Optimal Load and Power Spectrum During Jerk and Back Jerk in Competitive Weightlifters

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Abstract

Flores, FJ, Sedano, S, and Redondo, JC. Optimal load and power spectrum during jerk and back jerk in competitive weightlifters. *J Strength Cond Res* 31(3): 809–816, 2017—Although the ability to develop high levels of power is considered as a key component of success in many sporting activities, the optimal load (Pmax load) that maximizes power output (Pmax) remains controversial mainly during weightlifting movements. The aim of the present study was to determine Pmax load and optimal power spectrum (OPS) required to elicit Pmax by comparing jerk and back jerk exercises in competitive weightlifters. Thirteen male competitive weightlifters participated in 2 testing sessions. The first session involved performing one repetition maximum (1RM) in the back jerk and jerk and the second session assessed a power test across a spectrum of loads (30–90%) of each subject's 1RM in the predetermined exercises tested. Relative load had a significant effect on peak power, with Pmax load being obtained at 90% of the subjects' 1RM in both exercises assessed. There was no significant difference between the power outputs at 80% of 1RM compared with 90% of 1RM. Furthermore, Pmax load and OPS were the same for jerk and back jerk, whereas peak power in the back jerk demonstrated no significant increases in every load of the power-load curve. We can conclude that it may be advantageous to use loads equivalent to 80–90% of the 1RM in jerk and back jerk in competitive weightlifters when training to maximize power.

Key Words peak power, Pmax load, Pmax, weightlifting

Introduction

Weightlifting exercises are one of the most effective ways to develop power output (26). Weightlifting exercises, including snatch, clean, and jerk, and variations of these exercises, are known to produce some of the highest average human power outputs of all resistance training exercises (14,20,23,25,31). To achieve a high level of performance, weightlifting exercises and their derivatives are generally used as training exercises in many sports (18,21) and conditioning programs (7,8).

The snatch and clean and jerk are the 2 lifts contested in the sport of weightlifting. The snatch is the first lift performed in competition and clean and jerk lift is the second which is divided in 2 parts: clean movement and jerk movement. In the jerk movement, large loads are accelerated rapidly (37) through ranges of motion that are mechanically similar to those in many sporting skills (15), achieving a power output value in this movement that is far in excess of those obtained during classic resistance exercises (14,25,31,33). On these lines, Stone et al. (31) reported that a 100-kg male weightlifter produced 5,400 W of power output during the jerk in weightlifting competition, a much higher value than the 1,100 and 300 W achieved by the same lifter in the squat and bench press, respectively, although that low values reported for the squat and bench press would be influenced by the methods used to calculate power. Similarly, Garhammer (14) reported almost 7,000 W during the clean pull in an attempt at a world record with 260 kg by a weightlifter of 125 kg of body weight. The second pull of snatch and clean is known to elicit the greatest amount of power output of all resistance exercises (8,11,14,31), whereas jerk and second pull power output values are usually found to be very similar in magnitude for elite lifters in top physical condition (14,34). These values and data suggest that the jerk movement might be an excellent exercise for achieving a high level of power output and improving muscular power.

Most of the world's weightlifting training programs are derived from models developed by the weightlifting federations of Bulgaria and the former Soviet Union (16). The Bulgarian philosophy uses a limited battery of 6 exercises (snatch, clean and jerk, power snatch, power clean and jerk, front squat, and back squat) in the weightlifting training. However, the Soviet system uses a greater variety of exercises, including the back jerk or jerk behind the neck (16). The back jerk is an exercise commonly included in weightlifting training programs not influenced by the Bulgarian

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methodology of training weightlifters, being the primary assistance exercise for improving the jerk phase of clean and jerk (16).

