Journal of Physical Education Research, Volume 6, Issue II, June 2019, pp.01-09
ISSN: Print-2394 4048, Online-2394 4056

THE ACUTE EFFECTS INCORPORATING A RESISTIVE EXERCISE ON SPRINT TIMES IN HIGH SCHOOL TRACK ATHLETES

K. STARKER, ABIGAIL LARSON, MARK DEBELISO*
Department of Kinesiology and Outdoor Recreation, Southern Utah University, Cedar City, UT, USA.
***Email:** markdebeliso@suu.edu*

How to cite this article: Starker, K., Larson, A., & DeBeliso, M. (June, 2019). The acute effects incorporating a resistive exercise on sprint times in high school track athletes. Journal of Physical Education Research, Volume 6, Issue II, 01-09.

Received: May 02, 2019 **Accepted:** June 15, 2019

ABSTRACT

The ability to achieve high velocities in a short period of time is a prerequisite for success in many sporting activities. Post activation potentiation (PAP) can be defined as an increase in neuromuscular activity that occurs immediately after a high intensity exercise or conditioning activity (Lim & Kong, 2013). PAP may improve subsequent exercise performance that requires high muscular power output. This study attempted to determine the acute effects of incorporating a resistive sprint exercise as a PAP conditioning activity on subsequent sprint time in high school track athletes. It was hypothesized that pulling a weighted sled at 10-15% of one's body weight, 3-4 minutes prior to a maximal effort 36.6 meter sprint, would significantly decrease time required to complete the sprint compared to a standard dynamic WU. A randomized repeated measures crossover study design was used to test fifteen high school track athletes (9 male, 6 female). Each participant completed two testing sessions: a dynamic WU prior to a 36.6 meter sprint and a dynamic WU followed by a resisted sled sprint pull as a PAP conditioning (10-15% of body mass) prior to a 36.6 meter sprint. Testing occurred on two different days with at least 48 hours between each session. A paired T-test was used to determine if there were significant differences in sprint times between WU strategies. The sprint times following the dynamic WU combined with a subsequent PAP conditioning activity were significant lower than the sprint times following a dynamic WU alone ($p<0.05$). Within the parameters of this study, a dynamic WU followed by a resisted sled sprint pull as a PAP conditioning activity improves sprint performance when compared to a dynamic WU alone.
***Keywords:** Post activation potentiation, warmup, sprint performance, weighted sled pull.*

1. INTRODUCTION

The use of post activation potentiation (PAP) warmup (WU) protocols have been shown to be an effective means to enhance speed and acceleration (Winwood, Posthumus, Cronin, & Keogh, 2016). Within the context of sprint performance, even very small improvements in finish time can be meaningful. Improvements in sprint performance can be achieved via faster reaction time, increased explosiveness off the blocks, and improved acceleration, the latter two are highly dependent on lower body power production and application (Saraslanidis, 2000). Power is the rate of performing work, (Delecluse et al., 1995) hence to increase power production an athlete must either increase ability to generate force or increase velocity of movement. Velocity of movement can be trained to some extent, but force production appears to be more adaptable to exercise training (Saraslanidis, 2000).

In most athletic competition scenarios, the ability to generate forces quickly (power) is more important than simply being able to generate high forces (strength). Specifically, an athlete's ability to accelerate, as well as maximal velocity, is a major determinant of success in many athletic pursuits. Factors such as age, muscle architecture, myofibril type, and muscle coordination influence acceleration and speed capacities (Blazevich, Cill, Bronks, & Newton, 2003; Smirniotou, 2008). In turn, these variables ultimately affect stride length (SL) and stride frequency (SF) (Saraslanidis, 2000). Improvements SL and/or SF will improve sprint speed.

Multiple training techniques can be used to improve SL and/or SF including: repetitive sprint training, tempo running, interval training, resistance training (RT), and plyometric training (Blazevich et al., 2003). Maximal gains in force output and velocity of movement are optimized when the training program promotes neuromuscular adaptations (Martinopoulou, Argeitaki, Paradisis, Katsikas, & Smirniotou, 2011). These adaptations include reduced neurological inhibition impulses in GTO's and muscle spindles, increased motor unit (MU) recruitment, improved synchronicity of MU recruitment, increased recruitment of high threshold MUs (more fast twitch fibers are recruited), increased firing rates, inhibition of antagonist

Correspondence: Mark DeBeliso (Ph.D.), Professor, Department of Physical Education and Human Performance, Southern Utah University, Cedar City, USA, Tel: 435-586-7812, Email: markdebeliso@suu.edu

muscles, increased acetylcholine release and/or increased sensitivity of acetylcholine receptors (Delecluse et al., 1995).

Resistive sprint training is a commonly used training technique that is designed to create an overload effect when using sled pulls/pushes, parachutes, and/or weighted vests (Khodaei, Mohammadi, & Badri, 2017). These training methods have been shown to increase neural activation and the recruitment of fast-twitch muscle fibers. Researchers suggest that resistive sprint training can improve SL as the result of enhanced muscular force output of the hip and knee extensors (Tabachnik, 1992; Upton, 2011).

