OPTIMIZING EXERCISE SELECTION FOR POWER DEVELOPMENT IN ATHLETES USING VELOCITY-BASED TRAINING

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The purpose of this study was to determine which lift and velocity range provide the highest levels of power and force production. 7 highly trained strength professionals performed 3 sets of paired powerlifting exercises: deadlift (DL) and back squat (SQ), power clean (PC) and hang clean (HC), and power clean (PC) and clean pull (CP). Velocity was also controlled for the lifts. Velocity ranges, 0.5-0.75 m/s, 0.75-1.0 m/s, and 1.0-1.3 m/s, were used. A 2 x 3 ANOVA with post-hoc test investigated the data. Lift choice mattered for average power, peak power, and force when controlling the velocity of movement.

KEYWORDS: powerlifting, power analyzer, velocity-based training

INTRODUCTION: Central to power development in athletes is strength training. The traditional means for improving athlete power are a manipulation of training volume and frequency based on the one repetition maximum (1RM). Traditional strength training does not move at speeds athletes needs. Training for strength does not mean an athlete will be powerful; however, an athlete must be strong before power training can be effective (Young, 2006). While the benefits of general strength training as a means to enhance force generation, body mass increase, and injury risk reduction are undeniable; the ability to directly transfer improvements to specific sports skills is limited (Young, 2006). Athletes lifting at slower velocity decrease in improvements the further the velocity deviates from the needed pattern (Behm & Sale, 1993). Athletes need to train at a velocity matching the sport's skills.
Velocity based training (VBT) provides a means to develop power within athletes by training with an optimal load independent of the 1RM and moving at greater velocities (Gonzalez-Badillo & Sanchez-Medina, 2010). Using velocity allows easily modifiable training programs (Gonzalez-Badillo, Marques, & Sanchez-Medina, 2011). Repetition velocity affects the neuromuscular demands as well as the desired training effects (González-Badillo and Sánchez-Medina, 2010). The actual velocity performed is the best reference to accurately determine the mechanical effort performed (Gonzalez-Badillo et al., 2011). Optimizing exercise selection throughout training is needed to train athletes efficiently and safely. Inexperienced lifting and incorrect technique demonstrate issues when using the 1 RM as the standard (Conceicao, Fernandes, Lewis, Gonzalez-Badillo, & Jimenez-Reyes, 2016). Each lift exposes athletes to injury risk. Acute injuries to the shoulder, low back, elbow, knees are common (Keogh, Hume, & Pearson, 2006). Movement velocity provides a level of effort as well as the degree of fatigue of an athlete during resistance training (González-Badillo and Sánchez-Medina, 2010). By selecting alternate lifts that decrease exposure to known lifting injury risk, athletes maintain strength and power during critical points in the season while minimizing injury risk. Alternate lifts are derivatives to the original lift (e.g., a clean pull is the first phase of hang clean) or lifts that contain similar movement patterns. Research comparing power and force between the original lift and the deviations exists. However, no research has investigated how controlling movement velocity affects power and force. The purpose of this study was to determine which lift and velocity range provide the highest levels of power and force production for 3 sets of paired lifts. The question posed whether one lift was better than another for average power, peak power, partial peak power, and force outputs and how lift velocity impacted the power and force outputs.

METHODS: A randomized observational cohort design guided this study. Participants included 7 male highly trained strength professionals (1.79±0.07 m, 92.3±15.1 kg). The study occurred over 8-weeks. The study paired 3 sets of powerlifting and Olympic lift exercises:

