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IS THERE A POST ACTIVATION POTENTIATION EFFECT ON SUBMAXIMAL BENCH AND HEX-BAR DEADLIFT TESTS?

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Abstract:
Post Activation Potentiation (PAP) is an acute enhancement of muscle function following a conditioning activity of high intensity. The majority of research regarding PAP has focused on the effects on maximal intensity movements, such as a vertical jump. There is limited information regarding the effects of PAP with the intent of improving submaximal muscular endurance performance. **Purpose:** The purpose of this study was to determine if a PAP warm-up (conditioning activity) would have a positive effect on the maximum number of repetitions one is able to successfully perform in the hex-bar deadlift (HDL) and barbell bench press (BP) at a submaximal intensity. It was hypothesized that the addition of a PAP conditioning activity to a dynamic warm up (DYN WU + PAP) would result in a greater number of repetitions performed compared to a DYN WU. **Methods:** Utilizing a repeated measures crossover design, eleven female NCAA track athletes participated in the six-session study. During the first session, participants were randomly separated into one of two groups and a 1-3 repetition maximum (1-3RM) for the deadlift (DL) was determined. During the second session, researchers determined the participant's 1-3RM for the bench press (BP). During sessions three through six, participants performed either a DYN WU or DYN WU + PAP prior to performing three sets of maximal repetitions of either the DL or BP at 65% 1-RM. All participants performed all trials in random order. The total number repetitions at 65% 1-RM over the three sets was compared between conditions (DYN

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WU or DYN WU + PAP) with a dependent t-test for both the BP and DL. **Results:** DYN WU+ PAP did not appear to have a significant or practical effect on the number of repetitions able to be performed when compared to DYN WU for BP (47.9±4.8 vs. 47.9±5.0) or DL (61.8±11.0 vs. 64.5±13.5), respectively. **Conclusion:** Within the parameters of this study, a DYN WU + PAP provided no improvement in submaximal performance in the BP or DL.

Keywords: bench press, deadlift, post activation potentiation (PAP), warm up, muscle endurance

1. Introduction

The main objective(s) of a strength and conditioning program should be to have a positive effect on one's athletic performance and to do so in a safe and efficient manner. One determinant of athletic performance is muscular strength, and as such, a large majority of training programs are designed with the goal to improve this attribute. Two exercises commonly used in resistance training programs to improve upper body strength and lower body strength include the bench press (BP) (Drinkwater et al., 2005) and deadlift (DL) (Crewther et al., 2013), respectively. Additionally, the hex-bar deadlift (HDL) variation has been shown to produce greater peak force, peak velocity, peak power, and reduce low back stress, compared to the conventional straight-bar deadlift (Swinton et al., 2011); suggesting the HDL may be a more beneficial exercise choice for athletes.

While the DL and BP are well-accepted exercises, implementation of these exercises can vary among programs. A myriad of exercise training protocols and approaches are being used in an attempt to increase maximal and submaximal muscle strength above and beyond those observed using traditional strength training methods. Utilization of post activation potentiation (PAP) exercises in conjunction with resistance, power, or speed training is one such approach. PAP is a neuromuscular/muscle fiber priming mechanism induced by a voluntary conditioning contraction performed at or near maximal intensity (Tillin & Bishop, 2009) that has been shown to enhance peak power output in upper and lower body movements when the appropriate exercise mode, intensity, and recovery time are implemented (NSCA, 2016). The back squat, BP, and variations of the DL are high load weight training exercises with documented success as PAP conditioning activities (Ah Sue et al., 2016; Crewther et al., 2013; Ferreira et al., 2012; Hamilton et al., 2016; Kilduff et al., 2007; Kopp & DeBeliso, 2017; Scott et al., 2016; Tano et al., 2016). In order to allow for a specific muscle group to be targeted and stimulated (Kopp & DeBeliso, 2017), the desired movement to be potentiated should be preceded by a PAP conditioning activity that is biomechanically similar (Golas et al., 2016). For example, the vertical jump is oftentimes paired with back squats as a PAP conditioning activity (Arias et al., 2016; Crewther et al., 2011; Kopp & DeBeliso, 2017; Jensen & Ebben, 2003; McCann & Flanagan, 2010). PAP conditioning activities at an intensity of at least 80% of the 1-RM have been shown to improve performance in subsequent movements that require substantial amounts of muscular power (Golas et al., 2016; Hamilton et al., 2016; Kopp & DeBeliso, 2017; Weber et al., 2008).