Another method used to improve sprint performance is post-activation potentiation (PAP). PAP is the increase in neuromuscular activity after a high intensity exercise or a conditioning activity (Lim & Kong, 2013). The use of PAP conditioning activities as a means to improve maximal sprint ability has been studied by several researchers (Kopp & DeBeliso 2017; Lim & Kong, 2013; Matthews, Matthews, & Snook, 2004; Springall, Larson, & DeBeliso, 2017; Smith et al., 2014; Tano, Bishop, Climstein, & DeBeliso, 2016; Winwood et al., 2016; Till & Cooke, 2009) with equivocal findings. Matthews et al., (2004) found a 3.3% improvement in sprint performance ($p<0.0001$) when using a back squat (BSQ) PAP WU protocol, including 5 repetitions with the athlete's 5 repetition maximum (RM) compared to a dynamic WU protocol in 20 trained male rugby athletes. Likewise, Yetter et al., (2008) used 10 strength training athletes and found a 2.3% improvement in sprint speed ($p<0.05$) when using a BSQ as a PAP WU protocol of 3 repetitions at 70% of the athletes 1RM, compared to a dynamic WU.

Many other studies have found no significant difference in sprint performance when using a PAP WU protocol compared to a dynamic WU protocol (Springall, Larson, & DeBeliso, 2017; Lim & Kong, 2013; Till & Cooke, 2009). Springall et al., (2017) tested 16 NCAA male and female track athletes to determine the effect of a PAP WU on sprint speed. The PAP WU included 6 repetitions of a barbell lunge or 6 repetitions of a barbell BSQ at 80% of the athlete's 1RM. Neither the lunge nor BSQ improved subsequent sprint performance compared to a dynamic WU ($p>0.05$). Similarly, Lim and Kong (2013) did not find a significant improvement in sprint speed ($p>0.05$) after using a PAP WU protocol that incorporated 3 repetitions of heavy BSQs in 12 trained track male athletes when compared to a dynamic WU protocol.

The majority of previous research has used heavy lifting modalities as the PAP conditioning activity. However, Winwood et al., (2016) and Smith et al., (2014) utilized a weighted sled pull protocol that varied in loads. Smith et al., (2014) used 24 anaerobically trained men and women and found a 2.24% improvement in sprint speed ($p<0.05$) when using a weighted sled pull ranging from 10-30% of the participant's body weight compared to a dynamic WU. Likewise, Winwood et al., (2016) found a 3.3% improvement in sprint performance using a weighted sled pull with a 75% of body weight load compared to a dynamic WU in 22 male rugby athletes.

Results from the aforementioned research supports the idea that a resistive sprint exercise serving as a PAP conditioning activity can result in subsequent enhancements in sprint time. It is unclear if a heavy lifting protocols improves sprint performance to a greater degree than a restive sprint protocol because there is a relative dearth of studies examining the latter. Utilization of a PAP conditioning activity technique that is biomechanically similar to sprinting such as a resistive sprint exercise, may allow for optimal potentiation of the specific motor units and muscle fibers required for sprint acceleration. Therefore, the purpose of this study is to determine if a PAP WU protocol comprised of a dynamic WU followed by a resistive sprint sled pull as a conditioning activity, is superior to a dynamic WU protocol alone for the purpose of enhancing 36.6 meter sprint in high school track athletes. This specific population was chosen because it is relatively underrepresented within this field of study.

2. METHODS AND MATERIALS

2.1 Participants

Participants in this study included high school male and female track athletes ages 15-18. All participation was voluntary. Injured or recently injured athletes were not allowed to participate. Prior to signing the informed consent, athletes were given instructions of all tasks and techniques required for testing and informed that they may withdraw at any time during the study. Prior to data collection, informed consent and parental consent of those under the age of 18 was obtained for all participants. Prior to participant recruitment, study approval (as well as informed consent documents) was granted by Southern Utah University Institutional Review Board.

While experience in the treatments and testing protocols varied (1-6 years), all athletes were familiar with the exercise testing modalities. The study was conducted during the athlete's post season of track and field and participants were routinely engaging in light training activities.

2.2 Instruments and Apparatus

Testing sessions and assessments were performed at the Port Angeles High School's outdoor track (Port Angeles, Washington USA) (Figure 1). All trials were conducted on a dry synthetic track surface. Trials were conducted in the evening with stable weather conditions. Instruments used in this study included a measuring tape, cones, hand held stopwatches, a sled (2.72 kg) with one metal tube (38.1cm) and a waist harness that connected to the sled via dual leads (9.74 m) (Figure 1). Weighted plates ranging from 4.54-11.34 kg were placed on the metal tube and were with the intention of yielding 10 – 15% of the participant's body mass (total sled load per participant=10 to 15% body mass + sled mass). A measuring tape was used to measure out the distance of 36.6 meters while cones were used as visual aids for the athletes to have a clear reference point from beginning to end. A LCD Chronograph Sports Stopwatch was used to measure time of each 36.6 meter sprint. A trained research assistant who was unaware of the study hypothesis conducted all timing. The reliability of handheld measuring devices has been reported to be exceptional with an ICC of 0.98 for the 36.6 meter sprint test (Mann, Ivey, Brechue, & Mayhew, 2015). The 36.6 meter sprint is a valid and reliable means to measure speed with test-retest reliability reported to range from 0.87-0.96 (Mckay, Miramonti, Jenkins, Gillen, & Leutzinger, 2017). All instruments were provided by the Port Angeles High School (Port Angeles, Washington USA).

