COMPARISON OF DEADLIFT VS. BACK SQUAT POSTACTIVATION POTENTIATION ON VERTICAL JUMP

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ABSTRACT

Strength coaches are searching for the best way to train their athletes to be bigger, faster, and stronger in order to increase performance. A unique form of power training is to try and invoke a postactivation potentiation (PAP). PAP is based on the premise of performing a heavy resistance exercise followed by a power exercise, resulting in increased power performance. Back squats (BS) are normally used, but a less researched tool is the hex bar deadlift. Therefore, the purpose of this study was to compare the potentiating effects of the back squat vs. HBDL on vertical jump performance. Ten resistance-trained men (age=22.15±2.66yrs, ht=178.10±7.20cm, mass=78.91±8.67kg) volunteered to participate and performed 3 pre countermovement jumps (CMJ) then 3 repetitions of BS or HBDL at 85% 1RM. To perform the CMJ, subjects jumped with arm swing on a force plate. The BS was performed with a standard barbell in a power rack with a safety squat device to insure a quad parallel position. The HBDL was performed using the low handles without straps. Following the BS or HBDL, subjects rested 8 minutes then performed 3 post CMJ. A control condition consisted of 3 pre CMJ, 8 minutes of standing rest, then 3 post CMJ. For jump height, there was an interaction of condition x time where the control and squat conditions resulted in a significant decrease in post vertical jump with no difference in deadlift. Manipulation of critical variables determines PAP outcomes. PAP is highly individualized and training experience of the subjects may have been too low to demonstrate increased performance.

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CHAPTER 1

INTRODUCTION

Coaches are searching for the best way to train their athletes to be bigger, faster and stronger. Research is also investigating new ways to manipulate training to produce an increase in performance. Vertical jump is important in numerous sports such as volleyball, basketball, soccer, as well as others using triple extension for power production. It is also used as a test of lower limb power. One unique form of training in regards to power is postactivation potentiation (PAP) which has been largely researched in regards to heavy resistance with back squats (7, (11), 19).

The phenomenon of PAP is based on the premise of performing a heavy resistance exercise, followed by a power or speed type of exercise. The mechanism behind PAP is phosphorylation of the regulatory light chains of myosin, a $Ca2^{+}$ dependent process (2, 3, 8, 11, 13). Thereby, muscular performance is enhanced acutely after a relatively high intensity activity (e.g. 1 repetition max (1RM) back squat performed before a vertical jump (VJ)(3, 5, 6). Training status, rest periods, volume and intensity have all been shown to affect PAP. Chiu et al. (3) found that force and power parameters were enhanced for athletes when compared to recreationally trained individuals. Previous research has shown vertical jump to increase with PAP (5, 10, 11).

The back squat is one of the most commonly used training exercises performed by fitness enthusiasts, and athletes. Numerous previous studies have used the back squat as

an exercise to produce PAP (3, 4, 9, 11). However, little research has investigated the deadlift exercise on PAP production. Traditionally deadlifts are performed with a standard barbell, but research has demonstrated that use of a hexagonal barbell results in greater values for force, power, and RFD (16, 17). Therefore, the purpose of this study was to compare the potentiating effects of the back squat vs. HBDL on vertical jump performance.

CHAPTER 2

REVIEW OF THE LITERATURE

Introduction

Postactivation Potentiation (PAP) has become increasingly popular for research. It is understood that PAP is the product of performing a heavy load activity followed by a rapid explosive movement. PAP production has normally been looked at using the back squat to increase the performance of the vertical jump. In order for PAP to occur training variables such as intensity, volume, training age, and rest need to be chosen carefully (21). Literature has also shown that the use of a hexagonal bar deadlift will have greater results in the production of increasing vertical jump (18, 19).

Postactivation Potentiation Response in Individuals

Loren et. al compared the response of postactivation potentiation(PAP) response in athletic(n=7) and resistance trained (n=17) individuals(3). Subjects participated in a 2 practice session and 4 testing sessions over 3 weeks. The 1 repetition max (1RM) of the high bar parallel back squat was tested. Jump squats were performed at 5 minutes and 18.5 minutes followed by the control or back squats of 5 sets of 1 at 90% of their RM. Athletic individuals compared to resistance trained individuals showed significantly greater ($p<.05$) force and power parameters. Postactivation potentiation can be more favorable in athletes when producing explosive strength performance compared to resistance trained individuals.

