Protocol Approval Date: June 23, 2014

I have been asked to participate in a research study on a power output utilizing post-activation potentiation, the ability to enhance the neuromuscular state of the body immediately following heavy bouts of resistance exercise, versus static stretching, lengthening a muscle to the point of moderate discomfort for a minimum of thirty seconds, on the vertical jump. The purpose of this study will be to measure power output by pre-loading the body by a 5-repetition maximum (5RM) back squat as well as static stretching before performing a vertical jump. I understand that I will be given a 5-minute warm-up and then asked to perform a 5RM back squat and static stretch followed by 5 countermovement jumps.

Potential risks from participating in this study include a possible muscle injury (e.g. strain) or soreness, which has been explained to me, and I accept them. In the event of an injury resulting from the research procedures, the cost of medical treatment in excess of that covered by third party payers will be provided without cost to me by William Paterson

University but additional financial compensation is not available. Benefits from participating include being able to understand how my body will produce the most power prior to competition.

I agree that my participation in this study is completely voluntary and that I may withdraw at any time without prejudice. I understand that all information collected in this study will be kept strictly confidential, except as may be required by law. If any publication results from this research, I will not be identified by name.

I understand that if I wish further information regarding this research, my participation, the conduct of the investigators, or my rights as a research subject, I may contact the Office of the Provost and Senior Vice President for Academic Affairs at 973-720-2122. I also understand that if I have any questions pertaining to my participation in this particular research study, I may contact the investigator by calling the telephone number(s) listed at the top of page one. I have been given the opportunity to ask questions and have had them answered to my satisfaction.

I may call the investigator Timothy Carpenter if I have any questions or concerns about this research and my participation. I may call the Associate Vice President and Dean for Graduate Studies and Research (973-720-3093) for information regarding my rights as a research subject.

I have read and understand the consent form. I agree to participate in this research study. Upon signing below, I will receive a copy of the consent form.

Name of Subject____________________ Signature of Subject___________________________

Date: _____________________________

Name of Investigator________________ Signature of Investigator_______________________

Date:______________________________

APPENDIX B

PAR – Q

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

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

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

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

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

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

If you answered

YES to one or more questions

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

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

NO to all questions

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

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

DELAY BECOMING MUCH MORE ACTIVE:

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

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

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

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

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

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

NAME ______________________________

SIGNATURE ______________________________ DATE ______________________________

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

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

APPENDIX C

Vertical Jump Data Sheet

ID #: ________________________________ Date: ______________________________

DOB: __________Age: ________________HT: ________________WT: ___________

Checklist:

_____ Signed PAR-Q

_____ Signed Informed Consent

Testing:

Estimated 1RM Back Squat: ________________lbs.

Estimated 5RM Back Squat: ________________lbs.

Actual 5RM Back Squat: ________________ lbs.

65% 1RM: ________________ lbs. (15RM)

75% 1RM: ________________ lbs. (10RM)

85% 1RM: ________________ lbs. (5RM)

Protocol:

	NON-Stretch	Static Stretching	PAP
DATE			
Standing Height			
Jump 1			
Jump 2			
Jump 3			
Jump 4			
Jump 5			

Notes: ____

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