LOWER EXTREMITY JOINT VELOCITY COMPARISONS DURING THE HANG POWER CLEAN AND JUMP SHRUG AT VARIOUS LOADS

Timothy J. Suchomel[1], Glenn A. Wright[2], and Jonah Lottig[2]

East Tennessee State University, Johnson City, TN, USA[1]
University of Wisconsin-La Crosse, La Crosse, WI, USA[2]

The aim of this study was to compare the kinematic profile between the hang power clean (HPC) and jump shrug (JS). Eighteen college students performed repetitions of the HPC and JS at 40, 60, and 80% of their 1RM HPC. Two trials at each load for each exercise were completed and the peak joint velocity of the hip, knee, and ankle joints were compared using a series of 2 x 3 repeated measures ANOVA. The peak joint velocity of the hip, knee, and ankle during the JS was statistically greater than the HPC at all loads. Statistically significant differences in hip joint velocity existed between repetitions at 40 and 80% 1RM HPC as well as between 60 and 80% 1RM HPC. Joint velocity during the JS was superior to the HPC at all loads examined. Differences in technique between exercises and loads may alter lower extremity joint velocity.

KEYWORDS: weightlifting movements, kinematics, triple extension

INTRODUCTION: Lower body muscular power is viewed as a vital component to an athlete's performance in sports. As a result, practitioners have placed a large emphasis on the development and improvement of lower body muscular power during the triple extension movement. Many different training methods and exercises have been prescribed to improve lower body muscular power, however weightlifting movements and their derivatives are often viewed as superior training stimuli (Comfort, Allen, & Graham-Smith, 2011a, 2011b; Cormie, McCaulley, Triplett, & McBride, 2007). Based on the number of derivatives, it is up to the practitioner to choose the most effective training method for their athletes.

When considering different exercises and their ability to train muscular power, both kinetic and kinematic aspects must be considered. Several previous studies have examined the kinetic differences between weightlifting movements and their derivatives (Comfort, et al., 2011a, 2011b; Suchomel & Wright, 2013; Suchomel, Wright, Kernozek, & Kline, 2014). Collectively, these studies suggest that the mid-thigh pull and jump shrug (JS) weightlifting derivatives produce greater force, center of mass velocity, rate of force development, and power as compared to the hang power clean (HPC), suggesting that these variations may provide a superior training stimulus as compared to a variation that includes the catch phase. Although the above kinetic information exists, there is a paucity of research that has compared the kinematic differences between weightlifting exercises and their derivatives.

In order to optimally train muscular power, both ends of the force-velocity curve should be trained (Haff & Nimphius, 2012). Thus, it is common for practitioners to prescribe both heavy and light loads in order to provide their athletes with a superior training stimulus. If practitioners are considering multiple exercises, data indicating how kinetics and kinematics change as an external load increases should be provided. Much of the extant literature on weightlifting movements has examined the optimal load of an individual exercise (Comfort, Fletcher, & McMahon, 2012; Cormie, et al., 2007; Kawamori et al., 2005; Kilduff et al., 2007), while only two studies have examined differences between exercises at multiple loads (Suchomel & Wright, 2013; Suchomel, et al., 2014). Furthermore, little research has examined how kinematics change as a result of load between weightlifting movements.

In order to provide information about the development of muscular power between exercises, both kinetic and kinematic information is warranted. Although previous research supports that the JS produces superior kinetic data as compared to the HPC, no kinematic data currently exists that compares these two clean derivatives. Therefore, the purpose of this study was to compare the hip, knee, and ankle peak angular joint velocity (JV_{Peak}) between the HPC and JS at various loads.

METHODS: Eighteen college students (males, n = 16; females, n = 2; age: 21.8 ± 1.9 years; height: 178.1 ± 6.2 cm; body mass: 89.0 ± 13.9 kg; 1RM HPC: 92.2 ± 15.7 kg; HPC experience: 6.00 ± 2.5 years) participated in this study. This study was approved by the university Institutional Review Board and all subjects provided written informed consent.