The jerk is performed starting with the barbell held firmly on the shoulders (on the lifter's anterior deltoids and below the head), so during the drive phase, the athlete must do a rapid neck extension to keep the bar's path as vertical as possible while avoiding hitting the chin with the barbell. However, the back jerk is started with the barbell on the shoulders and upper back (as in the back squat position); in this way, the trajectory of the barbell upward has no obstacles. In this context, the lower limb kinematics on the propulsion phase during the jerk and back jerk is very similar but because of the differences on the starting position of the barbell, there may be some kinematics differences. However, these differences have never been explored though could affect the training recommendations related with power profiles.

To maximize the power output during any exercise, there must be a compromise between force and velocity. Consequently, the optimal load (Pmax load) is the load intensity that elicits maximal power production in a certain movement (12). From a practical point of view, Pmax load and similar loads with no significant differences between them (optimal power spectrum, OPS) (5) are considered the most appropriate stimulus to improve the power developed in a specific technical gesture (28). According to previous researches related to weightlifting exercises (snatch, clean, jerk, and variations of these movements), the center of gravity of the barbell and that of the system (bar plus body mass) do not move in parallel (9–11,19,20,24,27). So, the success during weightlifting exercises is directly dependent on the capacity to move an external object as fast as possible, applying the maximum power to the barbell (17,20,27). Because the peak power attained varies with different relative loads (22,23), it is crucial that the load-power relationships of the jerk and back jerk should be examined to establish training recommendations for the use of these exercises.

The importance of power production has been reported as a key factor in weightlifting where the success depends on how much weight the athlete can lift (1RM) and not how much power the athlete can produce. In that sense, Stone et al. (33) claimed that power production is the most significant factor in determining success in weightlifting, and likewise, Hori et al. (18) indicated that the success of weightlifting depends on the power applied to the barbell against high loads (high-load speed strength). According to previous studies (14,33), during weightlifting, Pmax load is achieved with high loads; therefore, Pmax load is a key factor to achieve success during these types of exercises.

Although the jerk has been included in weightlifters' and athletes' strength and conditioning programs (23) and the back jerk is a common exercise used by many weightlifters, no previous investigations have simultaneously compared the Pmax load in jerk and back jerk. Hence, the aim of this investigation was to find Pmax load and OPS required to elicit Pmax during the jerk and back jerk in a group of competitive weightlifters, comparing the differences between exercises. In line with previous research findings (14,33), it was hypothesized that Pmax load during jerk and back jerk exercises would be achieved toward the heavier end of the load-power curve (70–80% of 1RM), with the highest Pmax being achieved in the back jerk exercise.

Methods

Experimental Approach to the Problem

In this study, 13 competitive and experienced male weightlifters were tested in 2 sessions. The objective of the first testing session was to determine the subject's 1RM for the back jerk and jerk. During the second testing date, subjects were required to perform a power test across a spectrum of loads (30–90%) of their predetermined 1RM, with 1 attempt at each load to help identify the optimal load (Pmax load) and OPS for maximal power output (Pmax).

Subjects

Thirteen experienced male weightlifters participated in the study. All the subjects were active in competitive weightlifting during the 2015 season, 8 of them being medalists in their respective body-weight categories in the Spanish National Championships of 2014, of 2015, or both. On the basis of their best weightlifting performance in competition, their Sinclair coefficient was 302.52 ± 37.57 (30). The descriptive characteristics of the subjects are shown in Table 1. Before participating in the study, all the participants read and signed an informed consent statement in conformity with guidelines set by the local ethics committee. The study conformed to the principles of the World Medical Association's Declaration of Helsinki.

Procedures

Two test sessions were carried out in the weightlifters' usual training environment to assess 1RM and power. Before the start of each test session, participants went through a standardized 20-minute warm-up. In both sessions, the order of the exercises assessed was back jerk followed by jerk, and 10-minute rest was allowed between exercises. This

Table 1. Descriptive data for participant characteristics (mean ± *SD*).

	Male (n = 13)
Age (y)	25.94 ± 6.87
Height (m)	174.65 ± 3.27
Body mass (kg)	72.15 ± 9.88
Sinclair coefficient	302.52 ± 37.57
Weightlifting experience (y)	13.46 ± 8.20

Figure 1. Weightlifter perform the lift with the accelerometer fixed to the bar according to the study by Sato et al. (29).

recovery period is similar to that applied in weightlifting competitions between the snatch and the clean and jerk movements.

