International Journal of Health Sciences
March 2021, Vol. 9, No. 1, pp. 9-16
ISSN: 2372-5060 (Print), 2372-5079 (Online)

Published by American Research Institute for Policy Development
DOI: 10.15640/ijhs.v9n1a2
URL: https://doi.org/10.15640/ijhs.v9n1a2

Effects of Hex Bar Deadlift Training Loads on Vertical Jump Performance During Complex Training

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Abstract

This research examined different complex training loads and their ability to induce post activation potentiation. 12 recreationally trained participants (23.50 ± 3.52 years) performed a hex- bar deadlift for three repetitions at 60 or 80% 1 rep maximum, followed by a four-minute rest. Following the rest interval an akimbo variation vertical jump was performed, followed by an additional four-minute rest interval. This complex training pair was repeated four times and was randomized and counterbalanced. Results showed no significant interactions between vertical jump height and power at baseline, or after 60%, and 80% 1 repetition maximum. However, there were individualistic responses between responders and non-responders. The present results show that during a complex training prescription, hex-bar deadlifts at 60 and 80% were unable to induce postactivation potentiation, which was highly individualized in recreationally trained participants.

Keywords: complex training, postactivation potentiation, rate of force development, vertical jump, power

Introduction

Power or Rate of Force Development (RFD) is a measure of the speed at which contractile elements of the human musculature can produce force (Aagaard et al., 2002) and is one of the most important qualities in vertical jumping performance, while arguably considered more important than overall maximal strength (Kraemer, 2012). During a typical competition setting, an athlete may have only 50-250ms (Andersen & Aagaard, 2006; Oliveira, et al., 2013) to activate the musculature of the lower extremities to maximally propel the center of mass in the vertical direction. However, the production of maximal force may never be realized in a competition setting, as it has been shown to take upwards of 300ms or more to recruit and discharge specific motor units required to produce maximal force (Aagaard et al., 2002). Taken together, the necessity for maximal force production during competition and the temporal constraints a competition setting places on maximal muscular activation, the ability to express explosive power becomes an even more critical component to athletic success, especially while performing a vertical jump assessment.

Additionally, sporting activities that do not specifically depend on jumping performance such as a defensive lineman in American football, power production, or the velocity at which force is applied, is a useful measure of performance which has been assessed in Olympic Weight Lifters, (Tricoli et al. 2005; Teo et al., 2016; & Hackett et al., 2016) and baseball, rugby and soccer athletes (Cormier et al., 2020). Commonly, strength and conditioning specialists employ vertical jump testing to assess and monitor the athlete's power capabilities and training regimen effectiveness during, and following the completion of various training programs such as traditional resistance training (Harries et al., 2012), Olympic Weightlifting (Teo et al., 2016; Tricoli et al., 2005), plyometric training (Markovic & Mikulic, 2010) and complex training (Mangine et al., 2008; Fatouros, 2000; Li et al., 2019).

Complex training (CT) can be considered an advanced method that simultaneously trains the force and velocity of the movement in effort to enhance RFD and power, although enhancements during this mode of training are inconclusive and highly individualistic (McCann et al., 2010; Batista et al., 2011; Crum et al., 2012). CT takes a resistance exercise and pairs it with a biomechanically similar plyometric or explosive movement, such as a hex-bar deadlift (HBD), and a vertical jump to create a complex pair. The notion behind this pairing is to subsequently enhance the jump height and power following the resistance exercise though postactivation potentiation (PAP) of the musculature, being that skeletal muscle tends to be more responsive following exposure to maximal or near maximal contractions. HBD, a less technical movement than Olympic style weightlifting, has been shown to be an

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appropriate vertical jump training exercise (Scott et al., 2017) due to the fact that when compared with a conventional deadlift, HBD produced greater peak force, velocity, and power when using %1RM loads (Lockie, et al., 2017).

