FORCE-TIME CURVE COMPARISON BETWEEN WEIGHTLIFTING DERIVATIVES

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INTRODUCTION: Weightlifting derivatives are frequently implemented in resistance training programs due to their ability to train the explosive triple extension movement (Suchomel et al., 2015). While the use of full weightlifting movements involving the catch phase has been repeatedly supported throughout the literature, previous research has indicated that weightlifting pulling derivatives that exclude the catch phase may produce a training stimulus that is similar (Comfort et al., 2011a, 2011b) or superior (Suchomel, Wright, Kernozek, et al., 2014; Suchomel, Wright, & Lottig, 2014) to derivatives involving the catch phase. Developing a better understanding of the differences between weightlifting catching and pulling derivatives is warranted in order for effective exercise prescription.

A common method of comparing weightlifting movements has been through an analysis of the movement's force-time (F-T) curve. While the previously mentioned studies provide evidence that weightlifting pulling derivatives may produce greater instantaneous F-T curve characteristics, limited research has compared force production between these exercises through an examination of the entire F-T curve. Previous research has demonstrated the effectiveness of full F-T curve analysis in examining both the countermovement jump (Sole, 2015) and jump squat (Cormie et al., 2008). This form of analysis is thought to provide a mechanistic understanding of performance by examining a movement's entire force production history. Information gathered from such an analysis may provide sport scientists and practitioners with a better understanding of the distinct movement characteristics of weightlifting derivatives. Therefore, the purpose of this study was to examine differences in force production between weightlifting derivatives by comparing the F-T curves of each movement.

METHODS: Sixteen resistance-trained males (age = 21.6 ± 1.3 years; body mass = 86.8 ± 16.1 kg; height = 180.5 ± 6.3 cm; one repetition maximum hang power clean (1-RM HPC) = 110.3 ± 20.7 kg; relative 1-RM HPC = 1.3 ± 0.2 $kg \cdot kg^{-1}$) participated in this study. All subjects provided written informed consent in accordance with the University's Institutional Review Board. Subjects participated in four sessions. During the first session, 1-RM HPCs were obtained and subjects were familiarized with the jump shrug (JS) and hang high pull (HHP). The subsequent testing sessions required the subjects to complete exercise sets of either the HPC, JS, or HHP at 30, 45, 65, and 80% 1-RM HPC using previously described technique (Suchomel, Wright, Kernozek, et al., 2014). During each testing session, the subjects performed two repetitions at each load with one minute of rest between each repetition and two minutes between each load. The order of the final three testing sessions was randomized. The load order was randomized during the first testing session and was kept constant during the subsequent testing sessions in order to prevent a fatigue or potentiation effect.

All repetitions were performed on a portable force platform (Kistler, Winterthur, Switzerland) sampling at 500Hz. Relative peak force (PF_{Rel}) during the concentric phase of the movement was determined by dividing PF by the subject's body mass. The analysis of the F-T curves was performed using a resampling technique similar to previous research (Sole, 2015). Each F-T curve was modified to an equal number of data points by adjusting the time delta between samples and resampling the signal. The F-T curves could then be expressed as a percentage (0-100% of the movement). Intraclass correlation coefficients (ICC) were used to examine the test-retest reliability of PF_{Rel}. A 3 x 4 (exercise x load) repeated measures ANOVA with Bonferroni *post hoc* tests was used to compare PF_{Rel}. Upper and lower 95% confidence limits were calculated for each average curve to determine statistical differences between normalized F-T curves and effect sizes (Cohen's *d*) were used to indicate practical significance.

RESULTS: The ICC values for PF_{Rel} of all repetitions ranged from 0.98-0.99. Statistically significant exercise, load, and interaction effects existed for PF_{Rel} (all $p < 0.001$). *Post hoc* analysis revealed that the JS (40.2 ± 2.7 $N \cdot kg^{-1}$) produced statistically greater PF_{Rel} compared to the HPC (35.5 ± 4.0 $N \cdot kg^{-1}$; $p < 0.001$, $d = 1.38$) and HHP (36.5 ± 3.7 $N \cdot kg^{-1}$; $p < 0.001$, $d = 1.14$), while no statistical differences existed between the HPC and HHP ($p = 0.338$, $d = 0.26$). Several areas of non-overlap existed between the normalized F-T curves (Figure 1). At 30% 1-RM, JS relative force was greater than the HPC and HHP from 75.7-99.1% and 81.3-98.7 % of normalized times, respectively, while the HHP exceeded the HPC from 79.1-86.5%. At 45% 1-RM, JS relative force was greater than the HPC and HHP from 76.1-99.1% and 80.9-98.7% of normalized times, respectively, while the HHP exceeded the HPC from 94.8-98.7%. At 65% 1-RM, JS relative force was greater than the HPC and HHP from 79.1-98.7% and 80.4-97.4% of normalized times, respectively, while the HHP exceeded the HPC from 94.8-100%. Finally, at 80% 1-RM, JS relative force was greater than the HPC and HHP from 78.3-97.8% and 80.9-96.5% of normalized times, respectively, while the HHP exceeded the HPC from 79.1-99.6%.