Each subject participated in a familiarization and testing session. The familiarization session was used to determine each subject's 1RM HPC and to familiarize the subjects with proper JS technique. Upon arrival for the familiarization session, each subject completed a standardized warm-up. Following the warm-up, each subject's 1RM HPC was determined using methods described by Baechle et al. (2008). All HPC repetitions were performed using the technique described by Kawamori et al. (2005). Loads were increased until two unsuccessful attempts at a given load occurred. Any HPC repetition caught in a squat position with the upper thigh below parallel to the floor was ruled unsuccessful. After obtaining a 1RM, each subject completed submaximal exercise sets of the JS using the technique described by Suchomel et al. (2013). Subjects returned to the lab for their testing session 48 – 72 hours later. Following the standardized warm-up, subjects were fitted with 21 reflective markers. Markers were placed on anatomical landmarks including the left and right ASIS, the sacrum, lateral and medial joint condyles of the knee, malleoli of the ankles, posterior portion of the shoes, and near the toes between metatarsals one and two. In accordance with Bush & Gutowski (2003), additional triads of markers affixed to a plastic shell were placed on the thighs and shanks of each leg. After being fitted with markers, each subject performed two, single maximal effort repetitions of the HPC and JS at loads corresponding to 40, 60, and 80% of their 1RM HPC. Exercise order was randomized while loads were completed in ascending order. Subjects rested one minute between repetitions at the same load and two minutes between each new load.

The 3D kinematic data were collected at 240 Hz by six Eagle cameras (Motion Analysis Corporation, Santa Rosa, CA, USA). The mean residual errors were 2.1 – 2.53 mm over a volume of 3.5 x 2.5 x 2.0 m. Data were collected in EVa RT (Version 4.6, Motion Analysis Corporation, Santa Rosa, CA, USA) and marker coordinate data were imported into Orthotrak (Version 5.2, Motion Analysis Corporation, Santa Rosa, CA, USA) using custom Matlab programs (Mathworks Inc., Natick, MA, USA) for data analysis. Marker trajectories were filtered using a fourth order Butterworth filter.

Peak angular joint velocity from the hip, knee, and ankle were obtained using finite difference formulas that use change in angular displacement and sampling time interval (Hamill & Knutzen, 2003). The average JV_{Peak} between the two trials was used for analysis. A series of 2 (Exercise) x 3 (Load) repeated measures ANOVA were used to compare the hip, knee, and ankle JV_{Peak} between the HPC and JS performed at loads of 40, 60, and 80% 1RM HPC. The Bonferroni technique was used for *post hoc* analyses when necessary. Effect sizes (*d*), statistical power (*c*), and 95% confidence intervals (CI) were also calculated. All statistical analyses were completed using SPSS 21 (IBM, New York, NY, USA) and statistical significance was set at $p \leq 0.05$.

RESULTS: Descriptive JV_{Peak} data of the HPC and JS are shown in Table 1. Statistically significant exercise main effect differences in JV_{Peak} existed between the HPC and JS for the hip ($F_{1,17}$ = 12.765, p = 0.002, c = 0.920), knee ($F_{1,17}$ = 75.160, p < 0.001, c = 1.00), and ankle ($F_{1,17}$ = 72.495, p < 0.001, c = 1.00). *Post hoc* analysis revealed a statistically greater hip JV_{Peak} during the JS (473.2 ± 287.1 °/s) compared to the HPC (352.7 ± 211.2 °/s; p = 0.002, d = 0.48, CI = 49.32 – 191.59). Similarly, a statistically greater knee JV_{Peak} existed during the JS (1029.5 ± 357.7 °/s) compared to the HPC (526.1 ± 291.2 °/s; p < 0.001, d = 1.54, CI = 380.86 – 625.86).