Weber et al., (2008) compared the use of bodyweight squats to a more intense load of 85% of the athletes 1RM which showed a significant increase in vertical jump height after performing the 85% condition following three minutes of rest. However, a significant reduction in vertical jump height was observed while performing only the squat jump, which may indicate the heavy condition exhibited an environment favorable to PAP. Furthermore, Smilios et al., (2005) investigated the effects of low to moderate loads performing half squats and loaded jump squats on vertical jump performance. Their results revealed that squat jump improved only after the first set of the 60% in the half squat group. This agrees with Seitz et al., (2014), Crum et al., (2012), and Weber et al., (2008), who all found increases in squat jump performances who utilized 90%, 50-65% and 85% 1RM, respectively. However, Lowery et al., (2012) agrees with previous studies in regards to a moderate load of 70% and 95% enhancing vertical jump and power after four minutes of rest, but disagrees with Crum et al., (2012) in that, light loading resulted in no change in jump height when compared to baseline. However, training status may have implications on these enhancements.

Seitz et al., (2014), Crum et al., (2012), and Weber et al., (2008) recruited elite rugby players, individuals currently in a structured resistance training program, and Division 1 track and field athletes, respectively. However, Chiu et al., (2003) investigated PAP in athletic and recreationally trained individuals and found significant differences between both groups, with the athletic trained individuals exhibiting signs of PAP through enhanced power production and force output when compared to recreationally trained. Therefore, with the vast array of intensities showing improvements of high-level performers, known individualistic nature of PAP depending upon activity level and sparse use of the HBD within the literature during a complex training regimen, the purpose of this study is to analyze the effects on jump height and power output after performing a HBD during a complex training regimen.

2. Methods

2.1 Experimental Approach to the Problem

This study was designed to investigate the effects of an HBD at varying intensities during a complex training regimen to determine if jumping performance and lower limb power was acutely affected. Based upon numerous studies that show an increase (Smilios et al., 2005; Scott et al., 2017), decrease (Jensen & Ebben, 2003), or no change (Scott & Docherty, 2004; McCann et al. 2010) in jump performance after completing a complex training regimen, coupled with the limited data on HBD intervention for complex training and the individualistic nature (McCann et al., 2010; Batista et al., 2011; Crum et al., 2012) of the PAP response, further investigation is warranted. Therefore, this study presents a 60% and 80% intensity prescription to the eligible participants over the course of 3 days to analyze jump height and power during a complex training paired regimen.

Participants came to the Human Performance Lab on three separate days separated by 48 hours. Day one served as the baseline measurement for vertical jump height and calculated power. Prior to collection of the baseline data, anthropometrics, resistance training history, and a systematic determination of 1RM for the HBD. The 1RM protocol was performed using guidelines by the National Strength and Conditioning Association (NSCA) (Haff & Triplett, 2016). 48 hours following the baseline measurements, the participants arrived to the Human Performance Laboratory to perform a structured warm-up followed by a four-minute rest. Subsequent to the warm-up and rest period, four sets of three reps of the HBD was performed at 60% or 80% of the participants 1RM followed by a four-minute rest period, terminating with modified akimbo squat jump following each set. This process was randomized and counterbalanced for all participants.

2.2 Participants

Twelve male (23.5 ± 3.53 years) (**Table 1)** participants who were at least 18 years of age, non-collegiate athletes, with a self-reported training age of at least one year with no injuries within the last 6 months were recruited for this study. All subjects were recreationally trained with 33% of the participants training for hypertrophy, 42% training for general health and fitness and 25% partaking in a sport specific regimen. All subjects voluntarily read and signed an informed consent which is in accordance with the guidelines for study approval set forth by the William Paterson University IRB committee. Additionally, participants were screened for contraindications via Physical Activity Readiness Questionnaire (PARQ) form.

Table 1. Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Age (yrs)	12	19.00	28.00	23.50	3.53
Height (cm)	12	165.10	186.00	175.51	6.60
Weight (kg)	12	66.80	94.40	79.64	9.92
Lifting Experience(yrs)	12	1.00	10.00	5.50	3.15
1RM	12	102.04	231.29	153.63	41.33

Means, minimum, maximum and standard deviation of descriptive variables.