It is known that athletes will respond to postactivation potentiation better than resistance trained individuals. Postactivation potentiation is not exclusively limited to athletes. Resistance trained individuals (RTI) can be placed on a spectrum of relative strength. Jo et al. (7) examined the recovery duration after a potentiating stimulus on muscular power in recreationally trained individuals. The role of fatigue plays a possible role on PAP in resistance trained individuals. Participants performed 1 set of 5 repetitions at 85% 1RM, and then rested at 5, 10, 15, and 20 minutes followed by the Wingate test (7). PAP is enhanced when there is a heavy exercise performed followed by an explosive movement i.e. back squat followed by a vertical jump. Results suggested that there were no significant differences, and rest duration might not explain the discrepancy of PAP response in RTI. What they did discern was that the relatively stronger individuals were able to potentiate with a rest of 5-10 mins whereas the weaker individuals required longer rest periods. PAP and fatigue can co-occur, but to see an increase in performance PAP needs to exceed fatigue (6, (15)). This is a possible reason why RTI's are not able to potentiate when compared to athletes. The balance of fatigue and PAP needs to occur in order for an individual to potentiate.

Gourgoulis et al. did a similar study observing resistance trained men. The purpose was to study the effect of warm-up program including submaximal half-squats on vertical jump ability. The participants performed 5 sets of half squats with 2 repetitions at intensities of 20, 40, 60, 80, and 90% of their 1 RM, and vertical jump was performed immediately following the last set (6). There were two groups created based on their 1 RM values. Again the maximally stronger participants improved their vertical jump (4.01%) more than subjects who had lower maximal strength (0.42%)(4). The

vertical jump is an important component used in most sports. The reason for the differences in improvement could be due to neural activation. More trained individuals have an increase in the rate firing and recruitment of their motor units compared to those not as trained.

Most research looks at male RTI or athletes. The influences of type of muscle contraction, gender and lifting experience on PAP were observed by Rixon et. al. One set of countermovement jump (CMJ) was performed to find the baseline measures of jump and height. A second set was performed after a maximal voluntary contraction, and a third set of CMJ was performed after a maximal dynamic squat. When looking at gender comparison, males performed significantly better than females. As previous research has stated experienced lifters still displayed better results compared to unexperienced lifters. In addition, the isometric condition evoked a greater PAP than the dynamic condition (16).

Intensity and Rest Variables

There is no clear method on how to produce the ideal conditions for post activation potentiation (PAP) to occur. PAP is enhanced when there is a heavy exercise performed followed by an explosive movement i.e. back squat followed by a vertical jump. Wilson et al. did a meta-analysis of PAP and Power: effects of conditioning, activity, volume, gender, rest periods, and training status. Effects sizes of muscular power were taken from a total of 32 studies. There was significant ($p < .05$) evidence that suggested training at a moderate intensity (60-85% 1RM loads) or greater loads than 85%(21). The rest time following the conditioning activity showed significance ($p < .05$)

between 7-10 minutes. PAP was optimal using multiple sets versus single sets, and the effects increased the greater the training age of the individual.

Lowery et. al investigated the effects of low, moderate, and high intensities under varying rest period lengths, with the volume load controlled on Vertical Jump height and peak power. As stated in the Wilson paper moderate loads between 60-85% RM and greater loads more than 85% showed to be successful in the production of PAP. Lowery et al. controlled for volume to find out what is the correct intensity. The participants had a minimum of 3 years resistance training. Participants came in for four testing sessions; one day was for familiarization of the vertical jump and the assessment of their 1RM back squat. Participants returned on three separate days to perform the back squat at low intensity (56% 1RM) at 5 repetitions, moderate intensity (70% 1RM) at 4 repetitions, and high intensity (93% 1RM) at 3 repetitions (10). The loads and repetitions were choses mathematically equivalent volume loads (repetition Xs weight lifted) regardless of the participants 1RM (10). At the low intensity there was no change in the participant's vertical jump, but the moderate and high intensity condition vertical jump and peak power increased the same. For the moderate condition changes were observed at minute 4 and returned to baseline by minute 8. For the high intensity condition the values peaked from minutes 4 to 8 and did not return to baseline until minute 12 (10). The duration of PAP seems to be found with moderate to higher intensities at resting period of 4-8 minutes for those who are resistance trained, but higher intensities seem to lengthen the period of PAP.

