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THE EFFECTS OF A HEAVY RESISTANCE WARM-UP ON SPRINT SPEED: A POST ACTIVATION POTENTIATION STUDY

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ABSTRACT

The purpose of this study was to determine the effects of a post activation potentiation (PAP) warm-up on sprint speed, with an emphasis on the role of specificity regarding the preparatory conditioning activity. It was hypothesized that a unilateral conditioning activity (barbell lunge) would provide a greater PAP effect on short sprint ability then a bilateral conditioning activity (barbell back squat). Sixteen NCAA Track Athletes participated (7 males, 9 females) in the study. The experiment employed a repeated measures crossover design where, following a familiarization session, each subject completed a randomly assigned warm-up (WU) on three different days with at least 48 hours between sessions. Following the randomly assigned WU, sprint speed was tested over a distance of 36.6 meters as well as quartiles. The WU's were: a dynamic, a dynamic followed by a unilateral barbell lunge (BL), and a dynamic followed by a bilateral back squat (BS). A repeated measures ANOVA was utilized to determine if there were significant differences between sprint times for each WU strategy. There were no statistically significant differences in sprint times between WU conditions at 36.6 m or any quartile (p>0.05). Within the parameters of this study, neither an intense bilateral or unilateral conditioning activity improved short sprint performance beyond that of a dynamic WU activity.
***Keywords:** Unilateral, bilateral, squat, lunge, PAP.*

1. INTRODUCTION

The development of sprint speed and acceleration are crucial components of many training regimens as maximal speed and acceleration are critical aspects of many sports. To maximize an athlete's ability to achieve high movement velocities, they

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must learn to skillfully apply force to propel themselves forward as quickly as possible (Baechle & Earle, 2008, p.459). Alemdaroglu (2012) and Shalfawi, Enoksen, and Tønnessen, (2014) found that there is a significant relationship between an athlete's ability to generate power and top sprint speed. Therefore, it stands to reason that an athlete's ability to increase power production is almost certainly a considerable factor when developing sprint speed.

There has been a great deal of interest and research as to whether post-activation potentiation (PAP) can improve power output and sprint speed. PAP refers to the increased neuromuscular state that occurs immediately after a high intensity exercise or conditioning activity (Anthi, Dimitrios, & Christos, 2014; Robbins, 2005). An example of PAP might be a heavy resistance exercise of near maximal effort followed by a biomechanically similar power exercise, such as performing a 5-RM back squat followed by a vertical jump (Smith, Lyons, & Hannon, 2014). There have been several studies that have shown the acute effects of a heavy resistance back squat (BS) on vertical jump (VJ) performance (Crewther, Kilduff, Cook, Middleton, Bunce, & Yang, 2011; Smilios, Pilianidis, Sotiropoulos, Antonakis, & Tokmakidis, 2005; Weber, Brown, Coburn, & Zinder, 2008). Likewise, there is emerging research employing heavy resistance conditioning activities during a warm-up (WU) to capitalize on the resulting PAP for improving maximal sprint efforts (Matthews, Matthews, & Snook, 2004; Lim & Kong, 2013; Yetter & Moir, 2008). The majority of researches regarding PAP WUs and sprint performance have been conducted using a heavy BS for the conditioning activity, resulting in an increase in sprint speed of up to 3.3% (Crewther *et al.*, 2011; Matthews *et al.*, 2004; Smilios *et al.*, 2005; Weber *et al.*, 2008). Heavy BS's as a modality have demonstrated the stimulus necessary in order to elicit the arousal needed to improve sprint performance, however there may be other modalities that could prove superior to the BS for eliciting PAP prior to sprinting. Perhaps using an exercise that is more biomechanically similar (specificity) to running could further increase power production and sprint speed. To date, little research has examined other conditioning activities (modalities) as a means to induce PAP and potentially improve sprint performance.