Arguably, the most difficult variable for the literature to agree on is the optimal amount of recovery time between the PAP conditioning activity and the subsequent movement. Fatigue appears to outweigh any potentiation effects when movements are conducted immediately (10-15 sec) after the conditioning activity (Arias et al., 2016; Jensen & Ebben, 2003; Kilduff et al., 2007). Some research has indicated that a recovery period as short as two minutes will allow for PAP-induced performance enhancements (Scott et al., 2016), but the majority of literature has found longer rest periods are required for significant improvements (Ah Sue et al., 2016; Crewther et al., 2011; Ferreira et al., 2012; Kilduff et al., 2007; Kopp & DeBeliso, 2017; McCann & Flanagan, 2010; Mitchell & Sale, 2011; Tillin & Bishop, 2009).

Current research is also equivocal in regards to the efficacy of PAP conditioning exercises for sedentary and non-resistance trained individuals. Some research indicates a positive performance effect only for those with high relative and absolute strength while those with low relative and absolute strength exhibited fatigue (Harrison, 2011). However, others have found both strong and weak athletes benefit from PAP conditioning activities (Ah Sue et al., 2016; Hamilton et al., 2016; Jensen & Ebben, 2003; Scott et al., 2016; Seitz & Haff, 2016; Tano et al., 2016).

The majority of research examining the use of PAP conditioning exercises have tested for effects on maximal intensity movements, such as the vertical jump, standing long jump, sprints, and loaded sled pushes (Ah Sue et al., 2016; Arias et al., 2016; Crewther et al., 2011; Jensen & Ebben, 2003; Kopp & DeBeliso, 2017; Scott et al., 2016; Tano et al., 2016). However, to date, there has been no research conducted to examine the potential of using a PAP conditioning exercise as a means to improve muscle endurance and/or the ability of the muscle to repeat submaximal contractions. Given the amount of research supporting the implementation of PAP conditioning activities for the purpose of improved athletic performance, using a similar protocol prior to submaximal resistance training could improve the number of repetitions able to be performed to failure when compared to a typical progressive dynamic warm up (DYN

WU). Therefore, the purpose of this study was to determine if the addition of a PAP conditioning activity to a DYN WU increases the maximum number of repetitions able to be successfully performed in the BP and HDL when compared to DYN WU alone.

2. Methods

2.1 Participants

The participants for this study were a convenience sample of female athletes from Pepperdine University's track team, specifically sprinters. Permission from the head coach was granted prior to the study. Student athletes were asked to volunteer for the study. Permission from the Institutional Review Board was obtained before conducting any training or assessments of the participants. Participants were given a written consent to read and sign before any testing or data collection. All participants were 18 years of age or older.

2.2 Instruments and Apparatus

All sessions were held at the Athletic Performance Center inside the Ralph Strauss Tennis Center at Pepperdine University (figure 1). Equipment necessary to conduct this study included 20.45kg Olympic barbells, weight benches (to conduct the BP) and hex-bars, weighted plates (ranging from 1.4-20.45 kg), and Accusplit 601X stopwatches (Accusplit, Pleasanton, California, USA).

2.3 Protocol for Determining 1-3 RM Loads

After WU sets of six and four repetitions (sets x reps; 1 x 6; 1 x 4), participants were given up to six sets of three repetitions (6 x 3) to obtain a 1 to 3-RM. If a participant could only complete 1 to 3 repetitions successfully at any time during the working sets, the test was over. If a 2 or 3-RM was obtained, a 1-RM was estimated using a training loading chart from Baechle & Earle (2008). The 1-RM test is considered the gold standard for assessing muscular strength regardless of muscle group location or the gender (Seo et al, 2012). Submaximal tests have also been used, however, to successfully predict 1-RM strength (Dohoney et al., 2002). The 1-RM was rounded to the nearest five-pound increment. Submaximal intensities for BP and DL were calculated from the estimated 1-RM and loads were rounded to the nearest five-pound increment (tables 2 and 3).

Figure 1: Pepperdine University Athletic Performance Center

2.3 Procedures

Data collection occurred over the span of six sessions (each approximately 60 minutes in length) and all sessions were completed over the course of three consecutive weeks with at least 48 hours between sessions (figure 2). Session One included the collection of anthropometric measurements (age, height, weight) (table 1), participants were randomly assigned to one of two groups after which a 1 to 3-RM for HDL was obtained. Individual 1 to 3-RM BP values were obtained during Session Two.