Figure 1: Port Angeles High School Track and resistive pulling sled

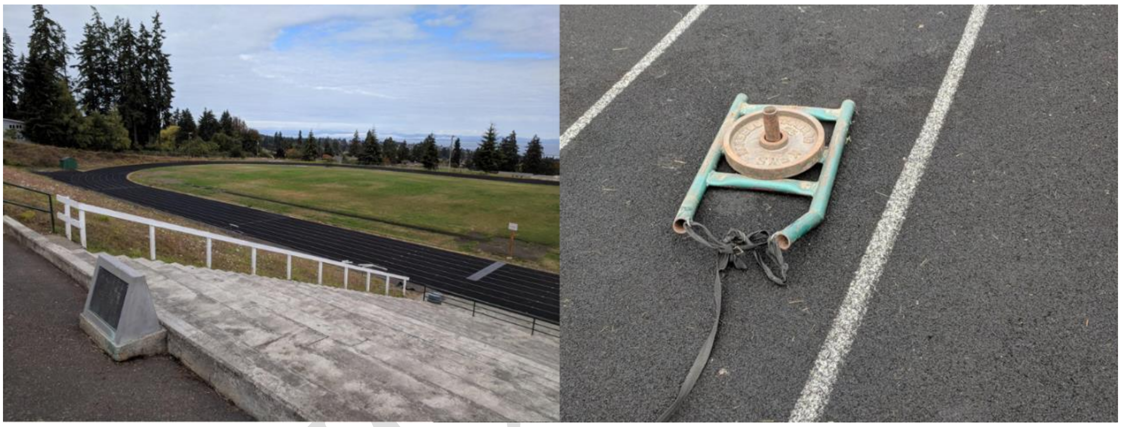
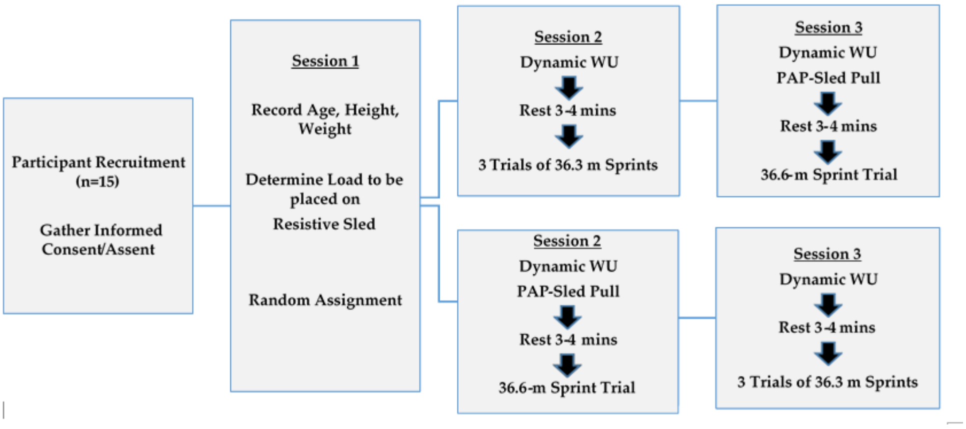


Figure 2. Summary of study events (left to right). PAP-post activation potentiation



WU-warm up

2.3 Procedures

Each participant was randomly assigned to perform one of two WU conditions prior to sprinting 36.6 meters trials. Athletes were then given a 48 hour recovery period until the next session in which each participant performed the alternate WU condition. Athletes met after practice for an initial evaluation where each participant's height, weight, and age were recorded (Figure 2). After, participants were instructed on the WU procedures for the following two sessions and subsequent sprint testing procedures. All testing was done during the athlete's track and field post-season.

Athletes were randomly assigned to complete one of the two WU protocols: a dynamic WU, and the same dynamic WU followed by a PAP conditioning activity. The PAP conditioning activity was the pulling of a sled loaded to 10-15% of the participant's body mass and was conducted on the same track surface as was the sprint trials. The study employed a repeated measures crossover design where half of the participants performed the dynamic WU alone and the other half of the participants performed the dynamic WU followed by a PAP conditioning activity during the first session. During session two the participants crossed over with respect to the WU procedures prior to the sprint trials.

The dynamic WU which was familiar to the participants included: a 400 meter jog, 20 meter a skips, b skips, c skips, lunges, side lunges, quadriceps stretch, single-leg unweighted Romanian deadlift (RDL), hamstring stretch, eight leg swings on each leg, followed by 3x60 meter submaximal sprints with a walk back. Participants were given 3-4 minutes after their WU to prepare for their 36.6 meter sprint trials. Performing a 36.6 meter sprint utilizes primarily the ATP-CP system which requires a recovery period of at least 3 minutes to restore resting ATP and creatine phosphate levels (Martinopoulou et al., 2011).