2.3 Procedures

On day one, participants arrived at the Human Performance Lab, and prior to the warmup, the participants were asked to sign the Physical Activity Readiness Questionnaire (PARQ). First, the participant's age, height and weight were recorded. Secondly, the participants were asked to describe their resistance training history. Participants were then instructed perform a warm-up that consisted of two minutes on the stationary bicycle and were instructed to maintain between 70 and 80 revolutions per minutes (Rave et al., 2009). Following a two-minute rest period (Seitz et al., 2014), the baseline modified akimbo squat jump was assessed using the Just Jump® Jump Mat (Probotics, Birmingham, AL). This method was chosen due to it being one of the most reliable jumping tests for the estimation of the explosive characteristic of the lower limbs in physically active men (Markovic et al., 2004). Once on the jump mat, the participants assumed the modified akimbo hand placement to reduce the arm swing which can have an influence on vertical jumping performance. The participants were given the following verbal countdown "3, 2, 1, GO!" When the participants heard the number 1, they dropped down into a half-squat where the femurs were parallel with floor with the hands remaining on the back of the head with fingers interlocked. When the participant heard the word "GO!" they were instructed to jump while keeping the hands on the head, and keeping the legs fully extended. This was repeated for five jumps, with 30 seconds rest in between (Rave et al., 2009). After completion of the vertical jump testing, a four-minute rest period was given, in order to ensure complete recovery prior to the HBD 1 RM testing.

Day two and three served as trial conditions. Participants arrived at the Human Performance Lab and began the same two-minute stationary bicycle warm-up as the first day. After a two-minute rest period, the participants were instructed to perform three repetitions of the HBD at the randomly assigned 60 or 80% of their 1 RM. After a four-minute rest period, the participants were then instructed to perform one modified akimbo squat jump, following the same instructions as the baseline vertical jump assessment. The participants repeated this sequence for four sets, with four minutes of rest in between each set. Power (watts) was calculated using a validated equation (Sayers et al.,1999), specifically for squat jump:

$$\textbf{Watts} = \textbf{60.7(jump height [cm])} + \textbf{45.3(body mass[kg])-2055}$$

2.4 Statistical Analysis

All statistics were performed utilizing SPSS version 24 (SPSS INC, Chicago IL, USA). A Kolmogorov-Smirnov was conducted to assess normality of distribution as well as a Mauchly's test for Sphericity for homogeneity of variances. To determine the difference between the three levels of the independent variable (baseline, 60% and 80%) a 3x4 (condition by trial) repeated-measures analysis of variance (RMANOVA) was conducted ($p \leq .05$).

3. **Results**

3.1 Vertical jump Performance

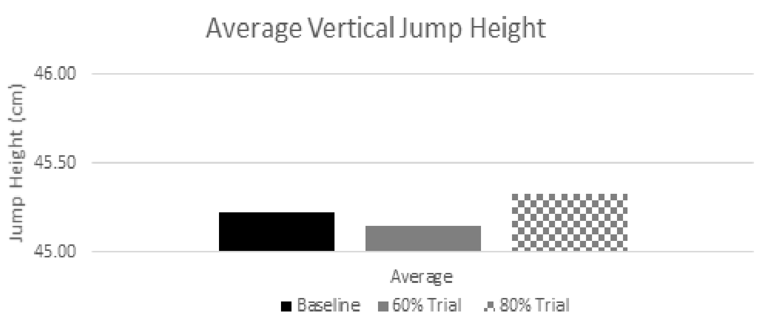

Figure 1. Average vertical jump height (baseline, 60% and 80%) across all participants, with the largest, but non-significant increase occurring in the 80% trial. For jump height, no significant interactions between condition and

trial were observed in either the 60% or 80% condition $F(2.44, 4.90) = 1.29, p < .05$ (Figure 1). When comparing to baseline the 60% and 80% conditions, an increase of .07 and .10 centimeters, respectively, was observed. These results revealed that the percentage of the participants 1RM did not have any effect on vertical jump performance across trials.

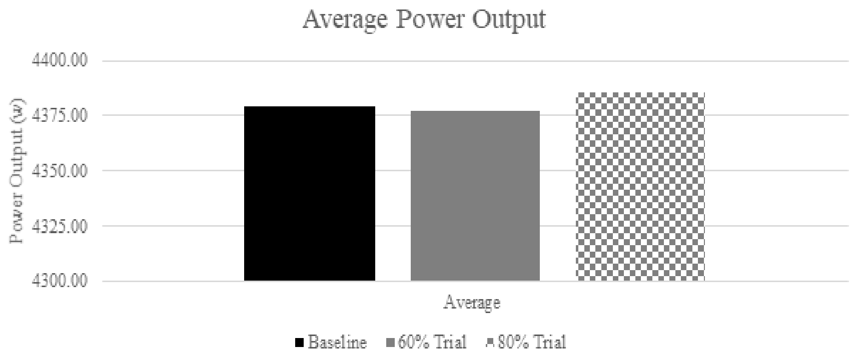

Figure 2. Average power output (baseline, 60% and 80%) participants 1RM across all participants, with the largest, but non-significant increase occurring in the 80% trial.