Given the unilateral nature of sprinting, using a conditioning activity that is also unilateral in nature, such as the barbell lunge (BL), could create a more biomechanically similar conditioning activity during a PAP WU when compared to a bilateral conditioning activity such as the BS. Hip extension is the primary movement that generates the concentric propulsion of each flight phase during the start, acceleration, and maximum velocity phases of sprinting. Justification for choosing a BL exercise is supported by Fauth, Garceau, Lutsch, Gray, Szalkowski, Wurm, and Ebben, (2010), who reported increased activation of the gluteal muscles and hamstrings with a BL as compared to a traditional BS. Due to the importance of hip extension in the mechanics of sprinting, it seems reasonable to assume that the muscles of the posterior chain contribute more to power output and running speed than the anterior muscles of the leg. Evidence for this rationale is provided by Baechle and Earle (2008) in their analysis of running speed (Baechle & Earle pg. 462-468).

Therefore, the purpose of this study was to determine if a high intensity BL is superior to a BS in a PAP WU protocol designed to elicit an acute increase in sprint performance and if either PAP WU strategy is superior to a traditional dynamic WU protocol. The research hypothesis expects that the WU strategies employing a PAP conditioning activity would yield superior sprint performance when compared to a dynamic WU alone. Further, it is hypothesized that the PAP WU strategy employing the unilateral BL as the conditioning activity would be superior at improving sprint performance when compared to a PAP WU strategy utilizing a bilateral BS as the conditioning activity.

2. METHODS AND MATERIALS

2.1 Participants

The participants for this study were a convenience sample of male and female athletes from Southern Utah University's track and field team; specifically sprinters, jumpers, and hurdlers. Permission from the head coach was granted prior to the study. The student athletes were invited to volunteer for the study. Permission from the University Institutional Review Board for the use human subjects in research was obtained before conducting any training or assessments of the participants. Further, the participants were given a written consent to read and sign before any action in the study was taken. All athletes were 18 years or older. These athletes were experienced in the treatments and testing protocols. By using trained and experienced athletes we hoped to maximize the potential benefits of the PAP WU's, while minimizing the effects of learning between testing procedures. The study was conducted during the athlete's pre-season where the participants were engaged in a supervised and scheduled strength and conditioning program as managed by their Track and Strength/Conditioning coaches. Only healthy athletes who were not injured or recovering from injury were allowed to participate.

2.2 Instruments and Apparatus

All study sessions were held at the Athletic Complex at Southern Utah University. Equipment necessary to conduct this study included a squat rack, 20.45 kg barbell, weighted plates (ranging from 1.14-20.45 kgs) located in the Athletics' weight room. A Brower TC Motion Start Timing System (Brower Timing Systems, Draper, Utah, USA) was used to measure the athletes' speed over a distance of 36.6 meters, with quartile split times recorded by hand with the Accusplit 625M35 stopwatch (Accusplit, Pleasanton, California, USA). The sprints were performed and recorded on the University's competition/practice track that is in close proximity of the weight room.

2.3 Procedures

Participants met for an initial familiarization period and three data collection sessions (each 45 min in length at least 48 hours apart). During the initial familiarization period the participant's height, weight, and age were recorded. Afterwards they were instructed on the WU procedures for the following three sessions and subsequent sprint testing procedures. Noting that all of the participants were proficient in the BL, BS, and sprint activities.

During the three data collection sessions the participants were randomly assigned to one of three WU protocols (dynamic, dynamic plus PAP BL, and dynamic plus PAP BS). All sessions began with a dynamic WU comprised of low intensity exercises that the athletes were familiar with (400 m jog, 20 m lunges, 10 m side lunges both ways, 20 m of alternate-skips, 20 m of back-skips, 2x10 m leg swings (both front and side), 2x80 m submaximal sprint, and walk back). The aim of the dynamic WU was to increase blood flow and body temperature as well as provide sport specific drills to prepare the athletes for the upcoming sprint trials (Baechle & Earle, 2008, p. 296-297).