During the dynamic only WU session, each athlete performed three 36.6 meter sprints running with 3-4 minutes recovery between each trial. All athletes started out in a three point stance and wore personal competition-style track spikes.

Likewise, during the dynamic WU followed by a PAP conditioning activity session, athletes completed the dynamic WU described above followed by a 36.6 meter weighted sled pull at 10-15% of body weight. All athletes wore track spikes and started in a three point stance. Athletes were instructed to run at maximum velocity. After the weighted sled pull, athletes were given a rest period of 3-4 minutes prior to performing an unweighted maximal 36.6 meter sprint.

Each sprint trial was done at about the same time of day with relatively similar temperatures and wind speeds of 2.0 m/s with no record of wind gusts according to the National Weather Service (https://www.weather.gov/). There was no rain and the track was dry during all of the sprint trials on both data collection days.

2.4 Design and Analysis

This repeated measures cross-over design examined 36.6meter sprint time after a dynamic WU compared to the same dynamic WU followed by a subsequent PAP conditioning activity (resistive sprint sled pull). Times for the three sprint trials in the dynamic WU protocol were averaged and compared to the sprint times collected after the dynamic WU with a subsequent PAP conditioning activity. Likewise, the lowest of the three sprint trials collected following the dynamic WU alone were compared to the sprint times following the dynamic WU with a subsequent PAP conditioning activity. Differences in sprint time were analyzed via paired samples t-tests. Significance for the study was set *a priori* $\alpha \leq 0.05$. Further, given the concerns regarding reproducibility of research (Open Science Collaboration, 2015) and relying solely on p-values as the means of assessing the outcome of a research investigation (Amrhein, Korner-Nievergelt, & Roth, 2017); the American Statistical Association (ASA) (Wasserstein, & Lazar, 2016) suggests "a variety of numerical and graphical summaries of data". As such, effect size calculations were also conducted. Statistics were carried out in Microsoft Excel 2013 as well as with the assistance of an Excel spreadsheet provided by McDonald (2014). The spread sheet of data was peer reviewed for errors as suggested by Al Tarawneh and Thorne (2017).

3. RESULTS

Fifteen participants (female=6, male=9) completed the study without incident and the demographics are presented in Table 1. The average body mass percentage used for the sled pulls was 16.5%±2.5% (total sled load per participant=10 to 15% body mass + sled mass), which was slightly greater than that previously recommended (10-15%) in order to increase sprint speed (Alcaraz et al., 2009).

The results of the paired t-test suggest there is a significant improvement in sprint times following a PAP WU (comprised of a dynamic WU followed by a PAP conditioning activity of a resistive sprint sled pull) when compared to a dynamic WU alone ($p < 0.01$), see table 2 and 3. The average of the three trial 36.6 meter sprint times following the dynamic WU for males and females was 5.52±0.27 seconds and 6.17±0.57 seconds, respectively. The lowest sprint times for males and females was 5.36±0.22 and 6.06±0.59 respectively, when using a dynamic WU protocol in comparison to 5.28±0.23 and 5.92±0.62 when incorporating a PAP WU protocol. The results of this study show a significant difference (improvement) when using a PAP WU protocol compared to a dynamic WU protocol ($p < 0.01$).

Table 1: Participant descriptive information

	Age (years)	Height (cm)	Mass (kg)	BMI	% of BM
Female (n=6)	16.0±1.1	156.2±3.5	52.2±1.2	21.4±0.9	8.6±0.2
Male (n=9)	16.8±0.7	183.7±9.7	77.2±5.8	22.9±1.6	14.7±1.1

Percentage (%) of BW-indicates the mean and standard deviation for the percent of body mass pulled in the post-activation potentiation activity, mean±SD, BMI-body mass kilograms/height (meter)^2.

Table 2: Sprint trial data (seconds)

	Trial 1	Trial 2	Trial 3	Trial Average	Trial Lowest	PAP WU
Female (n=6)	6.17±0.57	6.24±0.61	6.11±0.55	6.17±0.57	6.06±0.59	5.92±0.62*
Male (n=9)	5.55±0.37	5.54±0.25	5.47±0.29	5.52±0.27	5.36±0.22	5.28±0.23*

Trial Average-average of trial sprint times following the dynamic WU, PAP WU-sprint time following the PAP WU, *significantly lower than the lowest dynamic WU sprint trials (p<0.01).

Table 3: Female and Male Combined Sprint times 36.6 Meter

	Dynamic WU	PAP WU	Effect Size
Lowest time*	5.64±0.51**	5.54±0.52	-0.20
3-trial average time	5.78±0.52***	-	-0.47

Mean±SD of the lowest 36.6 meter dash times following the dynamic warmup (WU) protocol, PAP WU-post activation potentiation warmup protocol using a weighted sled pull as the PAP conditioning activity, ** Significantly greater than PAP WU (p<0.01), *** significantly greater than PAP WU (p<0.01).