For power output, no significant interactions between condition and trial were observed in either the 60% or 80% condition $F(1.11, 2.21) = 1.05, p < .05$. (Figure 2). When comparing to baseline the 60% and 80% conditions, a decrease of 2.62W was observed, whereas in the 80% condition a slight increase of 6.15W was observed.

Furthermore, there was an 8.57W increase when comparing the 60% to the 80% condition. These results reveal that the percentage of the participants 1RM did not have any effect on power output across trials.

2. ***Individual Differences***

Though not statistically significant, there was evidence of responders and non-responders when using the different loads. For individual power performances (Figure 4), three participants produced their highest power outputs with the 60% 1 RM load, seven participants produced their highest power performance with the 80% 1 RM load, while two participants performed their highest power outputs during the initial baseline jump.

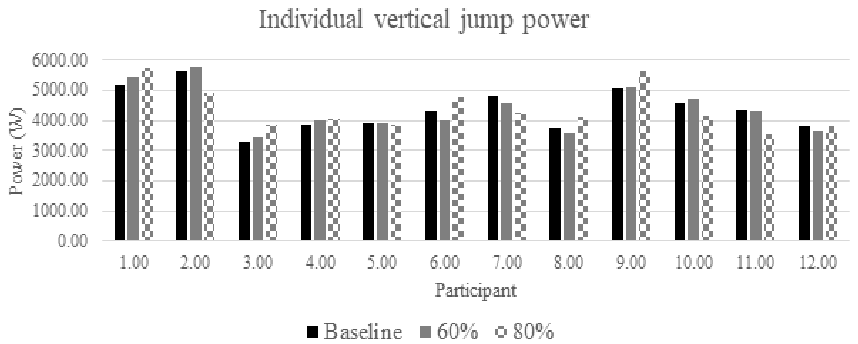

Figure 3. Individual power output for the baseline, 60% and 80% condition highlighting the individualistic nature of PAP response.

As evident by Figure 3., two participants produced their highest power at baseline, three participants produced their highest power at 60%, and seven participants produced their highest power at 80%. This graph shows the influence of training history and participant characteristics has on the individualistic nature of PAP expression in the context of power output. Although no significant interaction was observed, increases to power output when compared to baseline is noteworthy.

4. **Discussion**

This research aimed to analyze the effects on jump height and power output after performing a HBD during a complex training regimen. Our principal finding was no significant interactions existed between the baseline measurements and the HBD protocols using 60% or 80% of 1RM. However, the individual responses show how CT utilizing a HBD may have the potential for inducing PAP, subsequently improving performance. These results agree with McCann et al., (2010), Batista et al., (2011), Crum et al., (2012) and Evetovich et al., (2015), who all showed inconsistent results on their participant's ability to express PAP on jumping performances and noted highly individualistic responses. Our results disagree Scott et al., (2017), who showed improvements in performances using a similar HBD protocol.

4.1 Neuromuscular and Skeletal Muscle Mechanisms

Numerous studies have shown how the ability to express PAP, and subsequently augment vertical jump height, is dependent on a prerequisite strength level (Seitz et al., 2014, Seitz, et al., 2016; Wilson et al., 2013; Tillin et al., 2009). Scott et al., (2017), defined stronger individuals as those who had an average HBD 1RM of at least two times their body mass. Participants in the current study possessed an average HBD 1RM of 1.89 times their body mass, defining them as 'weak' when compared to the aforementioned stronger individuals, of which showed improvement. Therefore, the lack of prerequisite relative strength amongst our individuals may have led to an inability to recruit and activate a sufficient number of the type II motor units that are utilized when high force and power performances are required. Being that enhanced excitability of motor units are said to be a potential mechanism of PAP (Tillin & Bishop; 2009, Hodgson et al., 2005; Blazevich & Babault, 2019; Docherty et al., 2004; Ebben, 1998), a base level of strength may be needed to enhance the ability to increase the excitability of the motor unit pool. Being the participants in the current study did not possess the recommendation by Scott et al., (2017) of a 1RM of two times their body mass in the HBD, performance seems to be affected, specifically the degradation of a preferable muscular environment to exploit PAP.