During the sessions where the participants were randomly assigned to the dynamic only WU, they subsequently waited 5 minutes (rest) and proceeded to have their 36.6 m sprint trials recorded. Three trials were collected of the 36.6 m sprints separated by 3 minutes of rest as described below.

During the session where the participants were randomly assigned to the dynamic and BS PAP WU, the participants repeated the dynamic WU described above followed by performing a progression of BS. The progression of BS included 4-5 sets of 12-6 repetitions of increasing intensity culminating in a BS of 6 repetitions at 80% of a one repetition maximum (1-RM), considered the PAP conditioning activity. Following a five minute rest period, the participants proceeded to perform the three 36.6 m sprint trials.

Likewise, during the session where the participants were randomly assigned to the dynamic and BL PAP WU, the participants repeated the dynamic WU described above followed by performing a progression of BL. The progression of BL included 4-5 sets of 12-6 repetitions of increasing intensity culminating in a BL of 6 repetitions at 80% of 1-RM, considered the PAP conditioning activity. Following a five minute rest period, the participants proceeded to perform the three 36.6 m sprint trials.

The 1-RM BS values had been previously collected (within the last 6 weeks) and were used to calculate each participant's 80% 1-RM BS load and the associated 80% 1-RM of a BL load (Ebben, Feldmann, Dayne, Mitsche, Chmielewski, Alexander, & Knetgzer, 2008) as the PAP conditioning activity intensities.

The sprint testing procedure was designed to test the athlete's speed over a distance of 36.6 m with Brower TC Motion Start Timing System with two photogates (at the start and finish line). Athletes started from a standing position 30cm behind the start line photogate. This starting position has been shown to be reliable when using photogates (Duthie, Payne, Ross, Livingstone, & Hooper, 2006). The starting positions and distance from the first photogate were kept constant for every participant on every trial. The 36.6 m sprint was broken into quartiles where the start and finish were recorded by the Brower System with photo gaits. The quartiles were recorded via stop watch (i.e. by hand) by the Track Coach and PI of the current investigation. Since indoor facility was not available onsite, some consideration was taken with regard to wind and temperature. For each sprint trial a wind gauge was positioned at exactly one half the distance from start to finish (18.3 m), 1.22 meters above the ground, and 2 meters away from the athletes' running lane. Studies examining the effects of wind over a distance of 100m have concluded that the positive effects of a tailwind, are less than the negative effects created by a headwind (Dapena & Feltner, 1987; Linthorne, 1994). For this reason all sprint trials were run in the direction of the wind when wind was present. In addition to running in the direction of the wind we also omitted any data that registered a difference of 2.0 m/s wind speed or greater. Linthorne (1994) concluded that over a distance of 100m, a 2.0 m/s tail wind would provide a 0.10 second advantage for men and a 0.11 second advantage for women. The effects over 36.6 m would be much less. With that said, trial data ≥2.0 m/s wind speed were omitted from analysis. There was no rain on any data collection session and the track was dry during all of the sprint trials. Temperature and time of day were also recorded for every trial, and athletes were limited to sign up for the same time of day for each of their trials.

2.4 Reliability

The reliability of short sprints has been reported to range from r=0.89-0.97 (Miller, 2012). Mayhew, Houser, Briney, Williams, Piper, and Brechue, (2010) reported the reliability of electronic measurement systems as very high (ICC =

0.98). Likewise, the intra-rater reliability of handheld measuring devices has also been reported to be excellent with ICC's ranging from 0.90-0.97. The validity coefficient between electronic and held devices is also considered very high (ICC = 0.98) (Mayhew *et al.*, 2010).

2.5 Design and Analysis

The dependent variables analyzed in this study (36.6 m and the quartile split sprint times) were compared following three WU conditions during three data collection sessions. For each data collection session 3 × 36.6 m sprint trials were collected with the best time of the three trials used for statistical analysis. The study used a randomized repeated measures study design that employed repeated measures ANOVA for statistical analysis for each dependent variable. Bonferroni post techniques were to be employed should statistical significance be achieved following statistical analysis. The statistical significance for this study was set at $\alpha \leq 0.05$. Further, because the participant's in this study were considered highly trained, we considered a meaningful effect size to be 0.5-1.0 standard deviations in sprint times between WU conditions (Miller, 2012).