deadlift (DL) and back squat (SQ), power clean (PC) and hang clean (HC), and power clean (PC) and clean pull (CP). Traditional technique was used for all lifts. Lifts were paired by similar movement pattern or with a deviation from the original. Velocity ranges, 0.5-0.75 m/s (accelerative strength), 0.75-1.0 m/s (strength/speed), and 1.0-1.3 m/s (speed/strength) were used. Participants performed a 1RM of each lift pair a minimum of 7 days before the test day for the scheduled pairing. A minimum of 48 hours rest occurred before each test day. Order of lift and velocity for each lift pairing were randomly assigned. A portable power analyzer (Tendo Power Analyzer, Tendo Sports Machine, Slovak Republic) was used to collect the data. Average power, peak power, and force were recorded from the Tendo after the completion of the lift. Participants performed 3 repetitions of each lift within the designated velocity. Lift load for the paired load was determined by the completion of a 1 RM a week previous to testing. The 1RM% for each of the velocity zones was as follows: 90% (0.5-0.75 m/s), 65% (0.75-1.0 m/s), and 45% (1.0-1.3 m/s) and is based upon the Strength-Velocity Continuum developed by Bosco. Data were scaled for body mass and lift load (Jaric, 2003; Jaric, Mirkov, & Markovic, 2005). A 2 x 3 ANOVA with post-hoc test investigated the data.

RESULTS: A 2 x 3 ANOVA of lift type (DL, SQ) and velocity (0.5-0.75, 0.75-1.0, 1.0-1.3 m/s) on DV of average power, peak power, and force was conducted. Table 1 lists means and standard deviations for average power, peak power, and force for lift type and velocity. There was a significant main effect of DL vs. SQ on average power ($F(1, 66) = 18.25$, $p<0.0001$), peak power ($F(1, 66) = 27.66$, $p<0.0000$), and force ($F(1, 66) = 13.65$, $p<0.0004$). A significant main effect of lift velocity on average power ($F(2, 66) = 220.04$, $p <0.000$), p=<.0000, peak power ($F(2, 66) = 159.46$, $p<0.0000$), and force ($F(2, 66) = 155.34$, $p<0.000$) was found. The main effect of lift type on average power was significant $F(1x2, 71) = 6.2989$ $p=0.0031$. Tukey-Kramer HSD indicated that slower velocity was better than the higher paired velocity in genertating average power, peak power, and force when compairing DL and SQ. The interaction of velocity on lift type was significant for average power $F(1x2, 89) = 6.30$, $p<0.0013$).

Table 1: Mean (±SD) of Power and Force Variables by Lift and Velocity (DL and SQ)

		Avg. Power (W)	Peak Power (W)	Force (N)
Power Clean		730.2 (±171.5)	1327.0 (±387.4)	1288.3 (±199.3)
Hang Clean		750.0 (±169.1)	1515.2 (±250.5)	1285.6 (±196.8)
0.5-0.75 m/s	Dead Lift	528.8 (±96.2)	856.1 (±131.3)	1112.0 (±166.7)
	Squat	561.5 (±140.8)	1260.5 (±177.2)	1169.8 (±222.5)
0.75-1.0 m/s	Dead Lift	727.58 (±122.9)	1333.3 (±291.9)	1271.8 (±210.3)
	Squat	715.7 (±92.2)	1436.8 (±158.6)	1232.6 (±195.2)
1.0-1.3 m/s	Dead Lift	934.08 (±155.9)	1791.7 (±328.7)	1481.2 (±222.1)
	Squat	972.9 (±143.0)	1848.3 (±217.1)	1454.4 (±226.1)

A 2 x 3 ANOVA of lift type (PC, CP) and velocity (0.5-0.75, 0.75-1.0, and 1.0-1.3 m/s on the DV of average power, peak power, partial peak power, and force was conducted. Table 2 lists the means and standard deviations for average power, peak power, and force for lift type and velocity. A significant main effect for lift type of PC vs. CP on average power ($F(1, 84) = 30.32$, $p<0.0000$), peak power ($F(1,76) = 25.60$, $p<0.0000$), and force ($F(1, 84) = 34.42$, $p<0.0000$) was found. Significant main effect of lift velocity between PC and CP on average power ($F(2, 84) = 36.54$, $p<0.0000$), peak power ($F(2, 84) = 36.54$, $p<0.0000$), and peak power ($F(2, 84) = 27.27$, $p<0.000$), and force ($F(2, 84) = 30.16$, $p<0.0000$) was found. Tukey-Kramer HSD indicated that .5-.75 m/s and 0.75-1.0 m/s were better compared to 1.0-1.3 m/s in gernetating average power, partial peak power, peak power, and force when comparing the PC and CP. The interaction of velocity on lift type (PC vs. CP) was significant for partial peak power $F(1x2, 89) = 7.17$, $p<.0013$).