Finally, the ankle JV_{Peak} during the JS (996.1 ± 301.4 °/s) was statistically greater than the ankle JV_{Peak} during the HPC (515.7 ± 283.1 °/s; $p < 0.001$, d = 1.64, CI = 361.39 – 599.50).
Statistically significant load main effect differences in JV_{Peak} existed between loads of 40, 60, and 80% 1RM HPC for the hip ($F_{1.09,18.56} = 8.264$, $p = 0.009$, $c = 0.80$) and knee ($F_{1.30,22.02} = 5.580$, $p = 0.020$, $c = 0.687$), but not for the ankle ($F_{1.46,24.86} = 2.910$, $p = 0.087$, $c = 0.446$). *Post hoc* analysis revealed statistically greater hip JV_{Peak} at 40% 1RM (492.6 ± 289.2 °/s), compared to the hip JV_{Peak} at 80% 1RM (348.5 ± 213.0 °/s; $p = 0.019$, $d = 0.57$, CI = 21.45 – 266.63). Similarly, the hip JV_{Peak} at 60% 1RM (397.7 ± 251.9 °/s) was statistically greater than the hip JV_{Peak} at 80% 1RM ($p = 0.003$, $d = 0.21$, CI = 16.32 – 82.12). No other statistical differences existed ($p > 0.05$).
No statistically significant exercise x load interaction effects existed for the hip ($F_{2,34} = 1.129$, $p = 0.335$, $c = 0.232$), knee ($F_{1.21,20.48} = 1.737$, $p = 0.191$, $c = 0.260$), or ankle ($F_{2,34} = 0.529$, $p = 0.594$, $c = 0.130$).

Table 1: Hip, knee, and ankle JV_{Peak} descriptive data (n = 18; M ± SD)

Exercise	Load (% 1RM HPC)	JV (°/s)		
		Hip	Knee	Ankle
HPC	40%	406.5 ± 200.6	561.9 ± 250.1	584.7 ± 405.8
	60%	310.2 ± 106.0	506.4 ± 198.4	472.9 ± 168.6
	80%	341.4 ± 287.1	510.2 ± 400.5	489.5 ± 221.4
JS	40%	578.6 ± 341.0	1125.2 ± 384.3	1045.9 ± 302.5
	60%	485.3 ± 321.3	1072.1 ± 378.1	998.7 ± 326.2
	80%	355.6 ± 104.2	891.2 ± 276.4	943.8 ± 282.4

DISCUSSION: This study compared lower extremity kinematics between the HPC and JS performed at loads relative to 40, 60, and 80% of each subject's 1RM HPC. The main findings of this study were threefold. First, statistical differences in hip, knee, and ankle JV_{Peak} existed between the HPC and JS with the JS producing greater velocities at each joint and load. Second, statistical differences in hip and knee JV_{Peak} existed between the examined loads (40%, 60%, and 80% 1RM HPC), however no differences in ankle JV_{Peak} were found between loads. Finally, no statistical exercise x load interaction effects existed for any joint.
The JS produced statistically greater JV_{Peak} compared to the HPC across all joints examined. Specifically, the JS produced 29.2%, 64.7%, and 63.6% greater JV_{Peak} at the hip, knee, and ankle compared to the HPC, respectively. The differences in JV_{Peak} are likely because the JS is more ballistic in nature as compared to the HPC. While the JS requires an individual to jump as high as possible, the HPC requires an individual to catch the bar in a semi-squat position. In order to complete the catch phase of the HPC, an individual must perform the triple extension movement and then drop under the bar to perform the catch. While the HPC is a very beneficial exercise that trains the triple extension movement, it is possible that an individual may focus on dropping under the bar to perform the catch instead of reaching full extension at each joint. Although joint extension values were not measured in this study, this may cause reductions in JV_{Peak}. To the knowledge of the authors, this is the first study that has examined joint kinematic differences between the HPC and JS making it difficult to compare findings with another study. However, two studies examined kinetic differences between the HPC and JS and found similar findings (Suchomel & Wright, 2013; Suchomel, et al., 2014). Their studies indicated that the JS produced superior force, center of mass velocity, and power across the entire loading spectrum compared to the HPC. The findings of the current study provide further evidence of why the JS may be an effective exercise to implement into resistance training programs.
Statistically significant main effect differences in hip and knee JV_{Peak} existed between the loads examined. However, statistically significant *post hoc* comparisons only existed for the hip. Specifically, the hip JV_{Peak} at 40 and 60% 1RM HPC was 34.3% and 13.2% greater than the JV_{Peak} at 80% 1RM HPC, respectively. The data indicate that as the load increased, hip JV_{Peak}

