KINEMATIC AND KINETIC ANALYSIS OF THE HORIZONTAL HANG CLEAN PERFORMED WITH A VARIETY OF LOADS AND THEIR COMPARISON TO THE SPRINT START

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This study evaluated kinetic and kinematic aspects of the horizontal hang clean (H-HC) at a variety of loads and also compares these results to the standing sprint start (SSS). Subjects were tested during the H-HC at 30%, 50% and 70% of their five-repetition maximum (5RM), and during the SSS, using two force platforms. Analysis revealed significant differences for the H-HC conditions for the propulsive phase vertical GRF ($p \leq 0.001$), propulsive phase horizontal to vertical GRF ratio (H:V) ($p = 0.001$), subject/barbell displacement ($p \leq 0.001$), and velocity ($p \leq 0.001$). The propulsive H:V of the H-HC at 30% of the 5 RM was correlated to the propulsive H:V of the first step of the SSS ($p = 0.04$, r = 0.55). To maximize subject anterior displacement and velocity and propulsive H:V, practitioners should use the H-HC with loads of 30% of the 5 RM. Training in this manner offers specificity for sprinting starts.

KEYWORDS: weightlifting, sprinting, specificity, transfer of training, intensity

INTRODUCTION: The hang clean is a common weightlifting exercise that is used to train athletes. The traditional hang clean may be inferior as a training stimulus for sagittal plane anteriorly directed activities such as sprinting. Since specificity is fundamental for the transfer of training, there may be more optimal hang clean variations and loads for training athletes.

Traditional hang clean kinetics have been compared to the jump shrug, high pull, mid-thigh pull, and high power clean (Comfort et al., 2011). In previous studies, the kinetics of the traditional hang clean were assessed with a variety of loading conditions (Kawamori et al., 2014; Suchomel et al., 2014). Additionally, hang clean and hang snatch at a variety of loads have been compared using ground reaction forces (GRF) (Jensen & Ebben, 2002).

Training specificity should be prioritized to increase the likelihood that training exercises improve sports performance (Rumpf et al., 2012; Young et al., 2015). Power exercises primarily categorized by vertical displacement have little correlation to sprinting speed (Rumpf et al., 2012; Young et al., 2015). Previous studies assessing the GRF of the power clean typically focused on vertical mechanics (Jensen & Ebben, 2002), or horizontal displacement of barbell, but not of the subject (Comfort et al., 2011; Souza et al., 2002). Exercises that offer resistance along with horizontal displacement of the athlete are believed to be most valuable for developing sprinting ability (Rumpf et al., 2012; Young et al., 2015).

The horizontal hang clean (H-HC) is a variation of the traditional hang clean in which the subject produces a significantly higher horizontal and vertical ground rection force ratio (H:V) (Gold et al., 2020). Compared to the traditional hang clean, the propulsive H:V of the H-HC is more similar to the H:V of sprinting (Gold et al., 2020). Therefore, the H-HC should be used to increase the likelihood that the training will transfer to anteriorly directed activities in the sagittal plane, such as sprinting. However, it is not known if there is an exercise intensity for this exercise that optimizes the training specificity. Therefore, the purpose of this study was to assess a variety of H-HC loading conditions in order to determine the relationship between propulsive H:V, horizontal GRF, vertical GRF, horizontal displacement and velocity of the subject, and the relationship of these loading conditions to the kinetic characteristics to the standing sprint start (SSS).

METHODS: Subjects included 12 men (age = 19.67 ± 0.89 years, body mass = 87.53 ±10.40 kg, and height = 179.08 ± 7.94 cm). All subjects provided written informed consent for the study which

was approved by the Institutional Review Board. All subjects had at least one year of training with Olympic weightlifting variations. Subjects participated in one testing session and performed the H-HC in a variety of loading conditions as well as the SSS. The SSS was performed to allow for comparison of the H-HC to this aspect of sprinting. Prior to performing the H-HC and SSS, subjects completed a general and specific warmup. Subjects also received instruction, demonstration, and practiced the correct technique of the H-HC and the SSS. Practice consisted of three sets of three repetitions of the H-HC at 30%, 50%, and 70% of their estimated five repetition maximum load of the traditional hang clean. Subjects then performed five maximal effort SSS. The SSS was performed starting with a bilateral stance and subjects sprinted 10 meters. Subjects rested for five minutes prior to testing.
During testing, subjects performed the H-HC and the SSS on two flush to the floor mounted force platforms (Accupower, Advanced Mechanical Technology, Inc., Watertown, MA, USA) (Figure 1). Data were collected at 1000 Hz. Two sets of one repetition each were performed for all H-HC loading conditions and for the SSS. Three minutes of rest were allowed between each H-HC test set, and one minute for each SSS test set. The order of all test exercises was randomized.

