Short Communication

A comparison of maximal power clean performances performed from the floor, knee and mid-thigh

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Objectives: This study aimed to compare one repetition maximum (1RM) power clean performances, performed from the floor, the knee and from mid-thigh, to determine the differences between variations.

Design and Methods: Using a within subjects repeated measures design, healthy male subjects (n=12; height 1.83 ± 0.08 m; body mass 92.17 ± 13.18 kg; age 21 ± 3.69 years), performed each variation of the power clean on two separate occasions to determine reliability of each assessment. A repeated measures ANOVA with Bonferroni post hoc analysis was used to compare performances between each variation.

Results: Power clean from the floor (93.75 ± 16.53 kg) resulted in significantly greater loads lifted than the power clean from the knee (87.92 ± 16.85 kg, p=0.04, Cohens *d* = 0.35) and the mid-thigh power clean (87.33 ± 16.43 kg, p=0.02, Cohens *d* = 0.53). There was no significant difference between the power clean from the knee and mid-thigh power clean (p>0.05, Cohens *d* = 0.15). Coefficient of determination between the power clean and the power clean performed from the knee (R^2 = 0.923) and mid-thigh power clean (R^2 = 0.923) were high.

Conclusion: From the findings of this study, when maximal load is required, the power clean from the floor permits the use of the greatest load, which can be used to predict the 1RM of the other variations. Moreover, when determining changes in performance in each variation of the lift, changes ≥6.14%, ≥7.18% and ≥7.66% for the power clean, power clean from the knee and power clean from mid-thigh, respectively, can be considered meaningful changes.

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Key words: Mid-Thigh Power clean ■ Hang Power Clean ■ One Repetition Maximum ■ Prediction

INTRODUCTION

The power clean is commonly used within strength and conditioning training, with numerous derivatives including various starting positions: the floor, just above the knee (sometimes referred to as the hang position) and the mid-thigh position. Such exercises are used due to the similarities to sport-specific movements, as the exercises provide the opportunity to apply maximum force over a small period of time via triple extension of the ankles, knees and hips.[1,2] Similarly, Canavan, Garrett and Armstrong reported kinetic similarities during the propulsive phase of jumping and the Olympic lifts.[3] Moreover, Tricoli et al.[4] found that a weight-lifting exercise program containing the power clean and its variations improved 10 m sprint and counter-movement jump performance. Additionally, variations of the power clean, such as the hang power clean have been found to correlate with counter-movement jump, 20 m sprint and agility performance.[5]

Initial observational studies using Olympic Weightlifters determined that the second pull phase resulted in the highest bar velocities and therefore the greatest power output, as determined from bar velocity using an inverse dynamics approach.[6-11] In addition Enoka[12], Häkkinen, Kanhanen and Komi[13] and Souza et al.[14] identified that the second pull phase of the clean pull produced the highest vertical ground reaction force. More recently, the mid-thigh power clean has also been reported to generate greater peak force, rate of force development (RFD) and peak power in comparison to the hang power clean (starting from the knee) and the power clean (starting from the floor)[15,16] and is therefore a valuable exercise to include in a program for athletes new to Olympic lifting who require an increase in power. In addition the mid-thigh power clean may be easier to learn compared to other variations of the power clean. However, these studies used a standardized load of 60% 1RM power clean for all variations, to eliminate the effect of load, as their focus was to identify the effect of exercise variation on kinetic variables. Although no studies have yet compared 1RM performances between the variations of the power clean, this may have impacted the results of the aforementioned studies, if there are large variations between the 1RM performances of these variations.

Variations of these lifts are regularly performed with training loads generally prescribed based on 1RM performance in the power clean or hang power clean, with no empirical evidence illustrating the magnitude of the difference between lifts. The aim of this investigation, therefore, was to compare 1RM performances between the power clean performed from the floor, knee and mid-thigh. Based on the evidence that the greatest force, velocity and power occur during the second pull phase of the clean and its variations[13-16] it was hypothesized

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that the variations of the power clean would produce similar 1RM results due to each variation incorporating the second pull phase. A further aim was to generate an equation, based on the relationships between lifts, to predict 1RM performances in the power clean performed from mid-thigh and the knee, based on performance from the floor, to eliminate the need to test each variation of the lift.