During week two of the study (Sessions Three and Four) participants came in on two days, once for the HDL submaximal repetition test and once for BP submaximal repetition test, with at least 24 hours between sessions. Group 1 performed three sets of DL at 65% 1-RM to failure after completing only a DYN WU (Session Three) and three sets of BP at 65% 1-RM to failure after DYN WU + PAP conditioning activity (Session Four). Group 2 performed three sets of DL at 65% 1-RM to failure after DYN WU + PAP conditioning activity (Session Three) and three sets of BP at 65% 1-RM to failure after only DYN WU (Session Four). Four minutes were given between each set of BP and HDL, all sets were performed to failure.

During week three of the study (Sessions Five and Six) each group's exercise WU protocols switched. Group 1 performed three sets of HDL at 65% 1-RM to failure after completing DYN WU + PAP conditioning activity (Session Five) and three sets of BP at

65% 1-RM to failure after the DYN WU (Session Six). Group 2 performed three sets of HDL at 65% 1-RM to failure after DYN WU (Session Five) and three sets of BP at 65% 1-RM to failure after DYN WU + PAP conditioning activity (Session Six).

2.4 Dynamic WU

The DYN WU took approximately 8-10 minutes to complete and consisted of the following movements:

A. Inverted Hamstring to Knee Lift: 5 each leg
B. Lunge / Turn / Press / Slide: 5 each side
C. Inchworm: 5 repetitions
D. Lateral Squat: 5 each side

2.5 PAP Conditioning Activity

The PAP conditioning activity for both the HDL and BP was a modified protocol previously used by Sygulla and Fountaine (2014): five repetitions at 60% 1-RM, three repetitions at 75% 1-RM, and two repetitions at 90% 1-RM. Three minutes rest was given between each progression set. After the final PAP set at 90% 1-RM, the participants rested five minutes before attempting the first of three sets at 65% 1-RM to failure and four minutes rest separated each set thereafter.

Study Flow Diagram

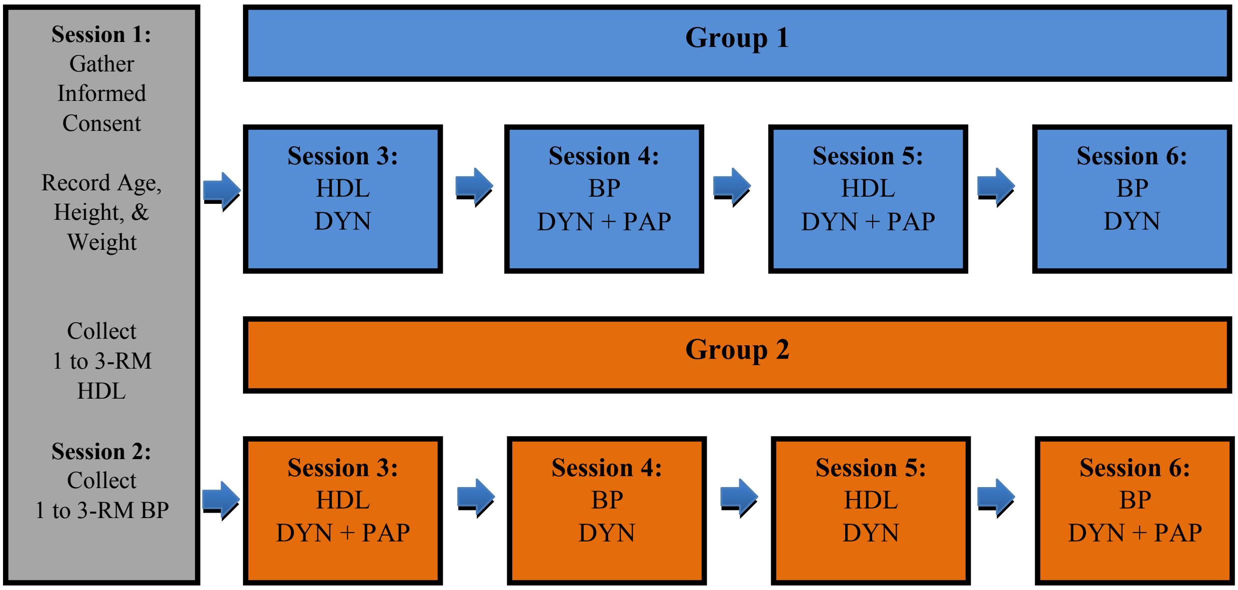

Figure 2: Study time line of events and procedures. HDL: Hex-Bar Deadlift; BP: Barbell Bench Press; DYN: Dynamic WU; PAP: Post Activation Potentiation conditioning activity

2.6 Statistical Analysis

The number of repetitions completed to failure per set was compared between the warm-up conditions for the HDL and BP with paired t-tests. Likewise, the total number repetitions completed across all three sets were compared between the warm-up conditions for the HDL and BP with a paired t-test (alpha<0.05).