4. DISCUSSION

The purpose of this study was to determine if a resisted sprint sled pull as a PAP conditioning activity in conjunction with a dynamic WU was superior to a dynamic WU alone for the purpose of enhancing 36.6 meter sprint times. It was hypothesized that the resisted sprint sled pull as a PAP conditioning activity in conjunction with a dynamic WU protocol would significantly decrease sprint times compared to a dynamic WU alone. The study results demonstrated that the resisted sprint sled pull as a PAP conditioning activity in conjunction with the dynamic WU significantly improved 36.6 meter sprint times ($p < 0.01$). The results of this study are consistent with other studies (Matthews et al., 2004; Smith et al., 2014; Winwood et al., 2016) which have shown acute improvements in speed as a result of implementing a weighted sled pull as a PAP conditioning activity.

The participants in this study were high school track athletes that had basic experience in resistive sprint training and other track related conditioning protocols. Previous studies have also used experienced athletes, familiar with the 36.6 meter sprint and weighted sled pulls; in these studies pulled weight varied from 10-150 % body mass (Smith et al., 2014; Winwood et al., 2016). Smith et al., (2014) found that a load of 10%, 20%, and 30% of body mass had a potentiating effect on subsequent sprint performance (p<0.05) while, Winwood et al., (2016) found that a load of 75% had a similar effect (p<0.05). These studies suggest that sled pull workloads below and above the previously recommended percent of body weight by Alcaraz et al. (2009) are also efficacious for inducing PAP. In the present study, female participants pulled and average of 13.8±0.3% of body mass and had an improvement of 0.26±0.08 seconds (average 3 trials), while male participants pulled an average of 18.3±1.4% of body weight and improved by 0.24±0.15 seconds (average 3 trials) compared to the dynamic WU trial. This may suggest that a PAP resistive sled sprint exercise that use loads of <18% of body mass may be effective loading for improving subsequent sprint performance in high school athletes. The results of the current study are consistent with the findings of previous studies in that inclusion of a PAP conditioning activity in combination with a dynamic WU enhances both upper and lower body muscular power output (Ah Sue et al., 2017; Berning et al., 2010; Dove et al., 2013; Hamilton et al., 2016; Harris et al., 2004; Harris et al., 2006; Harris et al., 2011; Mallander et al. 2008; Tano et al., 2016).

Recent research (Senefeld et al., 2018) has identified gender differences with respect to muscle fatigability and recovery for certain tasks. With that said we attempted to determine if there was a gender difference with respect to a PAP effect (or response) in the current study. All of the female athletes (6 of 6) experienced a PAP effect while only 6 of the nine male participants experienced a PAP effect. Statistical examination comparing the number of PAP responders versus non responders between genders via a Fishers Exact test (as recommended by McDonald, 2014) suggested there was not a significant difference in the number of responders between genders ($p=0.23$). In our opinion, this is precisely why the ASA (Wasserstein, & Lazar, 2016) suggests “a variety of numerical and graphical summaries of data”. While the p-value suggests no difference between genders regarding a PAP effect (i.e. response), only 66.7% of the male athletes experienced a PAP effect while 100% of the female athletes experienced a PAP effect. From a clinical/pragmatic perspective, the data regarding gender and PAP effect has value for coaches and athletes to keep in mind when designing PAP protocols.

Another issue to keep in mind regarding the resistive load being pulled has to do with the issue of mass versus force and friction coefficients (Tano et al., 2016). In the current study we have reported the total sled load per participant as equal to 10 to 15% body mass + sled mass. However, mass (kgs) is not force (Newtons) and to calculate the actual resistive force a few steps must be followed. Specifically, the resistive force (Newtons) that the sprinter needs to overcome is equal to the (total sled load (kgs) * 9.81 m/s2) * coefficient of friction between the sled and the ground surface. Different ground surfaces and sled to ground interface surfaces will have varying coefficients of friction. As such, practitioners need to keep these variables in mind when trying to develop specific PAP protocols that are unique to the training or competitive environment.

Resistive sprint pulls likely acutely enhance sprint performance via similar mechanisms as other PAP exercises. Previous research has explained that this ergogenic phenomena is a result of increased neural activation and muscle fiber recruitment of both the knee and hip joint muscles (Cissik, 2005; Delecluse et al., 1995). Motor neuron enhancement can increase fast twitch muscle fiber recruitment which in turn can increase power output (Dutie et al., 2002). Other contributing factors may include increase in reflux electrical activity, psychomotor enhancement, increased blood flow to muscles, and increased myosin light chain phosphorylation. Specifically, as myosin becomes phosphorylated it binds to actin more rapidly due to the saturation of calcium that is present during the muscular contraction of a PAP exercise (Dutie et al., 2002; Grange et al., 1993; Sweeney et al., 1993). The success of a PAP protocol is dependent on the recovery time. Recovery periods subsequent to a PAP conditioning activity are critical with respect to optimizing the outcome of a PAP protocol. Previous PAP studies have had successful outcomes with resting periods between 2-12 minutes in well trained athletes (Kilduff, et al., 2007; Ah Sue, Adams & DeBeliso, 2016). The current study used a potentiating period of 3-4 minutes allowing sufficient recovery not only for optimal muscle potentiation, but also for the creatine phosphagen energy system used in a 36.6 meter dash. Previous studies that have failed to exemplify a PAP phenomenon may have not provided sufficient recovery time following the PAP conditioning activity.