METHOD

Experimental Approach to the Problem

Subjects were asked to complete a 1RM for each variation of the power clean twice, over a period of three weeks, to establish the reliability of each variation. Power clean variations were performed in a randomized order across testing sessions. Additionally, each individual's best performance from each variation of the lift was compared to identify differences in the 1RM performances between variations. Subsequently, relationships between the power clean from the floor and performed from the knee and mid-thigh were determined using Pearsons correlation coefficients and coefficient of determination.

Subjects

Twelve male collegiate athletes (n=12; height 1.83 ± 0.08 m; body mass 92.17 ± 13.18 kg; age 21 ± 3.69 years), from a variety of sports, volunteered to take part in this study. Before maximal lifting could begin each participant provided written informed consent, with prior ethical approval provided by the institutional review board. To be eligible for this study they were asked to be competent in the power clean and its variations, as determined by a certified strength and conditioning coach, and have been regularly performing variations of the power clean for a period of ≥12 months.

One Repetition Maximum Assessment

All 1RM testing was completed in line with established protocols from the NSCA[17], with ≥48 hours between trials to minimize any effect of fatigue or muscle soreness. Subjects were also asked to abstain from strenuous exercise for 48 hours prior to testing and to maintain a similar dietary intake for the 24 hours prior to each testing session. Prior to 1RM testing subjects warmed up using an Olympic bar with Werk-San (Philadelphia, USA) weights plates weighing 40kg. Three sets of six repetitions of the exercise to be tested were performed for their warm up, along with some standardized mobility drills. Following this the load on the bar was increased gradually (5-10kg) until they were ready to start 1RM testing, based on their previous training loads. Six progressively increasing attempts were permitted to achieve a 1RM. After each attempt the weight of the bar was increased by a small increment (2-5kg) until the participant could not successfully perform the lift. This protocol was standardized for each variation of the power clean.

As the power clean from the floor is executed from a stationary start the same scenario was ensured during the power clean from the knee and the mid-thigh power clean, with the bar resting on blocks prior to the start of the lift. This also ensured that no counter movement could be performed to utilize the stretch shorten cycle (SSC) and eliminated any possible fatigue or potentiation that may have resulted from initially lifting the bar to the starting position.

Data Analysis

To determine the prediction equation for the 1RM power clean from the knee, a linear trendline was fitted to the data illustrating the relationship between the 1RM power clean from the floor and the 1RM power clean from the knee. The derived linear equation was subsequently re-arranged in order to allow 1RM power clean from the knee to be predicted from 1RM power clean from the floor. The same process was repeated to produce a prediction equation for the 1RM power clean from mid-thigh.

Statistical Analyses

All statistical analyses were performed using SPSS (IBM, USA). Shapiro-Wilk's test of normality showed that each of the three sets of data was normally distributed ($p>0.05$). Effect sizes were determined using the Cohen d method, and interpreted based on the recommendations of Rhea[18] who defines <0.35, 0.35-0.8, 0.8-1.5 and >1.5 as trivial, small, moderate and large respectively. Relative reliability between testing session, for each variation of the power clean, was determined using a 2-way random effects model intraclass correlation coefficient (ICCs), and interpreted with ICC r ≥0.8 considered to be very reliable.[19] Smallest detectable differences (SDD) were calculated, from the formula: $(1.96 \times (\sqrt{2})) \times SEM)$[20-22], to establish random error scores. Standard error of measurement (SEM) was calculated using the formula: $(SD\ (pooled) \times \sqrt{1-ICC})$.[23]

A repeated measures analysis of variance (ANOVA) with Bonferroni post hoc analysis was used to compare 1RM performances between each variation of the power clean. Pearson's correlations and coefficient of determination were also calculated between the power clean the other variations of the power clean to determine the relationships between 1RM performances. An apriori alpha level was set at $p\leq0.05$.