If the rest interval is too short, fatigue could play a role in potentiation, but if the rest interval is too long than peak potentiation may not occur. Weber et al. examined the

acute effects of heavy-load squats on consecutive squat jump performance. The study was done of NCAA division 1 track and field athletes which consisted of 100/200/400m (n=7), long/triple/high jump (n=4) and pole vault (n=1)(20). On three separate days the participants performed a 1RM back squat, the two other days consisted of 85% of 5 repetition back squat, and five repetition jump squat. There was improvement in mean and peak jump height, and GRF with the back squat condition. With the jump squat condition it decreased mean and peak jump height and significantly deceased GRF. A heavy loaded back squat before a set of squat jumps may increase the acute performance of jump height and peak GRF.

Load, volume, and intensity have shown to play a key role in the production of PAP. Most studies look at the effects of heavy loads and have shown an increase in vertical jump. Steig et al. took it one step further and did a study to compare the potentiating effects of depth jump vs. box jump warm-ups on vertical jump performance. The participants involved 8 collegiate and 9 club female volleyball players who participated on three testing days separated by 48 hours. The three different days consisted of the control, box jumps, and depth jumps followed by three post-test jumps. When looking at the post-test results there was a decrease in all variables. This suggested that rest time was too long or intensity was too low to create PAP (17).

Kilduff et al. did a study to determine the optimal recovery time required to observe enhanced muscle performance following the preload stimulus. Seven countermovement jumps and seven ballistic bench throws were performed at a 3RM at 15 seconds, 4, 8, 12, 16 and 20 minutes after the pre-load stimulus (9). Peak power output (PPO) was observed after each time period. PPO increased at 12 minutes of rest between

the pre-load stimulus and the ballistic bench throw and countermovement jump. The found that the optimal recovery time for a lower body exercise must be between 8-12 minutes and for the upper body it should be 12 minutes.

PAP Individualization

Even though literature greatly shows the existence of PAP is possible, many claim it is a matter of individualization that causes PAP. Mola et al. tried to determine the optimal recovery time for PAP to occur in professional soccer players. There were two different groups, experimental and control group. A countermovement jump was performed as baseline testing followed by 10 minutes of rest. The control group then performed a CMJ at 15 seconds, and at 4, 8, 12, 16, and 20 minutes, whereas the experimental group performed a 3RM squat and then an identical CMJ protocol (14). The set of 3RM squats did not produce PAP in all participants. Those who responded to PAP and those who did not were identified and had individual PAP limitations. The participants who responded to PAP actualized PAP at 4 minutes, 12 minutes, and 16 minutes after the 3RM squat (14).

Research had not completely ruled out that resistance trained individuals can potentiate. Batista et al. examined the influence of strength training background on postactivation potentiation response. How much of a person's training background will have an effect of PAP? Bodybuilders, track and field athletes, and physically active athletes were used for the study. The leg press exercise was chosen because of the similarity in activation of muscle in the vertical jump and back squat. Three separate test sessions followed by 96 hours of rest, subjects were required to perform 1 or 3 sets of maximal voluntary contractions last for 5 seconds, or the control sessions (2). There

were no significant vales found between the groups CMJ height or take-off velocity. PAP did not have an effect on a person's training background. When they investigated individual differences analysis showed that some subjects increased performance in response to the conditioning stimulus despite their training background (2).

Choosing the best variables to create the optimal environment for PAP to occur is very critical. Exercise selection and rest interval on PAP of vertical jump performance was investigated by McCann et al. They observed whether a strength or a power exercise would be better at creating PAP, and if a 4 or 5 minute rest interval would lead to a greater PAP effect (12). Subjects were required to perform a 5 repetitions of either the back squat or the hang clean at the midthigh position. Following the strength or power exercise subjects completed a CMJ after 4 minutes of rest or 5 minutes of rest. The power exercise was not better than the strength exercise, and 4 minutes of rest led to an increase in VJ performance. When the subjects were analyzed individually they found that some responded better to the squat and some with the clean. The same can be said with the rest intervals. Some participants were able to potentiate after 4 minutes, and some after 5 minutes. This possibly indicates that PAP can be an individualized phenomenon.

3RM-5RM Back Squat and PAP

PAP has been studied by observing rest intervals, conditioning stimulus, participants, volume, but what about the level of intensity? Mitchell et al. tested if a 5 RM squat would induce PAP leading to an increased height of a CMJ. Eleven male rugby union players with a minimum of 1 year experience in the back squat were recruited. Isometric twitch contractions were also evoked in the knee extensor muscles before and

after 4 minutes of the 5RM squat (13). The 5RM squat did induce PAP and increased height of CMJ.