The mechanism for enhanced sprint performance was not directly eluded in the present study. Another limitation to the present study includes the lack of comparison between the weighted sled pull and other PAP exercises, such as heavy squatting, and subsequent improvements in sprint performance.

This study tested the effect of PAP on sprint performance in a young and well trained population, previous research shows that implementing a PAP conditioning exercise prior to sprinting may enhance sprinting performance (Dutie et al., 2002; Hrysomallis et al., 2001; Matthews et al., 2004; Smith et al., 2014; Till et al., 2009; Winwood et al., 2016). The experience and training status of an athlete are crucial when implementing a PAP conditioning activity, based on the previously discussed mechanisms (Dutie et al., 2002; Gilbert et al., 2005; Matthews et al., 2004). Athletes who are not well trained, may not benefit from PAP WU protocol due to muscle fatigue that is associated with an intense conditioning activity which could hinder subsequent enhanced muscle contractility (Raiser et al., 2000; Hrysomallis et al., 2001).

Not all research has shown enhanced sprint performance when implementing a PAP WU protocol compared to a dynamic WU alone (Springall et al., 2017; Lim & Kong, 2013). Both of the referenced studies used weighted exercises such as BSQs, knee extensions and barbell lunges. In these studies there was no statistical difference ($p>0.05$) between any of the PAP protocols and sprint speed when compared to a dynamic WU alone. One reason for the lack of a PAP effect in the aforementioned studies may have to do with the selection of the PAP conditioning activity. The BSQ and lunge are axial load vectors while sprinting is an anteroposterior load vector (Contreras, 2017). A further explanation of a lack of a PAP effect in the aforementioned studies may be due to the relative strength of the athletes or prior training status as both studies showed low relative BSQ strength. The NSCA's PAP recommendations for relative strength of a BS 1-RM/body mass is equal to ≈2.0 (NSCA Hot Topics, 2016). The relative strength of the participant's BS 1-RM/body mass found in the Springall et al., (2017) study was 1.3 and 1.6 for females and males respectively, while Lim et al., (2013) study showed BS 1-RM/body mass of 1.8. In the present study testing for relative strength was not conducted, but based off visual speculation the majority of athletes would not meet NSCA requisite of being able to BSQ double of one's body mass. With that said, this is the fifth such study we are aware of in which study participants demonstrated a PAP effect in spite of their relatively lower body strength (Ah Sue et al., 2016; Hamilton et al., 2016; Kopp et al., 2017; Tano et al., 2016).

Additionally, both Springall et al., 2017 and Lim et al., 2013, performed their study during the athletes' pre-season, while the present study was performed during the off season as was Winwood et al., 2016 study. It is unclear whether the training status of an athlete during pre-season as compared to the post-season could have an effect on the efficacy of PAP protocols, but should be taken into consideration and is a potential avenue for future research.

5. CONCLUSION

In respect to the present study, additional research should be considered while replicating a similar protocol and design with a greater number of participants and the number of post PAP WU sprint trials. Due to time constraints, limited PAP WU sprint trials were carried out during the current study. Perhaps additional post PAP WU sprint trials would identify an even greater PAP effect on sprint performance as well as provide insight as to the duration on the PAP effect (i.e. elevated physiologic performance state). Researchers should also compare the weighted sled pull to other PAP protocols in order to determine which protocol is more feasible for enhancing sprint performance. Future studies also need to test a variety of loads using the athlete's body weight. The present study was able to show an acute decrease in sprint time after performing a sled pull at 13–18% of body mass, perhaps lighter loads maybe just as effective. Likewise, researchers should explore if PAP WU protocols are effective for longer sprint events (i.e. 100-400 meters).

Coaches and athletes that are considering using PAP protocols to enhance sprint performance should decide to do so on an individual basis and only in well-trained uninjured athletes with high relative lower body strength. Likewise, optimal intensity of the PAP exercise and recovery time after the PAP exercise have not yet been clearly elucidated, therefore PAP WU protocols should be used with caution.

6. REFERENCES

Ah Sue, R. Adams, K.J., & DeBeliso, M. (2016). Optimal timing for postactivation potentiation in women collegiate volleyball Players. *Sports, 4*(2), 27.

Alcaraz, P.E., Palao, J.M., & Elvira, J.L.L. (2009). Determining the optimal load for resisted sprint training with sled towing. *Journal of Strength and Conditioning Research, 23*(2), 480-485.

Alcaraz P.E., Palao J.M., Elvira J.L., & Linthorne N.P. (2008). Effects of three types of resisted sprint training devices on the kinematics of sprinting at maximum velocity. *Journal of Strength and Conditioning*, 22(3), 890-897.

AlTarawneh, G., & Thorne, S. (2017). A pilot study exploring spreadsheet risk in scientific research. *arXiv preprint arXiv:1703.09785*. arvix.org, Ithca, NY.

Amrhein, V., Korner-Nievergelt, F., & Roth, T. (2017). The earth is flat (p> 0.05): Significance thresholds and the crisis of unreplicable research. *PeerJ 5*, e3544.

Berning, J.M., Adams, K.J., DeBeliso, M., Sevene-Adams, P.G., Harris, C., & Stamford, B.A. (2010). Effect of functional isometric squats on vertical jump in trained and untrained men. *The Journal of Strength Conditioning and Research*, 24(9), 2285-2289.