3. RESULTS

A total of 20 athletes participated in the study, however only 7 males and 9 females completed the study. One male that didn't finish the study was experiencing hamstring tightness and decided to withdraw from the remaining two testing sessions. The others withdrew without explanation. Hence the results of this study are based on 16 participants and their demographics are reported in Table 1.

Table 1: Participant descriptive information (n=16)

	N	Age (years)	Height (cms)	Mass (kgs)	1-RM BS (kgs)	1-RM BS/BM
Female	9	19.9 ± 1.6	171.6 ± 9.1	65.7 ± 13.8	84.6±32.8	1.3±0.2
Male	7	19.6 ± 2.1	181.1 ± 3.0	71.8 ± 4.7	111.7±16.3	1.6±0.2

1-RM BS-one repetition maximum back squat,
1-RM BS/BM- one repetition maximum back squat/body mass

The participant mean and standard deviation 36.6 m sprint times are provided in Table 2 for both the best trial time (lowest) as wells as the average of the three trials. The results of the repeated measures ANOVA suggested that there was no difference in 36.6 m sprint times between the 3 WU strategies ($p>0.05$). Further, a visual inspection of the mean sprint times suggests virtually no difference between WU conditions for both the lowest and 3-trial average scores. As such, percent change and effect size calculations of 36.6 m sprints times between WU conditions were deemed unnecessary.

Table 2: Sprint times 36.6 meters

	Dynamic WU	PAP WU SQ	PAP WU BL
Lowest time	5.17±0.47	5.19±0.48	5.18±0.47
3-trial average time	5.22±0.48	5.23±0.48	5.23±0.50

PAP WU SQ- PAP Warm Up with the Back Squat,
PAP WU BL- PAP Warm Up with the Barbell Lunge

The participant mean and standard deviation of the 36.6 m quartile sprint split times are provided in Table 3 for the average of the three trials. The results of the repeated measures ANOVAs suggested that there was no difference in sprint split times between the 3 WU strategies at any quartile ($p>0.05$). Visual inspection of the mean sprint split times suggests virtually no difference between WU conditions at any quartile. With that said, percent change and effect size calculations of sprint split times between WU conditions were deemed unnecessary and hence not conducted.

Table 3: 36.6 meter sprint quartile split times

Split	Dynamic WU	PAP WU SQ	PAP WU BL
1st Quartile	1.68 ±0.14	1.68 ±0.13	1.67 ±0.15
2nd Quartile	1.18 ±0.12	1.17 ±0.11	1.18 ±0.11
3rd Quartile	1.17 ±0.12	1.16 ±0.13	1.18 ±0.13
4th Quartile	1.14 ±0.15	1.18 ±0.16	1.19 ±0.13
1st -4th Quartiles	5.17	5.19	5.22

4. DISCUSSION

The purpose of this study was to determine if a high intensity BL was superior to a high intensity BS in a PAP WU protocol designed to elicit an acute increase in sprint performance and if either PAP WU strategy was more beneficial than a non-PAP dynamic WU protocol. It was hypothesized that the PAP WU strategy employing the unilateral BL as the conditioning activity would be superior at improving sprint performance when compared to a PAP WU strategy utilizing a bilateral BS as the conditioning activity. Secondarily, we hypothesized that both WU strategies employing a PAP conditioning activity would yield superior sprint performance when compared to a dynamic WU alone. Contrary to our hypothesis, the data recorded during the current study demonstrated almost no difference in sprint times regardless of the WU strategy employed.