3. Results

Eleven, resistance-trained female athletes participated in this study. Table 1 provides participant descriptive information. Data collection was conducted during the scheduled in-season strength and conditioning sessions. Of the eleven athletes who participated, three were unable to complete the HDL portion of the study (one due to an injury at track practice and the other two had back tightness during the HDL sets at 65% 1-RM). As a result, there were 11 and 8 data sets included in the data analysis for the BP and HDL, respectively.

Table 1: Participant descriptive information

	N	Age (years)	Height (cms)	Mass (kgs)	Est. 1-RM (kgs)
Bench Press	11	19.7±1.2	170.3±7.7	64.0±4.6	45.5±6.9
Hex Deadlift	8	19.9±1.1	170.3±9.2	62.2±3.8	109.9±25.7

Participant means and standard deviations for descriptive information. Of the initial 11 participants, 8 were able to complete the hex-bar deadlift portion of the study. Est.1-RM based off calculations from Baechle & Earle (2008).

The DYN WU+ PAP conditioning activity protocol did not have a significant effect on the number of submaximal repetitions performed on DL and BP. The average total repetitions performed in the BP was nearly identical between DYN WU+ PAP conditioning activity (47.9±4.8) and DYN WU (47.9±5.0) conditions. While the average number of HDL repetitions between DYN WU + PAP conditioning activity was (61.8±11.0) and DYN WU (64.5±13.5). It should be noted that the total number of repetitions performed decreased when DYN WU+ PAP conditioning activity was performed (Table 4). Table 5 shows the mean (+/- standard deviation) number of repetitions performed for each of the three sets for HDL and BP under both warm-up conditions. The number of HDL repetitions performed decreased for each of the three sets following the DYN WU + PAP compared to the DYN UP sets. There was no statistical difference between the total number of repetitions performed between WU conditions across all three sets for either the BP or HDL (p>0.05). Likewise, there was not a statistical difference between repetitions performed per set between WU conditions for either the BP or HDL (p>0.05).

Table 2: Bench Press Intensity Calculations for Conditioning Activity

#	Bench (lbs)	Completed Repetitions	Est. 1-RM (lbs)	Rounded 1-RM (lbs)	65% 1-RM (lbs)	Rounded 65% 1-RM (lbs)	1-RM (kgs)	65% 1-RM (kgs)
1	85.0	2	89.5	90	58.5	60.0	40.9	26.6
2	105.0	2	110.5	110	71.5	70.0	50.0	32.5
3	75.0	1	75.0	75	48.8	50.0	34.1	22.2
4	100.0	3	107.5	110	71.5	70.0	50.0	32.5
5	110.0	1	110.0	110	71.5	70.0	50.0	32.5
6	80.0	2	84.2	85	55.3	55.0	38.6	25.1
7	105.0	3	112.9	115	74.8	75.0	52.3	34.0
8	110.0	3	118.3	120	78.0	80.0	54.4	35.5
9	90.0	1	90.0	90	58.5	60.0	40.9	26.6
10	80.0	2	84.2	85	55.3	55.0	38.6	25.1
11	100.0	3	107.5	110	71.5	70.0	50.0	32.5

Participants could attempt up to six sets of three repetitions (6 x 3). The "Completed Repetitions" column shows the number of successfully completed repetitions during the participants' last attempted set. Pounds-lbs; Kilograms-kgs.

Table 3: Hex-Bar Deadlift Intensity Calculations for Conditioning Activity

#	Deadlift (lbs)	Completed Repetitions	Est. 1-RM (lbs)	Rounded 1-RM (lbs)	65% 1-RM (lbs)	Rounded 65% 1-RM (lbs)	1-RM (kgs)	65% 1-RM (kgs)
1	145.0	3	155.9	155	100.8	100.0	70.5	45.8
2	285.0	2	300.0	300	195.0	195.0	136.4	88.6
3	180.0	3	193.5	195	126.8	125.0	88.6	57.6
5	235.0	3	252.7	255	165.8	165.0	115.9	75.3
6	210.0	3	225.8	225	146.3	145.0	102.3	66.4
8	250.0	3	268.8	270	175.5	175.0	122.7	79.8
10	195.0	3	209.7	210	136.5	135.0	95.5	62.0
11	300.0	3	322.6	325	211.3	210.0	147.7	96.0

Participants could attempt up to six sets of three repetitions (6 x 3). The "Completed Repetitions" column shows the number of successfully completed repetitions during the participants' last attempted set. Pounds-lbs; Kilograms-kgs.