Studies have also been conducted using at 3RM squat. Evetovich et al. and Crewther et al both observed the PAP effects of 3RM back squats on athletic performance. Crewther et al. had participants perform the back squat followed by either CMJ, 5 and 10 m sprint or 3-m horizontal sled pushes with a 100kg load (4). There were improvements in CMJ height at rest intervals 4, 8, and 12 minutes. When the recovery period was individualized 3RM squats were found to acutely enhance CMJ height. Evetovich et al. found significant improvements when they looked at VJ, horizontal jump performance, shot-put performance, and sprint performance in National Collegiate Athletes Division II male and females.

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Deadlift

Investigation of the phenomenon PAP is usually done using the traditional back squat exercise. Thompson et al. examined the effects of 10 weeks of barbell deadlift training on rapid torque characteristics of the knee extensors and flexors, they also analyzed the relationships between training- induced changes in rapid torque and VJ performance (19). Novice trained individuals were involved in a 10 week deadlift training program where subjects performed CMJs before and after the program. The program consisted of 5 sets of 5 training twice a week for 10 weeks. Individuals 1RM were not tested because majority of individuals were not able to perform the deadlift correctly. A nontraditional method of training load determination was used that involved the subject lifting the heaviest external load possible, which allowed them to complete 5

sets of 5 repetitions with correct technique (19). The 10 week deadlift program did enhance rapid torque capacities in the knee extensors and flexors. The changes of torque accompanied improvements in vertical jump height.

In the 10-week deadlift program they found it was harder for individuals to properly execute the deadlift. Swinton et al. did an analysis of straight and hexagonal barbell deadlifts (HBD) using submaximal loads. Male powerlifters were used for the study and subjects were asking to perform a hex-bar or straight bar deadlift at 10, 20, 30, 40, 50, 60, 70, and 80% of their 1RM (18). Studies have shown for multi-joint resistance exercise that power is maximized when lifting loads of 30-60% 1RM (18). They found that individuals were able get a heavier 1RM in the hex-bar deadlift compared to the straight bar deadlift. The hex-bar deadlift increased the peak moment at the knee and decreased at the lumbar spine and hip compared to the straight bar. Greater peak force, peak velocity, and peak power values were significantly higher when compared to the straight bar deadlift.

CHAPTER 3

METHODS

IRB and Consent Form

All procedures were approved by the University Institutional Review Board for human subjects. Participants signed an informed consent prior to testing, and were asked to refrain from lower body resistance training 48 hours prior to each session.

Participants

Twenty male recreational basketball players between the ages of 20-29yrs old (age=22.15±2.66yrs, ht=178.10±7.20cm, mass=78.91±8.67kg) volunteered. Subjects completed a total of 5 testing sessions separated by 48-72 hours over a 3 week period.

Procedures

Set-Up

On day one, participants were measured for height and mass using a stadiometer (752KL, Seca; Ontario, CA, USA) and a digital scale (ES200L; Ohaus Corporation Pinebrook, NJ, USA). They then performed a dynamic warm- up consisting of alternating leg swings, knee pulls, and walking lunges, twice for a distance of 10 meters. Day one also involved testing baseline countermovement vertical jump (CMJ), and one repetition maximum (1RM) of either hexagonal bar deadlift (HBDL) or high bar back squat (BS).

Countermovement Vertical Jump

Participants stood on an AMTI force plate (Advanced Mechanical, Inc., Watertown, MA, USA), sampling at 1000Hz which was interfaced with custom LabVIEW (version 2014, National Instruments) data collection and analysis software. An Epic Combine Jump Station was also used to measure vertical jump height. They performed a countermovement to a self-selected depth then maximally jumped as high as possible with arm swing and reached for the vanes on the Epic device. Jump height was assessed pre and post on days 1, 3, 4 and 5.

Day 1 and 2: 1RM Testing

The HBDL and BS 1RM tests were performed on separate days. The BS was performed using a standard barbell (placed at C7) inside a power rack (Rogue Fitness, model, city state). Participants started by warming up with 10 repetitions at 50% of their predicted 1RM, 5 repetitions at 70/%, 3 repetitions at 80%, and one repetition at 90%, each followed by 2 minutes rest. 3-5 attempts were performed to determine 1RM. If they successfully completed one repetition, weight was increased by 5-20 pounds. If they were not able to complete the lift, weight was reduced by 5-10 pounds. The same procedures were used for the HBDL (low handles, no straps). 1RM tests were counterbalanced on day 1 and 2.