Table 2: Mean (±SD) of Power and Force Variables by Lift and Velocity (PC and CP)

		Avg. Power (W)	Peak Power (W)	Force (N)
Lift				
Power Clean		934.1 (±140.3)	3054.1 (±592.3)	1646.9 (±231.5)
Hang Clean		842.9 (±163.5)	2430.3 (±486.4)	1383.9 (±210.3)
0.5-0.75 m/s	Power Clean	856.5 (±159.2)	2686.3 (±409.2)	1433.4 (±231.7)
	Clean Pull	767.5 (±154.3)	1950.1 (±261.1)	1251.9 (±224.9)
0.75-1.0 m/s	Power Clean	895.2 (±182.4)	2642.7 (±473.5)	1561.9 (±182.6)
	Clean Pull	800.8 (±210.5)	2307.2 (±374.3)	1357.8 (±209.2)
1.0-1.3 m/s	Power Clean	1040.3 (±240.8)	3784.3 (±1237.1)	1916.9 (±329.3)
	Clean Pull	960.4 (±231.8)	3033.6 (±725.6)	1542.0 (±262.9)

A 2 x 3 ANOVA of lift type (PC, HC) and velocity (0.5-0.75, 0.75-1.0, and 1.0-1.3 m/s) on the DV of average power, peak power, partial peak power, and force was conducted. Table 3 lists the means and standard deviations for average power, peak power, partial peak power, and force for lift type and velocity. No significant main effects for lift type between PC vs. HC for average power, peak power, partial peak power, and force were found. A significant main effect of lift velocity of PC vs. HC on average power ($F(2, 76) = 2.76$, $p<0.0000$), $p<0.000$), peak power ($F(2, 76) = 25.09$, $p <.0000$), and force ($F(2, 76) = 17.55$, $p<0.000$) was found. Tukey-Kramer HSD indicated that the slower velocity was better than the higher paired velocity in generating average power and peak power when comparing the PC and HC. Partial peak power and force were better when using 0.5-0.75 m/s than 1.0-1.3 m/s when comparing the PC and HC according to Tukey-Kramer HSD.

Table 3: Mean (±SD) of Power and Force Variables by Lift and Velocity (PC and HC)

		Avg. Power (W)	Peak Power (W)	Force (N)
Power Clean		941.6 (±242.6)	3009.1(±1222.3)	1852.3 (±714.1)
Hang Clean		1048.6 (±225.5)	3071.0 (±929.7)	1981.0 (±529.4)
0.5-0.75 m/s	Power Clean	808.4 (±209.5)	1968.6 (±529.1)	1373.3 (±289.5)
	Hang Clean	876.6 (±116.5)	2255.1 (±330.1)	1602.0 (±207.8)
0.75-1.0 m/s	Power Clean	942.4 (±216.3)	3065.4 (±877.9)	1911.8 (±539.5)
	Hang Clean	1073.4 (±159.4)	3197.6 (±848.3)	2013.8 (±520.1)
1.0-1.3 m/s	Power Clean	1044.3 (±252.7)	3780.9(±1330.2)	2161.7 (±901.2)
	Hang Clean	1180.5 (±243.9)	3687.9 (±733.6)	2290.1 (±504.8)

DISCUSSION: This study determined which lift and velocity range provide the highest levels of power and force production. The study also investigated which lift of the pair was better for average power, peak power, partial peak power, and force outputs and how velocity impacted the power and force outputs. Lift and velocity of lift impacted the power and force outputs. As expected, power and force outputs varied within the velocity ranges. The 0.5-0.75 m/s velocity provided lower power and force outputs across the three pairs of lifts. The power and force outputs of squat, power clean, and hang clean were higher than their paired lifts of deadlift, clean pull, and power clean in most comparisons. Along with the significant differences in the angular positions of the joints of the lower extremities, the deadlift is a sequential movement compared to the simultaneous movement of back squat (Hales, Johnson, & Johnson, 2009). SQ outperformed the DL for average power, peak power and force in both lift and velocity comparisons in this study. Differences between average power and peak power outputs were more pronounced than force output during the velocity comparisons for most test conditions.