Table 4: Reps and Volume

	DYN + PAP HDL	DYN HDL	DYN + PAP BP	DYN BP
Total Reps	61.8±11.0	64.5±13.5	47.9±4.8	47.9±5.0
Total Volume (kgs)	4347.7±1130.6	4477.3±992.0	1416.3±254.1	1418.0±264.2

Participant means and standard deviations of total reps and volume completed under each condition. DYN: Dynamic; WU: Warm-up; PAP: Post Activation Potentiation Conditioning Activity.

Table 5: Set Repetition Totals

Set	DYN + PAP HDL	DYN HDL	DYN + PAP BP	DYN BP
1	21.0±7.4	22.0±7.2	18.8±3.5	16.5±2.1
2	21.3±3.3	21.5±5.2	15.6±2.1	16.8±3.3
3	19.5±4.6	21.0±4.4	13.5±1.2	14.6±2.2

Means and standard deviations of repetitions for individual sets under each condition.
DYN: Dynamic; WU: Warm-up; PAP: Post Activation Potentiation Conditioning Activity.

4. Discussion

A fundamental goal of the overall athletic conditioning program is to increase maximal and submaximal muscle strength. Furthermore, improvements in strength allow for adaptations in other performance-related constructs such as power and speed (Evetovich et al., 2015; Seitz et al., 2014). The HDL and BP are common resistance training exercises that have been shown to elicit positive strength adaptations when performed regularly at various intensities (Mangine et al., 2015). PAP is a technique that has been shown to improve single, maximal strength and power attempts but maximal training (i.e. 1-RMs) is rarely conducted within the usual strength training program, therefore, within this context, the applicability of the supporting research is limited. A majority of periodized programs, both in and out of season, are performed at submaximal intensities with the goal of utilizing submaximal loads to improve one's maximal strength, power, and muscle endurance. Therefore, the purpose of this study was to determine if the addition of a PAP conditioning activity would lead to an increased number of repetitions performed in the HDL and BP at a submaximal intensity. These exercises were performed following two WU scenarios (DYN WU + PAP conditioning activity and DYN WU). We hypothesized that the PAP conditioning activity would lead to an increase in the number of successful repetitions able to be performed in the HDL and BP exercises; however, our data refute this hypothesis and suggest the number of repetitions performed was not significantly improved by the inclusion of the PAP conditioning activity and may actually have had a fatiguing effect.

The lack of improvement noted in the current study is not consistent with previous studies which have demonstrated that a PAP conditioning activity can significantly increase both upper and lower body power output (Harris, Dolny, Browder, Adams & DeBeliso, 2004; Harris et al., 2006; Mallander et al., 2006; Berning et al., 2010; Harris, Kipp, Adams, DeBeliso & Berning, 2011; Dove et al., 2013; Hamilton et al. 2016; Ah Sue, Adams & DeBeliso, 2016; Tano et al., 2016; Kopp & DeBeliso, 2017). However, not all studies have shown a performance benefit; Tillin and Bishop (2009) observed several factors that could affect the PAP-fatigue relationship and concluded that variables such as the intensity and volume of the conditioning activity, recovery period following the conditioning activity, the type of conditioning activity, type of activity being tested, and characteristics of the participants all could potentially affect the effectiveness of the PAP protocol. With so many factors, it should not be surprising that most research indicates that the magnitude of the PAP effect is highly variable (Arabatzi, 2014; Docherty, 2007; Gouvea, 2013; Harrison, 2011; Seitz, 2016; Springall, Larson & DeBeliso, 2016; Sygulla, 2014; Till, 2009). In agreement with our findings, some findings suggest PAP conditioning activities can lead to a state of fatigue thereby limiting performance improvements (NSCA, 2016)). The amount of recovery required to elicit an improvement in performance has varied amongst research, but a majority of data has shown that limited rest (0-3 minutes following the conditioning activity) likely causes a fatiguing effect and negates any benefits associated with potentiation (Crewther et al., 2011; Jensen & Ebben, 2003; Kilduff et al., 2007; Gouvea, 2013). While the majority of studies that have examined PAP-related performance benefits have focused on lower body conditioning activities and power movements (Arabatzi et al., 2014; Evetovich et al., 2015; Mitchell & Sale, 2011; Rixon et al., 2007), Ferreira et al. (2012) found the mean BP power output of six repetitions at 50% of the 1-RM in 11 males to be significantly increased when tested 7-minutes after a PAP conditioning exercise (1-RM BP). Researchers measured power output in the subsequent repetitions following the PAP conditioning activity after 1, 2, 5, and 7 minutes of rest (a different rest period was used on four separate days). It is possible that Ferreira et al. found positive results in BP power output following the PAP conditioning activity due to a longer rest period employed (7-minutes) compared to the rest period of 5-minutes used in the current study. However, it is difficult to directly comparable the results of the Ferreira et al. research effort to the current study, as they measured BP power output a 50% 1-RM and the current study examined repetitions to failure at 65% 1-RM.