decreased. Despite being main effect data, justifications to support the findings can be made for both the HPC and JS. As previously mentioned, if an individual does not reach full extension at each of their joints because they are focused on dropping under the bar to perform the catch phase during the HPC, JV_{Peak} may be lower than if they had reached full extension (Newton, Kraemer, Hakkinen, Humphries, & Murphy, 1996). Furthermore, the decreases may be emphasized at heavier loads. This may then reflect changes in kinetic measures. Decreases in power development during the JS at higher loads likely occurred due to the breakdown of technique (Suchomel, et al., 2013). Heavier loads may increase the difficulty of extending the hips while performing the second pull characteristic of weightlifting movements.

CONCLUSION: The hip, knee, and ankle JV_{Peak} of the JS were superior to those of the HPC at all loads examined, indicating greater explosiveness during the triple extension movement. Heavier loads appear to affect hip extension during both the HPC and JS. As the external load increased, hip JV_{Peak} decreased. The changes in kinematics at higher loads are likely attributable to differences in technique. The JS is an explosive weightlifting derivative, as indicated by rapid JV_{Peak} at the hip, knee, and ankle, and should be considered as an exercise used to train muscular power. Moreover, implementing lighter loads with the JS may allow for greater JV_{Peak} to occur.

REFERENCES:

Baechle, T. R., Earle, R. W., & Wathen, D. (2008). Resistance Training. In T. R. Baechle & R. W. Earle (Eds.), *Essentials of Strength Training and Conditioning* (3rd ed., pp. 381-412). Champaign, IL: Human Kinetics.

Bush, T. R., & Gutowski, P. E. (2003). An approach for hip joint center calculation for use in seated postures. *Journal of Biomechanics, 36*(11), 1739-1743.

Comfort, P., Allen, M., & Graham-Smith, P. (2011a). Comparisons of peak ground reaction force and rate of force development during variations of the power clean. *Journal of Strength & Conditioning Research, 25*(5), 1235-1239.

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

Comfort, P., Fletcher, C., & McMahon, J. J. (2012). Determination of optimal loading during the power clean, in collegiate athletes. *Journal of Strength & Conditioning Research, 26*(11), 2970-2974.

Cormie, P., McCaulley, G. O., Triplett, N. T., & McBride, J. M. (2007). Optimal loading for maximal power output during lower-body resistance exercises. *Medicine & Science in Sports & Exercise, 39*(2), 340-349.

Haff, G. G., & Nimphius, S. (2012). Training principles for power. *Strength & Conditioning Journal, 34*(6), 2-12.

Hamill, J., & Knutzen, K. M. (2003). *Biomechanical Basis of Human Movement*. Philadelphia, PA: Lippincott Williams & Wilkins.

Kawamori, N., Crum, A. J., Blumert, P. A., Kulik, J. R., Childers, J. T., Wood, J. A., et al. (2005). Influence of different relative intensities on power output during the hang power clean: identification of the optimal load. *Journal of Strength & Conditioning Research, 19*(3), 698-708.

Kilduff, L. P., Bevan, H., Owen, N., Kingsley, M. I., Bunce, P., Bennett, M., et al. (2007). Optimal loading for peak power output during the hang power clean in professional rugby players. *International Journal of Sports Physiology and Performance, 2*(3), 260-269.

Newton, R. U., Kraemer, W. J., Hakkinen, K., Humphries, B., & Murphy, A. J. (1996). Kinematics, kinetics, and muscle activation during explosive upper body movements. *Journal of Applied Biomechanics, 12*, 31-43.

Suchomel, T. J., Beckham, G. K., & Wright, G. A. (2013). Lower body kinetics during the jump shrug: impact of load. *Journal of Trainology, 2*, 19-22.

Suchomel, T. J., & Wright, G. A. (2013). Power development comparisons between power clean variations at different relative loads [Abstract]. *Journal of Strength & Conditoning Research, 27*, S76-S77.

Suchomel, T. J., Wright, G. A., Kernozek, T. W., & Kline, D. E. (2014). Kinetic comparison of the power development between power clean variations. *Journal of Strength & Conditioning Research, 28*(2), 350-360.