The average three trial 36.6 m sprint times recorded in this study for males were 4.78 ±0.20 sec, precisely the same as NCAA Division I North American football tight ends (Miller, 2012). The average three trial 36.6 m sprint times recorded in this study for females were 5.56 ±0.33 secs which are slightly better than normative NCAA Division III female soccer players of 5.34 ±0.17 secs (Hoffman, 2006). The 1-RM BS for male participants in the current study (111.7 ±16.3 kgs) were reflective of 40^{th} $\%^{ile}$ BS scores of NCAA Division I male basketball players (Hoffman, 2006). The 1-RM BS for female participants in this study (84.6 ±32.8 kgs) were reflective of 90^{th} $\%^{ile}$ BS scores of NCAA Division I female softball players (Hoffman, 2006). With regards to the BL, we are unable to find normative BL scores reported in the literature for comparison with those documented in the current study.

The lack of improvement in sprint performance as a result of implementing a PAP scheduled WU is not consistent with previous studies which have demonstrated that a PAP warmup can significantly increase both upper and lower body power output (Harris, Dolny, Browder, Adams & DeBeliso, 2004; Harris, Moore, DeBeliso, Adams, Berning, & Hansen,, 2006; Mallander, Berning, Pederson, Adams, DeBeliso, Stamford, & Maud, 2006; Berning, Adams, DeBeliso, Sevene-Adams, Harris, & Stamford, 2010; Harris, Kipp, Adams, DeBeliso & Berning, 2011; Dove, Sevene, Harris, DeBeliso, Adams, Carson, & Berning, 2013; Hamilton, Berning, Sevene, Adams, & DeBeliso, 2016; Ah Sue, Adams, & DeBeliso, 2016., Tano, Bishop, Berning, Adams, & DeBeliso, in press). More specifically, the lack of improvement in sprint performance in the current study is in direct contrast to previous studies demonstrating that a WU that includes a PAP conditioning activity can acutely enhance sprint performance (Matthews *et al.*, 2004; Rahimi, 2007; Yetter *et al.*, 2008). The training status of an athlete is the primary element required for a PAP WU strategy to be meaningfully exhibited (Gullich & Schmidtbleicher, 1996; Hrysomallis & Kidgell, 2001; Gilbert & Lees, 2005; Kilduff, Bevan, Kingsley, Owen, Bennett, Bunce,... & Cunningham, 2007). Additionally, the National Strength and Conditioning Association (NSCA) states that PAP WU strategies should be “reserved for resistance-trained power athletes with high relative strength” (NSCA Hot Topics, 2016). The participants in this study were NCAA track athletes that were at least 18 years of age and were at least minimally experienced in resistance training and track related physical conditioning protocols. Acknowledging the aforementioned, the participants in the current study did not meet the NSCA’s PAP recommendations for relative strength of a BS 1-RM/body mass equal to ≈2.0. The relative strength of the participant’s BS 1-RM/body mass were 1.3 and 1.6 for females and males respectively. As such, relative strength and prior training status could have been responsible for the lack of improved sprint performance as a result of engaging in a PAP oriented WU strategy. Noting that we are aware of three previous studies where relative strength was well below the NSCA's recommendations and positive results were evidenced as a result of implementing PAP WU protocols (Hamilton *et al.*, 2016; Ah Sue, *et al.*, 2016; Tano *et al.*, in press).

While the prior training status and relative strength could have been a limitation in this study, muscle fiber composition should not have been. It has been suggested that individuals with a muscle fiber composition that is predominantly fast twitch have a greater likelihood of experiencing a positive result of a PAP WU strategy on muscle power performance enhancement (Hamada, Sale, MacDougall, & Tarnopolsky, 2000). The participants in this study were collegiate level athletes that competed in sprinting, hurdling, and jumping events; indicative of a predominance of fast twitch fibers. Fast twitch fibers are presumed to experience a greater degree of phosphorylation as a result of a PAP excitation event (conditioning activity), and hence potentiation, than slow twitch fibers (Metzger, Greaser, & Moss,1989; Moore, & Stull, 1984). As such, study participant fiber type composition should not have been a limitation in this study.