The PC outperformed the CP for average power, peak power and force in both lift and velocity comparisons. Comfort, Allen, & Graham-Smith (2011) determined that greater peak power output occurred with the mid-thigh clean pull when compared to the power clean. The differences between the average power, peak power, and force outputs were pronounced for the PC during the velocity comparisons for all test conditions. The results were expected even though the CP does have good power producing capabilities allowing for heavier loads. An athlete with poor PC technique can still use the CP as part of their training protocol, which is the first phase of the PC, as part of their training to develop power.

The HC outperformed the PC for average power, peak power and force in both lift and velocity comparisons. These movements differ only in their starting positions. The power clean begins from the floor, the hang power clean begins from just above the knees. Comfort et al., (2011) demonstrated greater peak power output with the hang clean and the midthigh power clean when compared to the power clean. With less distance to accelerate the bar, more force must be applied to clean successfully from the hang position. The differences between the average power, peak power, and force outputs were greater for the HC than the PC.

CONCLUSION: Lift choice did matter for average power, partial peak power, peak power, and force. Velocity range mattered in average power, force, and partial peak power in some but not all. Slower velocities were better for generating average power, peak power, and force between the DL and SQ and the PC and the CP. Lift choice and velocity interaction were not significant for these paired combinations. Understanding which lift and velocity range are best suited for generating desired power and force outputs will optimize exercise selection for athletes throughout their training cycles.

REFERENCES

Behm, D. G., & Sale, D. G. (1993). Velocity specificity of resistance training. *Sports Medicine, 15*(6), 374 388.

Comfort, P., Allen, M., & Graham-Smith, P. (2011). Kinetic comparisons during variations of the power clean. *The Journal of Strength & Conditioning Research*, *25*(12), 3269-3273.

Conceicao, F., Fernandes, J., Lewis, M., Gonzalez-Badillo, J. J., & Jimenez-Reyes, P. (2016). Movement velocity as a measure of exercise intensity in three lower limb exercises. *Journal of Sports Science, 34*(12), 1099-1106. doi:10.1080/02640414.2015.1090010

Gonzalez-Badillo, J. J., Marques, M. C., & Sanchez-Medina, L. (2011). The importance of movement velocity as a measure to control resistance training intensity. *Journal of Human Kinetics, 29A*, 15-19. doi:10.2478/v10078-011-0053-6

Gonzalez-Badillo, J. J., & Sanchez-Medina, L. (2010). Movement velocity as a measure of loading intensity in resistance training. *International Journal of Sports Medicine, 31*(5), 347-352. doi:10.1055/s-0030-1248333

Hales, M. E., Johnson, B. F., & Johnson, J. T. (2009). Kinematic analysis of the powerlifting style squat and the conventional deadlift during competition: is there a cross-over effect between lifts? *The Journal of Strength & Conditioning Research*, *23*(9), 2574-2580.

Hoffman, J. R., Cooper, J., Wendell, M., & Kang, J. (2004). Comparison of Olympic vs. traditional power lifting training programs in football players. *The Journal of Strength & Conditioning Research*, *18*(1), 129-135.

Jaric, S. (2003). Role of body size in the relation between muscle strength and movement performance. *Exercise and Sport Science Reviews, 31*(1), 8-12.

Jaric, S., Mirkov, D., & Markovic, G. (2005). Normalizing physical performance tests for body size: a proposal for standardization. *Journal of Strength & Conditioning Research, 19*(2), 467-474. doi:10.1519/R-15064.1

Keogh, J., Hume, P. A., & Pearson, S. (2006). Retrospective injury epidemiology of one hundred one competitive Oceania power lifters: the effects of age, body mass, competitive standard, and gender. *Journal of Strength & Conditioning Research, 20*(3), 672-681. doi:10.1519/R-18325.1

Young, W. B. (2006). Transfer of strength and power training to sports performance. *International Journal of Sports Physiology and Performance, 1(2*), 74-83.