Additionally, fiber type distribution may have not allowed an environment conducive to PAP. Tillin & Bishop (2009), noted how those with higher type II fiber distribution may have a greater benefit of PAP via CT. This theory stems from the work of Hamada et al., (2000) which showed high responders of PAP had greater type II fiber distribution. Due to the lack of overall group potentiation in the present study (Figures 1 & 2), our participants may have had a reduced type II fiber distribution, whereas stronger and more explosive and longer trained individuals typically possess a greater distribution of type II fibers (Haff & Triplett, 2016).

This greater type II fiber distribution may lead to greater motor unit excitability, ATPase activity, and increased myosin content which could potentially enhance force production. Due to the lack of relative strength, and the lack of PAP, our group likely did not have high type II fiber type distribution or skeletal muscle adaptations associated with power performances. In contrast to group data, individual responders to PAP (Figure 3), participant 1, 3 and 9 may have had a higher type II fiber distribution and skeletal muscle adaptations than the non-responders.

Therefore, function and distribution of skeletal muscle may have limitations that prevented PAP, and subsequently RFD and increased power output and vertical jump height. Specifically, the phosphorylation of MRLC may not have occurred, due to the lack of overall strength. Ca^{2+} sensitivity has been shown to be fiber type dependent. With increased force expression and power capabilities, type II fibers need increased Ca^{2+} concentration for contractions (Fitts, 2008). As more force is produced, there is a surge in Ca^{2+} release and sensitivity which will plateau at maximal efforts (MacIntosh, 2003). Thus, our 'weaker' population needed more force to move the training loads to promote increased concentrations of Ca^{2+} in the sarcoplasm. When the levels of Ca^{2+} in the muscle cells are at saturating or near-saturating levels, heightened sensitivity to Ca^{2+} is reduced, and subsequent phosphorylation of MRLC may be attenuated (Sale 2002; Hodgson et al., 2005; Blazevich & Babault, 2019). Due to the lack of performance improvements seen in the present study, phosphorylation of MRLC may have been blunted, reducing PAP and therefore reducing overall jump height and power output.

Foundational strength related adaptations are important, and ought to be developed prior to power development. Our sample's training history may explain the lack of strength needed to maximize power and PAP. 33% of the participants trained for hypertrophy, 42% trained for general health and fitness while 25% participated in a sport specific regimen. In regard to the SAID principle, individuals that undergo strength/power training obtain specific adaptations related to increasing the motor unit pool and their discharge rates, which can lead to increases in RFD and PAP much like the results of Aagaard et al., (2002). The adaptations from such training would have increased the neural drive to the skeletal muscle leading to greater RFD, power output and vertical jump performance. Thus, the current studies sample population lack of prerequisite strength, which provides the upper limit in which power and RFD can be produced, may have affected the ability to express enhanced RFD and power output following the CT protocol, subsequently leaving no advantage to the athlete in regards to a vertical jump assessment.

4.2 *Individual Differences*

The ability for one to express PAP relies on the ability to balance fatigue and potentiation (Sale, 2002, Tillin & Bishop 2009; Wilson et al., 2013). The four-minute rest interval used in the present study did not lead to any significant potentiation, which disagrees with other studies that utilized the same rest period (McCann et al., 2010; Scott et al., 2017) and similar HBD CT intervention (Scott et al., 2017). Compared to the HBD intervention by Scott et al. (2017), the current study had more volume which may have increased metabolites that promote fatigue such as adenosine diphosphate (ADP), hydrogen ions (H^+) and inorganic phosphate (Pi) (Fitts, 2008). These metabolites impair force production at the cross bridges and when pH drops below 6.7, the velocity of contraction is inhibited, potentially via the reduction of ADP release from the myosin heads (Fitts, 2008). Together, the accumulation of these metabolic byproducts has the ability decrease force production, velocity, Ca^{2+} sensitivity, and therefore any subsequent power production from the influence of PAP (MacIntosh, 2003; Fitts, 2008).

