A COMPARISON OF METHODS TO CALCULATE THE OPTIMAL LOAD FOR MAXIMAL POWER OUTPUT IN THE POWER CLEAN

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The aim of this study was to compare three calculation methods to determine the load that maximises power output in the power clean. Five male athletes (height=179.8 10.5cms, weight 91.8 8.8kg, power clean 1RM = 117.0 20.5kg) performed two power cleans at 10% increments from 50% to 100% of 1RM. Bar displacement data was collected using a Ballistic Measurement System (BMS) and vertical ground reaction force (VGRF) data was measured by a Kistler 9287B Force Plate. Power output was calculated for BMS (system mass), BMS (bar mass) and VGRF/BMS system mass. Optimal load was determined to be 70% for the BMS (system mass) and VGRF BMS (system mass) methods and 90% for the BMS (bar mass) method. Sports scientists should be aware of the technical issues underlying these findings due to the practical ramifications for athlete testing and training.

KEY WORDS: power output, power clean, methods, optimal load.

INTRODUCTION: Within the science of strength and conditioning, coaches and scientists are continually examining ways to quantify training methods with the aim of enhancing performance. Many sports that utilise strength and conditioning methods to enhance performance require the application of both speed and strength (Baker et al., 2001a,b; Newton & Kraemer, 1994; Wilson et al., 1993). Previous research has identified Olympic lifting as an activity that produces substantial mechanical power outputs (Garhammer, 1993). The power clean is a variant of the clean and jerk that is used to develop both strength and power. The difference between the power clean and the traditional Olympic clean is that the power clean requires the athlete to catch the bar with the thighs above a parallel squat position. Consequently, the power clean is typically performed with approximately 85-90% of the bar mass lifted in the full clean. Previous research examining the optimal load for maximising mechanical power output has usually examined jump squats and bench press throws performed in a Smith machine (eg. Baker et al., 2001a,b; Wilson et al., 1999) and has reported optimal power outputs of 30-60% of 1RM. The typical bar path during the power clean however, resembles an "S" shaped curve therefore, the instantaneous trajectory of the bar will be the resultant of both horizontal and vertical displacements of the bar (Garhammer, 1993). This also precludes using the Smith machine as a testing apparatus for the power clean as the normal kinematics of the movement would be altered. However, before the optimal load can be examined the methods that can be used in it's determination need to be closely examined. Dugan et al. (2003) examined the different methods that are used to determine power output in the squat jump. Previous methods of determining power output in strength and conditioning exercises have included; bar displacement only (eg. Baker et al. 2001), VGRF only (eg. Dugan et al., 2003), VGRF and displacement (eg. Newton et al., 1999) and accelerometry (eg. Thompson and Bemben, 1999). Dugan et al. (2003) concluded that a combination of VGRF and displacement of the bar was preferred. In the squat jump this is relatively easy to do as the initial velocity is equal to zero (Dugan et al., 2003). In the power clean however the system (weight of the lifter and bar weight) has to be isolated on the plate and this cannot be done without modifying the plate or suspending the bar above the floor. However, using inverse dynamics methods displacement alone can be utilized to predict VGRF as well as velocity and power output. If this can be done regular testing can be performed using cheaper and more portable equipment. The aim of this study was to compare three calculation methods that have been used to calculate power output and determine the load that maximises power output with each of these methods.

METHODS: Five male athletes (height=179.8 10.5cms, weight=91.8 8.8 kg) were invited to participate in this study. All subjects had a power clean in excess of their body weight (power clean 1RM = 117.0 20.5kg). Informed consent, in accordance with the University Ethics guidelines was obtained from subjects prior to testing. All subjects had a 1RM for the power clean which had been tested in training or testing within the preceding month. Subjects performed two lifts at each of the 10% increments from 50% to 100% of 1RM (total of 12 lifts). A complete warm up was given to the athletes and sufficient rest breaks were given to ensure complete recovery between increments. While completing each power clean vertical ground reaction force (VGRF) data were collected by a Kistler 9287B piezoelectric force plate (Kistler Instrument Corp, Switzerland) and bar displacement was measured by a Ballistic Measurement System (BMS) (Model 2003.1.4; Fitness Technology, Adelaide, Australia). Both measurement systems were synchronised via a 12 bit AD card. Data from each lift was captured and saved to file for later analysis. Three methods to calculate the peak power output were utilised for comparison they being; firstly, power output based on displacement measurement of the bar and utilising the system (body and bar) mass (BMS SM), secondly, power output based on displacement measurement of the bar and utilising bar mass only (BMS BM) and thirdly, power output based on a combination of VGRF and bar velocity and body mass. Power output calculations are outlined in Dugan et al. (2003). To determine the optimal load for peak power output, maximal power during the second pull was calculated as an average over the two trials. To determine the within-day reliability intra class correlations (ICC) were obtained from the two trials at each load intensity using the Statistical Package for the Social Sciences (SPSS V10.0). The Standard Error of Measurement (SEM) was calculated as follows:

$$SEM = S_x \sqrt{1 - ICC}$$

Where, was the pooled standard deviation of trial 1 and trial 2. The %SEM was calculated by:

$$\%SEM = \frac{SEM}{\bar{X}_1 + \bar{X}_2} * 100$$

Where, $\bar{X}_1$ and $\bar{X}_2$ were the means of trial 1 and 2 respectively.