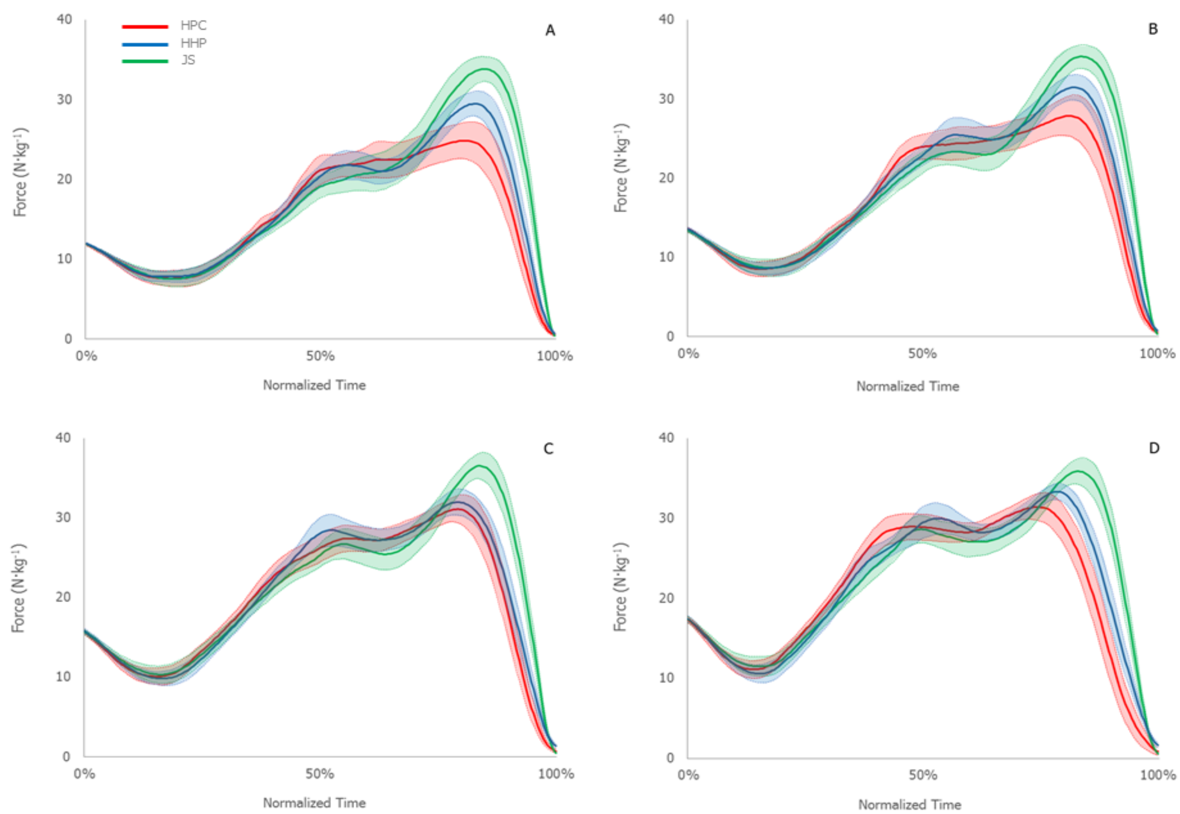

Figure 1. Normalized resampled force-time curves of the HPC, JS, and HHP performed at A) 30%, B) 45%, C) 65%, and D) 80% 1-RM HPC. *Note: shaded areas represent 95% upper and lower confidence limits.*

DISCUSSION: This study compared the F-T curves of three weightlifting derivatives across four loading conditions. In agreement with previous research (Suchomel, Wright, Kernozek, et al., 2014; Suchomel, Wright, & Lottig, 2014), the JS produced large practically significant magnitudes of PF_{Rel} compared to the HPC and HHP. The differences displayed may be due to the varying constraints of each exercise. For example, the goal of the JS is to jump as high as possible, whereas the goal of the HPC is to catch the load. Previous research suggested that the intent to catch the load may lead to an incomplete triple extension movement (Suchomel, Wright, Kernozek, et al., 2014). This in turn may lead to a decrease in the magnitude and rate of force production. The differences observed in the JS and HHP may be due to the manner in which the triple extension movement is performed. While the HHP results in the completion of triple extension, the ballistic nature of the JS led to greater PFs. Our findings are supported by research that compared force production between ballistic and non-ballistic exercises (Lake et al., 2012).

A unique aspect of the present study was the comparison of normalized F-T curves between exercises. Our findings indicate that the average F-T curves of the HPC, JS, and HHP were similar through approximately the first 75-80% of the movement. This is not surprising considering that each movement was initiated from the same starting position and performed similarly. The average F-T curve analysis indicated that the JS produced greater magnitudes of force earlier during the second pull movement compared to the HPC and HHP. Moreover, the greater magnitudes of force lasted for a longer period of time, creating a larger positive impulse during the movement. Practically speaking, the JS may provide a superior training stimulus for PF compared to the HPC and HHP.

In conclusion, key differences in both the magnitude of PF as well as the overall profile of the F-T curve existed between exercises. The JS produced superior PF and a markedly different F-T profile in the final 20-25% of the movement compared to the HPC and HHP and thus may be implemented to enhance PF_{Rel}. Practitioners should note that the greatest differences between exercises existed at lighter loads, suggesting that loads of 30-45% 1-RM HPC may provide the best training stimulus when using the JS.

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