RESULTS

The ICCs demonstrated a high reliability (ICC≥0.94, $p<0.001$) between sessions for each 1RM variation of the power clean (Table 1).

Repeated measures ANOVAs revealed a significant difference ($p\leq0.04$, power = 0.95) in load lifted across the variations of the power clean. Bonferroni post hoc analysis showed that the power clean from the floor (93.75 ± 16.53kg) resulted in significantly greater load lifted when compared to the power clean from the knee (87.92 ± 16.85kg, $p=0.04$, Cohen's $d = 0.35$) and the power clean from mid-thigh (85.50 ± 14.16kg, $p=0.02$, Cohen's $d = 0.53$), although the effect sizes reveal that the differences are small. There was no significant difference ($p>0.05$, Cohen's $d = 0.15$) between power clean from the knee and the power clean from mid-thigh.

Pearson's correlations showed a strong relationship ($r=0.961$, $p<0.001$) between the power clean from the floor

Table 1. Descriptive (mean ± standard deviation) and reliability (ICC) statistics and measurement error (SDD)

Variation	Trial 1 (kg)	Trial 2 (kg)	ICC	SDD (%)
Power Clean	93.33 ± 16.14	89.58 ± 18.40	0.97*	6.14
Power Clean from Knee	85.63 ± 14.62	87.92 ± 16.85	0.94*	7.18
Mid-Thigh Power Clean	86.08 ± 17.64	86.50 ± 14.16	0.97*	7.66

* = $p < 0.001$

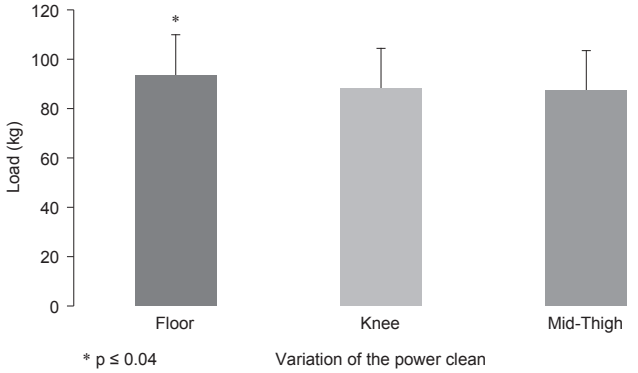

Figure 1. Comparison of 1RM performances from the floor, knee and mid-thigh

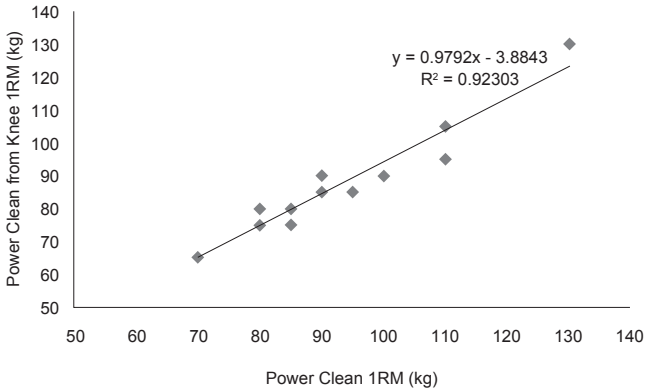

Figure 2. Relationship between the 1RM power clean and the power clean from the knee

and the power clean from the knee, with a resultant coefficient of determination of R2=0.923 (Figure 2). Similarly there was a strong relationship (r=0.961, p<0.001) between the power clean from the floor and the mid-thigh power clean with a coefficient of determination of R^2=0.923 (Figure 3).