The success of a PAP protocol is based on finding the optimal stimulus that allows the coexistence of fatigue while the muscles are in a potentiated state (Rassier & MacIntosh, 2000). Previous studies that have failed to induce a meaningful level of the PAP phenomena may have not provided sufficient recovery time following the conditioning activity, hence, fatigue was likely not in co-existence with the level of muscle potentiation (Arias, Coburn, Brown, & Galpin, 2016). Recovery periods subsequent to the PAP conditioning activity have been shown to be critical with respect to optimizing the outcome of a PAP protocol, noting that 3-12 minutes has been identified as ideal in well trained athletes (Gullich & Schmidtbleicher, 1996; Kilduff, *et al.*, 2007). The current study used a rest period of 5 minutes and likely did not play a role in the lack of a measurable PAP effect on sprint performance.

Previous PAP studies have suggested a potentiating period of 2-20 minutes (NSCA Hot Topics, 2016) following the PAP conditioning activity with the optimal muscle potentiation occurring at 10 minutes (Ah Sue *et al.*, 2016). The sprint trials in the current study were collected at 5, 8, and 11 minutes following the PAP conditioning activity. As such, we did not feel as though the timing of collecting the sprint trials had been outside of the PAP potentiation window.

According to the NSCA the "intensity of contraction is the most important factor in the selection of a potentiating exercise" (NSCA Hot Topics, 2016). In retrospect, the lack of a meaningful PAP effect on sprint performance in the current study may be related to the intensity used with the conditioning activity modalities. The current study used both the BS and BL as the conditioning activity modalities performed for 6 repetitions at 80% of a 1-RM. It is possible that using a greater % of a 1-RM may have yielded a meaningful PAP effect on sprint performance.

Our initial hypothesis that attempted to compare the PAP effect of a BS to a BL was based on the concept of specificity. Crewther *et al.* (2011) concluded that the potentiating effects of a PAP protocol were derived from some degree of movement specificity. The concept of specificity states that the more similar the training activity is to the sport movement, the greater the likelihood there will be a positive transfer to that sport (O'Shea, 2000). The first and easiest way for strength and conditioning professionals to incorporate specificity in training is to analyze the sport activity and determine the most important muscles in the activity. It is obvious that unilateral, alternating, hip and knee extension are crucial to sprinting; a movement closely approximated by the unilateral lunge.

High intensity BS have proven to be effective as a PAP conditioning activity modality (NSCA Hot Topics, 2016), but there may be two reasons why a weighted lunge could be an exceptional alternative. First, a lunge may be more biomechanically similar to sprinting because sprinting and lunges have unilateral attributes. Second, the strength and power of hamstring and hip extensor muscles are essential in producing the rapid horizontal displacement characteristic of high movement velocities (Baechle & Earle, 2008, p. 467-468; Higashihara, Ono, Kubota, Okuwaki, & Fuckubayashi, 2010). Though the research is limited, studies comparing the lunge and modified single leg squats to a traditional BS have shown increased electromyography levels in the hamstrings and hip extensor muscles during single leg exercises (Boudreau, Dwyer, Mattacola, Lattermann, Uhl, & McKeon, 2009; Fauth *et al.*, 2010; McCurdy, O'Kelley, Kutz, Langford, Ernest, & Torres, 2010). Hence, suggesting the BL maybe superior to the BS as a PAP conditioning activity modality in order to enhance sprint performance.

5. CONCLUSIONS

This study failed to demonstrate a meaningful PAP effect on sprinting performance when using a bilateral BS or unilateral BL as the PAP conditioning activity modalities. We suggest that the current study should be replicated with participants with greater relative strength and performing the PAP conditioning activity modalities at a greater intensity (85-90% of 1-RM). Finally, future PAP related studies should give attention to the issue of specificity as it relates to the PAP conditioning activity modality and the targeted sport activity.

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