Blazevich, A., Cill, N., Bronks, R., & Newton, R. (2003). Training specific muscle architecture adaptation after 5wk training in athletes. *Medicine and Science in Sports and Exercise, 35*, 2013-2022.

Contreras B. (2017). Force Vector Training, in: *NSCA Strongest Links*. https://www.nsca.com/Education/Articles/Force-Vector-Training/ Downloaded 7.10.2017.

Cissik, J.M. (2005). Means and methods of speed training: Part II. *Strength & Conditioning Journal, 27*(1), 18-25.

Delecluse, C., Van Coppenolle, H., Willems, E., Van Leemputte, M., Diels, R., & Goris, M. (1995). Influence of high-resistance and high-velocity training on sprint performance. *Medicine and Science in Sports and Exercise, 27*(8), 1203-1209.

Dietz, V., Schmidtbleicher, D., & Norht J. (1979). Neuronal mechanism of human locomotion. *Journal of Neurophysiology, 42*, 1212-1222.

Dove, B.C., Sevene, T.G., Harris, C., DeBeliso, M., Adams, K.J., Carson, C.A., & Berning, J.M. (2013). 5RM Bench press increases medicine ball put distance in untrained males but not untrained females. *Medicine and Science in Sports and Exercise*, 45(5), S597.

Duthie, G.M., Young, W.B., & Aitken, D.A. (2002). The acute effects of heavy loads on jump squat performance: an evaluation of the complex and contrast methods of power development. *Journal of Strength and Conditioning Research,* 16, 530–538.

Grange, R.W., Vandenboom, R., & Houston, M.E. (1993). Physiological significance of myosin phosphorylation in skeletal muscle. *Canadian Journal of Applied Physiology*, *18*, 229–242.

Gilbert, G., & Lees, A. (2005). Changes in the force development characteristics of muscle following repeated maximum force and power exercise. *Ergonomics*, 48, 1576–1584.

Hamilton, C., Berning, J.M., Sevene, T.G., Adams, K.J., & DeBeliso, M. (2016). The effects of post activation potentiation on the hang power clean. *Journal of Physical Education and Research*, 3(1), 1-9.

Harris, C., Dolny, D., Browder, K., Adams, K.J., & DeBeliso, M. (2004). The effect of prior contractile activity on power output. *Medicine and Science in Sports and Exercise,* 36(5), S2379.

Harris, C., Moore, J., DeBeliso, M., Adams, K.J., Berning, J., & Hansen, C. (2006). The effects of heavy squats on potentiating 30 second Wingate test performance. *Medicine and Science in Sports and Exercise*, 38(5), S292.

Harris, C., Kipp, K., Adams, K.J., DeBeliso, M., & Berning J.M. (2011). The effects of high intensity warm-up on shot put performance. *Medicine and Science in Sports and Exercise*, 43(5), S600.

Hrysomallis, C., & Kidgell, D. (2001). Effect of heavy dynamic resistive exercise on acute upper-body power. *Journal of Strength and Conditioning Research, 15*, 426–430.

Jakalski, K. (1998). The pros and cons of using resisted and assisted training methods with high school sprinters parachutes, tubing, and towing. *Track Coach*, 144, 4585-4589.

Khodaei, K., Mohammadi, A., & Badri, N. (2017). A comparison of assisted, resisted, and common plyometric training modes to enhance sprint and agility performance. *The Journal of Sports Medicine and Physical Fitness,* 57 (10), 1237-1244.

Kilduff, L.P., Bevan, H.R., Kingsley, M.I., Owen, N.J., Bennett, M.A., Bunce, P.J., & Cunningham, D.J. (2007). Postactivation potentiation in professional rugby players: optimal recovery. *Journal of Strength & Conditioning Research*, *21*(4), 1134-1138.

Kopp, K., & DeBeliso, M. (2017). Post-activation potentiation of a BSQ to Romanian deadlift superset on vertical jump and sprint time. *International Journal of Sports Science*, *7*(2), 34-36.

Lim, J.J., & Kong, P.W. (2013). Effects of isometric and dynamic postactivation potentiation protocols on maximal sprint performance. *Journal of Strength and Conditioning Research, 27*(10), 2730-2736.

Lockie, R.G., Murphy, A.J., & Spinks, C.D. (2003). Effects of resisted sled towing on sprint kinematics in field-sport athletes. *Journal of Strength and Conditioning Research, 17*(4), 760-767.

Mallander, S., Berning, J., Pederson, S., Adams, K.J., DeBeliso, M., Stamford, B., & Maud, P. (2008). 5RM bench increases medicine ball put distance in trained males and females. *Medicine and Science in Sports Exercise,* 40(5), S262.

Mann, J.B., Ivey, P.J., Brechue, W.F., & Mayhew, J.L. (2015). Validity and reliability of hand and electronic timing for 40-yd sprint in college football players. *Journal of Strength and Conditioning Research, 29*(6), 1509-1514.