The mean 1-RM BP scores collected in the current study were 45.5±6.9 kgs which are near identical to the $40^{\%ile}$ BP scores of NCAA Division I female basketball players reported by Hoffman (2006). The mean 1-RM DL recorded in this study (109.9±25.7 kgs) was considered as advanced for 18-23 year old females with 60 kg body mass (StrengthLevel.Com, 2017). The National Strength and Conditioning Association (NSCA) suggest that PAP should be reserved for those with "high relative strength" (NSCA, 2016). In the current study, participants were approximately 20 years of age and collegiate athletes with at least 1-year of resistance training and physical conditioning. However, the participant's strength to body mass ratios were on average 0.71 kg 1-RM BP/kg body mass and 1.77 kg 1-RM HDL/kg body mass. The 1-RM HDL/body mass ratio is low relative to the NSCA's PAP recommendations for relative strength. It is possible that the low relative strength of the participants could have been a factor regarding the lack of positive results but it should be noted the NSCA's recommendations regarding relative strength pertain to PAP effect on maximal performance and not submaximal exercise. Data deserving attention from this study is the total volume between the participants. The HDL volume was 4347.7 kg to 4477.3 kg for DYN WU + PAP conditioning activity and DYN WU, respectively (Table 4). As expected, the BP total volume was substantially less than HDL. The BP volume was near identical; 1416.3 kg and 1418.0 kg for DYN WU + PAP conditioning activity and DYN WU, respectively (Table 4). Training volume is a variable all strength and conditioning professionals should be conscious of when designing and implementing a strength and conditioning program for a team or athlete. An increase is training volume has the potential to lead to underperformance, which could progress to overreaching, and eventually overtraining (Kreher & Schwartz, 2012). To reduce the risk of this occurring, training volume should be monitored.

A potential shortcoming of the current study could be the small sample size that was available. Using eleven participants may not have been a large enough sample to detect a difference between DYN WU + PAP conditioning activity and DYN WU conditions, potentially leading the study to be falsely negative (Nayak, 2010). Having a greater sample size may have led to data suggesting a different conclusion rather than what was reached in the current study. Another potential shortcoming may be that data collection occurred during the participants' sport season. In addition to the activities associated with the study, the participants were attending practices and competitions. The combination of these activities may have created a state of fatigue thus affecting their performance during the submaximal HDL and BP trials. If strength and conditioning professionals attempt to implement PAP conditioning activities with submaximal exercises, it may be best to do this during the off-season.

To date, and to the best of our knowledge, this is the first study to utilize a PAP conditioning exercise as a means to improve submaximal resistance-training performance. Although no positive effect was found, it is possible the PAP conditioning activity fatigued the participants thereby negating any PAP effect. Decreasing the total volume of the conditioning activity, but keeping the intensity near maximal, may decrease likelihood of fatigue. Likewise, a longer rest period following the PAP conditioning activity may lead to an improvement in submaximal exercise performance. Future research should also examine the efficacy of different PAP conditioning activities and utilize a variety of participant populations (male, adult, untrained, etc.) as this may lead to the development of more refined recommendations for the use of PAP conditioning exercises within the context of the overall strength and conditioning program.

5. Conclusion

Within the parameters of this study: (1) there was not an improvement in completed repetitions in the BP or HDL following a PAP conditioning protocol; (2) the PAP protocol used in this study may have elicited a fatiguing effect rather than a potentiation; (3) therefore, the results of this study suggest that, if a similar PAP protocol is performed, improvements in submaximal exercise performance may not be achieved.

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