Figure 3. illustrates the delicate balance between fatigue and potentiation with 33.3 % of participants showing an improvement in power from baseline in both the 60% and 80% conditions, 25% of participants showing an increase in the 60% condition only and 16.6% of participants showing an improvement in the 80% condition only. These results solidify the notion the PAP response is highly individualistic (McCann et al., 2010) and may depend upon a variety of different factors such as the aforementioned relative strength levels and muscle characteristics, as well as fatigue state and specificity of current and previous training. Numerous studies have found that athletes tend to exhibit an increased instance of PAP when compared to recreationally trained and untrained participants (Chiu et al., 2003; Hamada et al., 2000; Wilson et al., 2013). Being that our population was recreationally trained, and as a whole, not considered 'strong' as defined by Scott et al., (2017), relative strength levels may be able to explain the increase in power for these four participants which agrees with Scott et al., (2017). These four participants that showed improvements in both conditions had a HBD 1RM of 2.14 times their body weight as well as an increased experience with ballistic style training, therefore giving them the requisite level of strength, as well as neuromuscular adaptations to take advantage of PAP and increase their power output. Moreover, three participants (2,5,10) increased power output only after the 60% condition when compared to baseline (Figure 3), but with a decline following the 80% condition. Inappropriate volume may be able to explain this decrease. An inverse relationship exists between volume and intensity.

As volume during the intervention is low while maintaining an intensity high enough to properly stimulate the musculature, PAP may be realized. While in contrast, if volume is high there is a greater chance of fatigue which would mitigate PAP (Sale, 2002 & Tillin & Bishop, 2009). Being that our volume was higher with less rest than those studies who saw improvements (McCann et al., 2010; Scott et al., 2017), fatigue may have dominated after performing the high volume at 80% 1RM. A reduction of volume may have allowed the prescribed rest interval to allow the fatigue causing metabolites to dissipate reducing fatigue while simultaneously enhancing the PAP effect, which was observed in the 60% condition.

In contrast, 16.6% of the current studies participants (6 and 8) were able to increase power output in only the 80% condition. For these individuals, it may possible that the 60% condition was not a strong enough stimulus to promote an increase in muscular excitability, as the theory for the heavy set during complex training is that skeletal muscle tend to be more explosive after being subjected to maximal or near-maximal contractions (Baker, 2003a), with the 80% condition serving as a potent stimulus to augment power output. Regarding the Henneman's size principle of motor unit recruitment, motor units that are explosive in nature are recruited as exercise intensity increases. Therefore, the threshold needed to augment skeletal muscle excitability and induce a PAP response was not met during the 60% condition, while in the 80% condition the threshold was exceeded, thus showing the observed increase in power output for these particular participants. Lastly, the training history of these individuals may explain the lack of potentiation with the lighter load. Participant 6 trained primarily for hypertrophy, while participant 8, trained on a non-specific basis primarily for general health and fitness. Being that these two training styles are not specific for the enhancement of power output or RFD, it may be plausible that they did not have sufficient neuromuscular and/or muscular adaptations that would facilitate faster muscular contractions.

5. **Conclusion**

In conclusion, this study has shown that a biomechanically similar exercise immediately prior to a vertical jump assessment can result in improvements, however improvements tend to be slight and highly individualistic. Strength and conditioning professionals need to be cognizant of this individualistic nature of the PAP response and program according to the specific need of the particular individual or goal of within a certain training cycle. Additionally, it is also shown that the HBD may be disadvantageous to some athletes prior to a vertical jumping assessment depending upon the intensity used, as not all athletes will respond favorably due to individual differences in muscle architecture, absolute strength levels and previous neuromuscular adaptations.

6. **Disclosure Statement**

The authors report no conflict of interest. No funding was used for this study.

7. **Abbreviations**

CT, Complex Training; PAP, postactivation potentiation; HBD, Hex-Bar Deadlift; RFD, Rate of Force Development; 1RM, 1-repetition maximum

8. **Acknowledgements**
None

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