For the BS, participants wore an electronic device (Safety Squat; Bigger Faster Stronger, Salt Lake, City, UT) that was wrapped around their right quadriceps. When a beeping noise was heard it meant they had reached quads parallel position. This device was used the entire study and the squat was not successful if they did not reach the parallel position.

Day 3, 4, and 5: Experimental Trials

Participants returned 48-72 hours later and performed the same dynamic warm-up as day one. First, 3 pre-CMJ were measured followed by 3 repetitions at 85% of either HBDL or BS. Eight minutes standing rest was then given followed by 3 post-CMJ. A control condition consisted of 3 pre-CMJ, 8 minutes of standing rest, then 3 post-CMJ. Conditions were counterbalanced.

Statistical Analyses

All analyses were performed with SPSS 21.0. Multiple 2x3 (time x condition) repeated measures ANOVAs were performed to determine differences for each variable. Dependent variables were force plate jump height, EPIC jump height, relative ground reaction force, take off velocity, peak power and impulse.

CHAPTER 4

RESULTS

For jump height, there was an interaction of condition x time ($p=0.018$). This was followed up by three dependent t-tests comparing pre and post for each condition. Results demonstrated a significant decrease in post vertical jump for the control and squat conditions with no difference in deadlift (Table 1).

For force plate jump height, impulse, take-off velocity, and peak power there were no interactions but there was a main effect for time ($p < 0.000$) where pre was greater than post (Table 1).

For relative ground reaction force, there was no interaction ($p = .605$) or main effects (Table 1).

Table 1. Means and standard deviations of all variables by condition and time.

	Control	Hex Bar Deadlift	Squat	Grand Means
Jump HT EPIC(cm)				
Pre	*62.17 ± 7.48	61.54 ± 7.14	*62.33 ± 7.57	
Post	60.90 ± 7.17	61.47 ± 7.73	60.87 ± 7.42	
Jump HT Force plate(cm)				
Pre	45.94 ± 6.63	45.72 ± 7.21	46.10 ± 7.29	*45.92 ± 6.86
Post	43.83 ± 6.46	44.61 ± 7.21	44.69 ± 7.42	44.37 ± 6.79
Impulse (Ns)				
Pre	247.39 ± 26.14	245.52 ± 26.22	246.50 ± 28.26	*246.47 ± 25.74
Post	242.99 ± 28.02	243.65 ± 26.22	240.89 ± 22.73	242.51 ± 24.18
Take-off Velocity (m/s)				
Pre	2.93 ± .22	2.92 ± .21	2.92 ± .20	*2.93 ± 0.19
Post	2.88 ± .24	2.91 ±.26	2.87 ± .21	2.88 ± 0.19
Peak Power (W)				
Pre	5129.55 ± 662.09	5098.26 ± 629.37	5180.53 ± 719.50	*5136.12 ± 621.92
Post	4652.77 ± 675.47	5065.12 ± 766.91	5002.63 ± 630.49	5010.17 ± 626.39
Relative GRF (N/kg)				
Pre	15.80 ± 2.72	15.76 ± 2.68	15.95 ± 2.80	
Post	15.43 ± 2.61	15.67 ± 2.95	15.61 ± 2.90	

* Greater than post.

CHAPTER 5

DISCUSSION

The purpose of this study was to compare the potentiating effects of a back squat vs. HBDL on vertical jump performance. The major findings were that post jump height decreased for the BS and control conditions with no change following HBDL while impulse, take-off velocity, and peak power decreased at post for all conditions. Possible reasons for this may be due to manipulation of critical variables such as training status, intensity, volume, rest period, and exercise choice.

Training status is an important factor for PAP (2, 3, 7, 16, 21). Chui et al. found that athletic individuals responded with greater PAP compared to those recreationally trained. However, Batista et al., when considering only strength training background, concluded it had no influence on PAP. There was no PAP effect for any of the conditions in the present study as previous studies have shown it to be highly individualized (7, 12, 14). Jo et al. examined the effects of recovery duration on a potentiating stimulus on muscular power in recreationally trained individuals and saw that stronger subjects were able to potentiate with lest rest whereas weaker subjects required more rest. McCann et al. also found PAP to be highly individualized when they examined subjects individually, they saw that some potentiated greater with the squat and some with the clean exercise. Additionally, some responded greater with 5-min rest and some with 4-min rest. Therefore, when trying to induce PAP, training experience and athletic ability should be

considered for optimization. The recreational basketball players in the present study had a large variety of training experience and strength levels which might have masked any PAP effects.