The strong relationships between the power clean and both the power clean from the knee and the mid-thigh power clean show that 92.3% of performance in the power clean from the knee and mid-thigh can be determined by the performance in the power clean:

1RM Power Clean from the Knee =
1RM Power Clean x 0.9792 – 3.8843

1RM Mid-Thigh Power Clean =
1RM Power Clean x 0.9547 – 2.1677

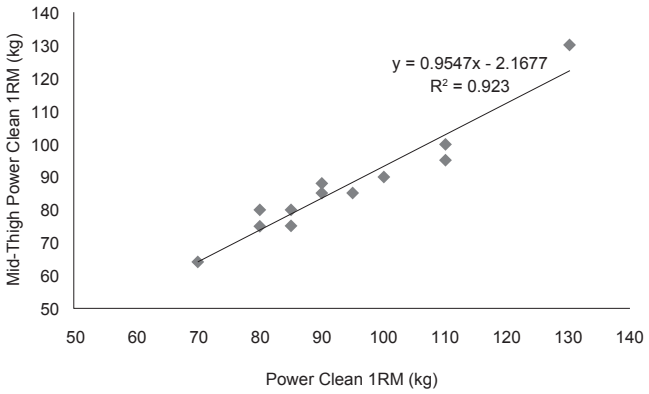

Figure 3. Relationship between the 1RM power clean and the mid-thigh power clean

DISCUSSION

Maximal power clean performance resulted in the highest loads lifted when performed from the floor, compared to the power clean performed from the knee (6.63% lower than power clean from the floor) and the mid-thigh power clean (7.35% lower than power clean from the floor), in contrast to the hypothesis. Strong relationships (r=0.961, p<0.001 R^2=0.923) were also observed between 1RM performance of the power clean and both the power clean performed from the knee and mid-thigh. Moreover, each method of assessing 1RM was highly reliable between sessions, with low smallest detectable differences ≤7.66%.

The greater load lifted during the power clean from the floor compared to the power clean performed from the knee and the mid-thigh power may be attributable to the fact the bar is displaced a greater distance and therefore already has momentum prior to reaching either the knee or mid-thigh position, where the greatest force is applied.[12-14] Additionally, the inclusion of the first pull during the power clean also results in an increased duration of the exercise, increasing the time available for the athlete to apply force to the bar which may result in greater bar velocity, possibly resulting in greater displacement of the bar, although this was not assessed in this investigation. Although these differences were statistically significant (p≤0.04), it can be seen from the effect sizes that these differences are small (Cohen's *d* = 0.35-0.53), with the percentage difference (6.63-7.35%) between the lifts only slightly greater than the SDD for the power clean (6.14%).

The strong relationships (r=0.961, p<0.001) between the power clean and both the power clean from the knee and the

mid-thigh power clean, show that 92.3% of performance in the power clean form the knee and mid-thigh can be determined by the performance in the power clean:

1RM Power Clean from the Knee =
1RM Power Clean x 0.9792 – 3.8843

1RM Mid-Thigh Power Clean =
1RM Power Clean x 0.9547 – 2.1677

Importantly, this may permit strength and conditioning coaches to accurately predict performance in the hang power clean and the mid-thigh power clean, removing the need and time required to assess 1RM performances in each variation of the lift. Furthermore, in studies which have used standardized loads to compare performances across various lifts, such as Comfort et al.[15,16] the results of this study highlight that the 60% 1RM load used during the hang and mid-thigh power cleans represent slightly higher (5-10%) percentages of the 1RM for those specific variations of the power clean.

A limiting factor of this study may have been the way in which the hang power clean and mid-thigh power clean 1RM was performed. Both variations were performed off blocks to ensure the subject was completely stationary, similar to how the subject was stationary when performing the power clean from the floor. It is suggested that future research identify if there are differences in performance of the power clean performed from the knee and mid-thigh positions if performed from blocks or when unsupported.

CONCLUSIONS

The findings of this study demonstrate that power clean performances are reliable and that the greatest load can be lifted when performing the power clean from the floor, compared to the power clean performed from the knee or mid-thigh, with the bar starting at rest on blocks. Additionally, due to the strong relationships between 1RM performances across these variations of the power clean, it is possible to predict 1RM performance in the power clean from the knee or mid-thigh from performance of the power clean performed from the floor, which may save time for strength and conditioning professionals by providing accurate estimations of 1RM performances of the other variations of the lift. When determining changes in performance in each variation of the lift, changes ≥6.14%, ≥7.18% and ≥7.66% for the power clean, power clean from the knee and power clean from mid-thigh, respectively, can be considered meaningful changes.