Martinopoulou, K., Argeitaki, P., Paradisis, G., Katsikas, C., & Smirniotou, A. (2011). The effects of resisted training using parachute on sprint performance. *Biology of Exercise, 7*(1), 7-23.

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

McDonald, J. H. (2014). Handbook of Biological Statistics (3rd ed.). Sparky House Publishing, Baltimore, Maryland. This web page contains the content of pages 77-85 in the printed version. Retrieved from: www.biostathandbook.com/fishers.html on October 15, 2017.

Mckay, B.D., Miramonti, A.A., Jenkins, N.D., Gillen, Z., & Leutzinger, T.J. (2017). Test-retest reliability of the 40-yd dash and vertical jump assessments in youth athletes. *Medicine & Science in Sports & Exercise*, *49*, 1082.

Murray, J., Harris, C., Adams, K.J., Berning, J., & DeBeliso, M. (2017). A comparison of resisted and assisted sprint training in collegiate sprinters. *Medicine & Science in Sports & Exercise, 49*, 1062.

National Weather Service (https://www.weather.gov/).

NSCA (2016). NSCA Hot Topic: Post-activation potentiation (PAP). https://www.nsca.com/Education/Articles/Hot-Topic-Post-Activation-Potentiation-%28PAP%29/

Open Science Collaboration, (2015). Estimating the reproducibility of psychological science. *Science,* 349(6251), aac4716.

Paradisis, G.P., & Cooke, C.B. (2001). Kinematic and postural characteristics of sprint running on sloping surfaces. *Journal of Sports Sciences, 19*(2), 149-159.

Rassier, D.E., & MacIntosh, B.R. (2000). Coexistence of potentiation and fatigue in skeletal muscle. *Brazilian Journal of Medical and Biological Research*, 33, 499–508.

Rumpf, M.C., Lockie, R.G., Cronin, J.B., & Jalivand, F. (2016). Effect of different sprint training methods on sprint performance over various distances: A Brief Review. *Journal of Strength & Conditioning Research*, *30*(6), 1767.

Rumpf, M.C., Cronin, J.B., Mohamad, I.N., Mohamad, S., Oliver, J.L., & Hughes, M.G. (2015). The effect of resisted sprint training on maximum sprint kinetics and kinematics in youth. *European Journal of Sport Science, 15*(5), 374-381.

Saraslanidis, P. (2000). Training for the improvement of maximum speed: flat running or resistance training. *New Studies in Athletics*, *15*(34), 45-51.

Senefeld, J., Pereira, H. M., Elliott, N., Yoon, T., & Hunter, S. K. (2018). Sex Differences in Mechanisms of Recovery after Isometric and Dynamic Fatiguing Tasks. *Medicine and science in sports and exercise*, *50*(5), 1070-1083.

Smirniotou, A., Katsikas, C., Paradisis, G., Argeitaki, P., Zacharogiannis, E., & Tziortzis, S. (2008). Strength-power parameters as predictors of sprinting performance. *The Journal of Sports Medicine and Physical Fitness*, *48*(4), 447-454.

Smith, C.E., Hannon, J.C., Mcgladrey, B., Shultz, B., Eisenman, P., & Lyons, B. (2014). The effects of a postactivation potentiation warmup on subsequent sprint performance. *Human Movement, 15*(1), 36-44.

Sweeney, H.L., Bowman, B.F., & Stull, J.T. (1993). Myosin light chain phosphorylation in vertebrate striated muscle: regulation and function. *American Journal of Physiology: Cell Physiology,* 264, C1085–C1095.

Springall, B., Larson, A., & DeBeliso, M. (2017). The effects of a heavy resistance warm-up on sprint speed. *Medicine & Science in Sports & Exercise*, *49*, 463.

Tabachnik, B. (1992). The speed chute. *Strength and Conditioning Journal 14*(4), 75-80.

Tano, G., Bishop, A., Climstein, M., & DeBeliso, M. (2016). The reliability of the prowler in high school male football players. *Journal of Sports Science*, *4*(4), 183-8.

Tano, G., Bishop, A., Berning, J., Adams, K.J., & DeBeliso, M. (2016). Post activation potentiation in north American high school football players. *Journal of Sports Science*, *4*(6), 346-352.

Till, K.A., & Cooke, C. (2009). The effects of postactivation potentiation on sprint and jump performance of male academy soccer players. *Journal of Strength and Conditioning Research*, *23*, 1960–1967.

Upton, D. E. (2011). The effect of assisted and resisted sprint training on acceleration and velocity in division IA female soccer athletes. *Journal of Strength and Conditioning Research, 25*(10), 2645-2652.

Wasserstein, R.L., & Lazar, N.A. (2016). The ASA's statement on p-values: context, process, and purpose. *The American Statistician*, *70*(2), 129-133.

Wibowo, R. (2017). The impact of assisted sprinting training (as) and resisted sprinting training in repetition method on improving sprint acceleration capabilities. *Jurnal Pendidikan Jasmani Dan Olahraga*, *2*(1), 79.

Winwood, P.W., Posthumus, L.R., Cronin, J.B., & Keogh, J.W. (2016). The acute potentiating effects of heavy sled pulls on sprint performance. *Journal of Strength and Conditioning Research, 30*(5), 1248-1254.