RESULTS AND DISCUSSION: The power clean is considered a special strength exercise that is used to develop quickness and jumping ability in athletes. To improve these capacities the principles of progressive overload and specificity need to be addressed in an athlete's training program. With reference to specificity, it has been found that the power clean is kinematically very similar to the vertical jump which makes it an ideal exercise for power athletes (Canavan et al., 1996). To address progressive overload, power output values in training must be increased to allow positive adaptation and this can be done in training by maximising power output values in exercises such as the power clean. To quantify the trial to trial variability in peak power output for each calculation method, reliability indices were calculated. Indices for peak power output for the BMS SM (ICC=0.84, %SEM=1.8%), VGRF/BMS SM (ICC=0.94, %SEM=1.1%) and BMS BM (ICC=0.83, %SEM=2.1%) showed that the data from the two trials at each load could be averaged to provide representative values for each subject and that these values are stable between repetitions. The load that maximised power output in the power clean in these subjects was found to be 70% of 1RM for the BMS SM and VGRF/BMS SM calculation methods and 90% of 1RM for the BMS BM method (Figure 1). When determining this figure however, consideration should be given to the %SEM value as in some cases loads within 10% may not provide a maximum through natural trial to trial variation. As the identical bar mass was lifted in each calculation method, this indicates that the method used to determine the optimal load is an important consideration for Sports Scientists. The argument of which calculation method to utilise will depend upon a few considerations. Firstly, the total power output in the power clean is generated from a combination of the horizontal and vertical work in lifting the barbell in addition to the work in lifting the body's CM (Garhammer, 1993). It has been found in a group of University athletes that the mean power output during a vertical jump as measured by VGRF was found to be 4678W (Johnson and Bahamonde, 1996). Hence, a substantial amount of power can be generated by jumping without additional load in the athlete's hands. Whilst the CM velocity would be slowed when performing a power clean (thus the component of power being relatively less) movement of the centre of mass should still be considered in a calculation where possible. With the BMS SM and VGRF BMS SM methods this factor can be considered. With the former method an assumption is made that the centre of mass moves at the same speed as the bar which in the power clean would be a dubious assumption due to the differing vertical range of movement the centre of mass and bar actually move over (Garhammer, 1993). In the VGRF/BMS SM method the force plate will consider the overall sum of the body's segments accelerations. As can be seen in Figure 1, there is some difference in the magnitude of power output between these two methods. Practically speaking however, strength and conditioners and coaches will be more interested in the percentage load of 1RM that maximises the power output rather than the exact quantification of power output for each load. The interesting finding of this study was that the optimal load was calculated to be the same percentage from the VGRF/BMS SM and BMS SM methods and the load-power curves virtually parallel each other. Whilst it is accepted that the method of calculating power output is most precisely done via the VGRF/BMS SM it seems that the determination of the optimal load may still be done cost effectively without a force plate. Not including the athlete's body mass in the calculation of power output not only considerably underestimates the actual values, as one performs the power clean with lower percentages of 1RM the error involved is relatively larger. This results in a large distortion of the load-power relationship and provides an incorrect optimal load, much higher than the true value.

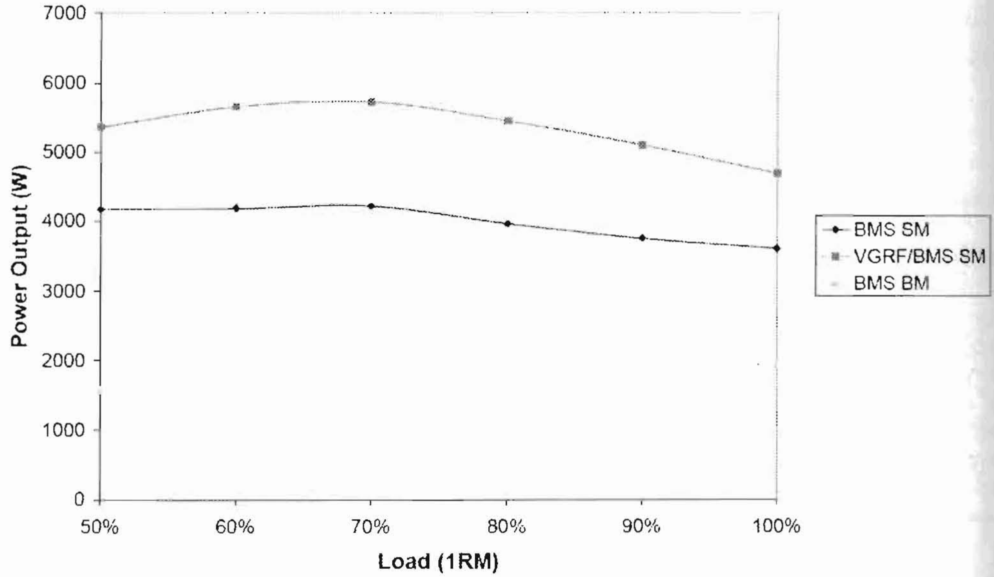

Figure 1: Mean load- power output graph from athlete performing the power clean.

When comparing the optimal load that has been recommended in previous studies of 30-60% of 1RM for the bench press (bar mass) and the squat jump (system mass) (eg. Baker et al., 2001a,b; Wilson et al., 1993) there is a clear difference in the optimal load in the power clean. The data from this study confirms the thoughts of Baker et al. (2001a,b) who postulated that the optimal load was higher than that for squat jumps and bench press. A possible reason for this finding is that the power clean is a composite exercise that involves many muscle groups.

CONCLUSIONS: It can be concluded within the limitations of this study that BMS SM and VGRF/BMS SM calculations lead to similar estimations of the load (%1RM) that maximises power output in the power clean. This is an important finding of this study as the cost of force plates may prohibit many strength and conditioners using scientific methods to quantify elements of training. Also, there are several logistical and technical reasons why Olympic lifts cannot be performed on a force plate unless it is permanently mounted in a floor. The BMS BM however, calculated a load at least 20-30% of 1RM higher than that found by the other methods.

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