REFERENCES

1. Stone MH. Explosive exercise and training. *Natl Strength Cond Assoc* J 1993;15:7-15.
2. Stone MH, Sanborn KIM, O'Bryant HS, et al. Maximum Strength-Power-Performance Relationships in Collegiate Throwers. *J Strength Cond Res* 2003;17:739-745.
3. Canavan PK, Garrett GE, Armstrong LE. Kinematic and Kinetic Relationships Between an Olympic-Style Lift and the Vertical Jump. *J Strength Cond Res* 1996;10:127-130.
4. Tricoli V, Lamas L, Carnevale R, et al. Short-Term Effects on Lower-Body Functional Power Development: Weightlifting Vs.Vertical Jump Training Programs. *J Strength Cond Res* 2005;19:433-437.
5. Hori N, Newton RU, Andrews WA, et al. Does Performance of Hang Power Clean Differentiate Performance of Jumping, Sprinting, and Changing of Direction? *J Strength Cond Res* 2008;22:412-418.
6. Garhammer J. Performance evaluation of Olympic weightlifters. *Med Sci Sports* 1979;11:284-287.
7. Garhammer J. Power production by Olympic weightlifters. *Med Sci Sports Exerc* 1980;12:54-60.
8. Garhammer J. Energy flow during Olympic weight lifting. *Med Sci Sports Exerc* 1982;14:353-360.
9. Garhammer J. Biomechanical profiles of Olympic weightlifters. *Int J Sports Biomech* 1985;1:122-130.
10. Garhammer J. A comparison of maximal power outputs between elite male and female weightlifters in competition. *Int J Sports Biomech* 1991;3:3-11.
11. Garhammer J, Gregor R. Propulsion Forces as a Function of Intensity for Weightlifting and Vertical Jumping. *J Strength Cond Res* 1992;6:129-134.
12. Enoka RM. The pull in olympic weightlifting. *Med Sci Sports* 1979;11: 131-137.
13. Hakkinen K, Kauhanen H, Komi PV. Biomechanical changes in the Olympic weightlifting technique of the snatch and the clean & jerk from submaximal to maximal loads. *Scand J Sports Sci* 1984;6:57-66.
14. Souza AL, Shimada SD, Koontz A. Ground reaction forces during the power clean. *J Strength Cond Res* 2002;16:423-427.
15. Comfort P, Allen M, Graham-Smith P. Comparisons of peak ground reaction force and rate of force development during variations of the power clean. *J Strength Cond Res* 2011;25:1235-1239.
16. Comfort P, Graham-Smith P, Allen M. Kinetic comparisons during variations of the Power Clean. *J Strength Cond Res* 2011;25:3269-3273.
17. Baechle TR, Earle RW, Wathen D. Resistance Training, in: *Essentials of Strength Training and Conditioning*. TR Baechle, Earle, R. W, ed. Champaign, Illinois: Human Kinetics, 2008, pp 381-412.
18. Rhea MR. Determining the Magnitude of Treatment Effects in Strength Training Research Through the Use of the Effect Size. *J Strength Cond Res* 2004;18:918-920.
19. Cortina JM. What is Coefficient Alpha? An Examination of Theory and Applications. . *J Appl Psychol* 1993;38:98-104.
20. Munro AG, Herrington LC. Between-session reliability of four hop tests and the agility T-test. *J Strength Cond Res* 2011;25:1470-1477.
21. Munro AG, Herrington LC. Between-session reliability of the star excursion balance test. *Phys Ther Sport* 2011;11:128-132.
22. Weir JP. Quantifying test-retest reliability using the intraclass correlation coefficient and the SEM. *J Strength Cond Res* 2005;19:231-240.
23. Thomas JR, Nelson JK, Silverman SJ. *Research Methods in Physical Activity*. Champaign, IL: Human Kinetics, 2005.