Figure 1. Starting and landing position (catch phase) of the horizontal hang clean at 30% of the subject's 5 repetition maximum.

The peak vertical and horizontal anterior GRF were obtained for the test exercises. In addition to GRF data, horizontal displacement of the subject/barbell was determined using center of pressure measurements from the force platforms from the propulsive and landing phase of the H-HC. Kinematic variables such as subject/barbell horizontal anterior displacement and velocity were derived from the center of pressure data. Data were analyzed with a statistical software program (SPSS 27.0, International Business Machines Corporation, Armonk, New York) using an ANOVA with repeated measure for exercise condition as a between subjects factor. Bonferroni adjusted pairwise comparisons were used to identify specific differences in horizontal GRF, vertical GRF, propulsive H:V, subject/barbell displacement, and velocity between the H-HC conditions. Pearson's correlation coefficients were used to assess the relationship between the propulsive H:V and subject/barbell horizontal displacement during H-HC conditions, and the relationship between the kinetic characteristics of the H-HC conditions and the first and second steps of the SSS. The trial-to-trial reliability of each dependent variable was assessed using average measures Intraclass correlation coefficients and analysis of variance for each of the dependent variables. The a priori alpha level was set at $p \leq 0.05$.

RESULTS: Analysis of the kinetic variables for the H-HC conditions revealed significant main effects for the propulsive phase vertical GRF ($p = 0.001$, $d = 1.00$, $\eta_p^2 = 0.74$) and H:V ($p = 0.001$, $d = 0.99$, $\eta_p^2 = 0.54$). There was no significant main effects for propulsive phase horizontal GRF ($p > 0.05$). There was no significant differences between H-HC conditions for landing phase horizontal or vertical GRF or H:V ($p > 0.05$). Data and results of the post-hoc analysis are shown in Table 1.
The analysis of the kinematic variables demonstrate significant main effects between the H-HC conditions for subject/barbell displacement ($p \leq 0.001$, $d = 1.00$, $\eta_p^2 = 0.60$) and subject/barbell velocity ($p \leq 0.001$, $d = 0.79$, $\eta_p^2 = 0.33$). Data and results of the post-hoc analysis are shown in Table 2.

The propulsive H:V of the first step of the SSS was correlated to the propulsive H:V of the H-HC 30 ($p = 0.04$, r = 0.55) but not the propulsive H:V of the H-HC 50 or H-HC 70 ($p > 0.05$). The propulsive H:V of the second step of the SSS was correlated to the propulsive H:V of the H-HC 30 ($p = 0.03$, r = 0.63), but not for the propulsive H:V of the H-HC 50 or H-HC 70 ($p > 0.05$). The propulsive H:V of all H-HC test conditions were correlated with each other ($p \leq 0.01$, r > 0.70). Intraclass correlation coefficients were calculated for all dependent variables, with all values ranging between 0.82 and 0.99 (all *p* values > 0.05).

Table 1. Comparison of the kinetics of the propulsive and landing phases between the three H-HC conditions (N = 12).

	H-HC 30	H-HC 50	H-HC 70
Propulsive H-GRF (N)	383.68 ± 91.94	376.16 ± 64.48	379.99 ± 51.98
Propulsive V-GRF (N)[a]	1924.67 ± 301.80	2108.59 ± 340.65	2376.83 ± 313.69
Propulsive H:V[b]	0.20 ± 0.04	0.18 ± 0.03	0.16 ± 0.02
Landing H-GRF (N)	438.61 ± 97.41	406.42 ± 134.39	393.25 ± 170.92
Landing V-GRF (N)	1656.29 ± 292.54	1655.71 ± 278.17	1748.58 ± 300.55
Landing H:V	0.27 ± 0.08	0.25 ± 0.09	0.23 ± 0.10

H-HC 30 = horizontal hang clean at 30% of subject's estimated five repetition maximum of traditional hang clean; H-HC 50 = horizontal hang clean at 50% of subject's estimated five repetition maximum of traditional hang clean; H-HC 70 = horizontal hang clean at 70% of subject's estimated five repetition maximum of traditional hang clean. GRF = ground reaction force; Propulsive H:V = ratio of horizontal anterior to vertical ground reaction force during propulsive phase; Landing H:V = ratio of the horizontal posterior to vertical ground reaction force during the landing phase; V = vertical; H = horizontal; Propulsive H = horizontal anterior; Landing H = horizontal posterior.
[a]Significant difference between H-HC 30 and HHC 50 and H-HC 30 and H-HC 70 ($p < 0.01$)
[b]Significant difference between H-HC 30 and H-HC 70 ($p < 0.01$)

Table 2. Comparison of subject/barbell displacement and velocity between the three H-HC conditions (N = 12).