Intensity can also influence PAP and several studies have shown that heavy loaded squats fail to produce PAP in recreationally trained individuals (1, 3, 6, 8, 20). In contrast, Weber et al. examined the acute effects of a heavy load back squat at 85% 1RM in track and field athletes and found they were able to potentiate their squat jump performance. A meta-analysis of PAP (21) documented significant PAP differences when using a moderate intensity load between 40-60% and heavy intensities greater than 85% 1RM. Arias et al. examined the acute effects of heavy deadlifts on vertical jump performance in men and found that 85% 1RM did not induce PAP, and caused an acute reduction in vertical jump performance. These studies demonstrate that an intensity of 85% may or may not be beneficial for PAP. Intensity of 85% was chosen for the study, but training experience of the recreational basketball players could explain the lack of positive findings.

Manipulation of volume is also critical when trying to elicit PAP (4, 5, 8, 13, 21). Khamoui et al. examined the effects of volume in a back squat at 85% 1RM on vertical jump parameters in recreationally trained men and found they were not able to potentiate after performing one set of 2, 3, 4, or 5 repetitions. Wilson et al. found that multiple sets were more effective than single sets to optimize PAP. However, Crewther et al. examined the acute potentiating effects of back squats on vertical jump, and found that a single set at 3RM significantly improved performance at 4, 8, and 12 minutes post compared to baseline in subelite male rugby players. Mitchell et al. examined the effects of a 5RM

back squat in rugby athletes and found that vertical jump height increased when a twitch was evoked followed by 4 min rest, then a 5RM squat, and then another 4- min rest. These studies demonstrate that PAP is dependent on volume. Based on previous studies, single and multiple sets have been effective for PAP, therefore we chose to use a single set of 3 repetitions. Studies that have previously shown single sets effective for PAP used subelite or athletic individuals. Again, training status of the recreational basketball players in this study may have masked any positive outcomes.

Rest is often the forgotten variable, but it has an important role in PAP (9, 10, 12, 14, 21). Mola et al. investigated the optimal recovery time to elicit PAP following a bout of high-intensity 3RM squats in professional soccer players followed by countermovement jumps at 4, 8, 12, 16, and 20 minutes of rest, and found no potentiation. Kilduff et al. also examined optimal recovery time following a 3RM bench press or squat then measured countermovement jumps at 4, 8, 12, 16, and 20 minutes of rest . They found that 8-12 minutes rest was adequate recovery to produce PAP for lower body and 12 minutes for upper body. Adequate recovery for PAP is the balance between fatigue and performance as heavy resistance exercise acutely increases fatigue and decreases performance. Following rest, PAP exceeds fatigue and performance is enhanced (7, 15). A PAP meta-analysis (21) found that overall, moderate rest periods between 7-10 minutes are best following a heavy overload stimulus. Subjects in the present study were given 8 minutes standing rest after the preload stimulus. Depending on their training level some subjects might not have recovered adequately to minimize fatigue and enhance performance.

Choice of exercise also plays an important role in the production of PAP. Previous research has shown that back squats are the exercise of choice for PAP related to vertical jumping (4, 5, 13, 20). However, very little research has been done using the hex bar deadlift. Arias et al. investigated the effects of heavy deadlifts on PAP and vertical jump by having subjects perform a pre vertical jump, followed by a post vertical jump at 15s, 2, 4, 6, 7, 10, 12, 14, and 16 minutes post. Their results demonstrated that deadlifts did not induce PAP at any time point. Swinton et al. examined the effects of load position on the kinematics and kinetics of weighted vertical jumps. Rugby union athletes performed maximal jumps with the barbell on their shoulders or used a hex barbell at 0, 20, 40, and 60% of their squat 1RM. The hex bar resulted in greater jump height, peak force, power, and peak RFD. In Swinton's study, greater peak power was produced with the hex barbell using a load of 20% 1RM, whereas the present study used 85% 1RM.

Proper manipulation of the critical variables associated with PAP is important to elicit an effect. Research has yet to find the perfect combination of these variables to adequately produce PAP across exercises, populations, volumes, rest times, intensities, and training status. In the present study with recreationally trained basketball players, 85% 1RM back squats or hex bar deadlifts failed to increase acute vertical jump performance. Therefore, future research should continue to investigate the best combination of critical variables to elicit PAP.

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