	HHC 30	HHC 50	HHC 70
Displacement (m)[a]	1.24 ± 0.23	1.03 ± 0.23	0.90 ± 0.21
Velocity ($m \cdot s^{-1}$)[b]	2.05 ± 0.78	1.82 ± 0.61	1.70 ± 0.62

H-HC 30 = horizontal hang clean at 30% of subject's estimated five repetition maximum of traditional hang clean; H-HC 50 = horizontal hang clean at 50% of subject's estimated five repetition maximum of traditional hang clean; H-HC 70 = horizontal hang clean at 70% of subject's estimated five repetition maximum of traditional hang clean.
[a]Significant difference between H-HC 30 and HH-C ($p = 0.02$) and H-HC 30 and H-HC 70 ($p = 0.002$)
[b]Significant difference between H-HC 30 and H-HC 70 ($p = 0.038$).

DISCUSSION: This is the second known study to assess the H-HC, and the first to evaluate the effect of H-HC load on kinetic and kinematic variables for the purpose of evaluating the potential transfer of training to sprinting starts. This study demonstrates that there are significant differences in H-HC V-GRF, propulsive H:V, subject/barbell displacement, and subject velocity based on exercise load. Performing the H-HC 30 was superior to the higher load conditions for most of these variables.

Previous research assessed the conventional hang clean and typically focused on only on V-GRF (Comfort et al., 2011; Souza et al., 2002). However, vertically oriented exercises are believed to have limited transfer of training to athletic activities such as sprinting (Young et al., 2015). As a result, whole body horizontally-oriented exercises have been recommended (Young et al., 2015) and exercises such as the H-HC have been investigated, demonstrating kinetics more similar to sprinting than the traditional hang clean (Gold et al., 2020).

Results of the present study demonstrate a propulsive H:V of .20 for the H-HC 30 condition. Previous research revealed an propulsive H:V of .16 for the H-HC in a testing condition of 70% of the 5RM load (Gold et al., 2020). That H:V is identical to the finding for the H-HC 70 in the present study. Previous research assessing the propulsive H:V of a variety of horizontally oriented plyometric exercises demonstrated H:V in a range of .20 to .29 (Duffin et al., 2019). Thus, the H-HC 30 in the present study is similar to that of some horizontal plyometrics. Previous research shows that the propulsive H:V during weighted sled towing ranged from .28 to .39 and increased with load (Kawamori et al., 2014). While, training exercises such as the H-HC and plyometrics do not produce propulsive H:V that are identical to sprinting, they are more similar than other strategies that are performed more fully in the vertical plane such as the traditional hang clean, which yielded a propulsive H:V of .09 (Gold et al., 2020). In fact, in the present study, the propulsive H:V of the H-HC 30 was correlated with the sprint start H:V. The propulsive H:V of sprinting in the present study was .41. This finding is similar to previous findings of .36 to .40 (Duffin et al., 2019).

In the present study subject/barbell velocity and displacement was highest in the 30% load condition. Subject/barbell horizontal displacement for the H-HC 30 was 98.39% larger than the traditional hang clean and is correlated with the H:V at the start of sprinting (Gold et al., 2020). Research with the traditional hang clean also displayed differences in RFD due to exercise load (Suchomel et al., 2014).

Result of this study are consistent with other research demonstrating that V-GRF were higher as a function of increasing hang clean loads (Jensen & Ebben, 2002). Landing kinetics of the present study were not significantly different between conditions.

CONCLUSION: To maximize the transfer of resistance training to sprinting, practitioners should use exercises such as the H-HC. When doing so, heavier loads will result in greater V-GRF. However, lighter loads such as 30% of the 5 RM should be used if the goal is developing a propulsive H:V that is correlated to the propulsive H:V associated with the sprint start, and to maximize subject horizontal anterior displacement and velocity.

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