1RM Testing. The subjects' 1RM was obtained for the back jerk and jerk following the standardized protocol presented by Baechle and Earle (1). The barbell was taken out of power rack before starting each exercise. The weightlifters had previously performed this test numerous times in conjunction with their normal training program for the purpose of monitoring strength development and therefore were well accustomed to the procedures for the test.

Power Testing. Two to 4 days after their 1RM was established, a power test session was performed. After the warm-up exercise sets, subjects carried out a maximum effort repetition for each load, which was systematically increased to 30, 40, 50, 60, 70, 80, and 90% of the subject's predetermined 1RM. The recovery period between loads was determined by the athlete but was in all cases between 3 and 5 minutes.

A 3-axis accelerometer (PS-2136A; PASCO Scientific, Roseville, CA, USA) operating at 100 Hz, and a Bluetooth wireless device (Airlink 2 PS-2010; PASCO Scientific) was used in the power testing. This accelerometer was chosen for its easy portability in the weights room and minimal disturbance of the flow of the lifting sessions without compromising the weightlifter's technique in data collection (29). The measuring device was attached to the barbell with the foam unit shown in Figure 1 according to the specifications set out by Sato et al. (29). The total mass of the measuring device plus the protective foam was 180 g, which is equivalent to a metal barbell collar (29). This weight is not enough to induce asymmetric disturbances during a lift. The accelerometer unit was placed underneath and in alignment with the long axis of the barbell on the left edge of the bar in relation to the lifter's position (Figure 1). In that position, backward-and-forward, side-to-side, and up-and-down bar movements are equivalent to the x, y, and z axes, respectively, in accordance with the factory configuration. Before each attempt, the position of the sensor unit was checked and if necessary restored to the configuration described above.

Concurrent (criterion-related) validity of the accelerometer system was assessed using 1-way analysis of variance (ANOVA) by comparing each selected measure with criterion, a 7 VICON-460 infrared video camera at 100 Hz (Vicon, Oxford, United Kingdom). According to Drouin et al. (13), the discrepancy between these measures was assessed for all trials performed by calculating the method error (ME) and the coefficient of variation of the method error (CV_{ME}). Exclusively for z axis, the results of acceleration demonstrate a good agreement between accelerometer (Pasco) and criterion measures (VICON) because ANOVA revealed no significant differences ($p > 0.05$) between them (CV_{ME} = 1.13%). Furthermore, the reliability was investigated using ICC (2,1), and the associated standard error of measurement (*SEM*) for each ICC was also calculated (36). Finally, registered data demonstrated near-perfect reliability

Table 2. Descriptive data for power for jerk and back jerk for each test occasion.*

	Peak power (W)		95% confidence interval	
Load (% 1RM)	Jerk	Back jerk	Lower bound	Upper bound
30	1,165.42 ± 279.95†		996.24	1,334.59
		1,420.65 ± 535.71†	1,080.27	1,761.02
40	1,652.66 ± 458.83†		1,375.39	1,929.93
		1,801.09 ± 572.37†	1,437.42	2,164.75
50	2,145.61 ± 504.13†		1,840.97	2,450.26
		2,383.58 ± 690.40†	1,944.91	2,822.24
60	2,493.72 ± 622.50†		2,117.55	2,869.89
		2,817.45 ± 629.55†	2,417.46	3,217.45
70	2,838.00 ± 606.48†		2,471.51	3,204.50
		3,022.95 ± 714.33†	2,569.09	3,476.82
80	3,019.66 ± 629.08		2,639.51	3,399.81
		3,248.44 ± 737.84	2,779.64	3,717.24
90	3,103.34 ± 616.87		2,730.57	3,476.10
		3,400.22 ± 691.07	2,961.14	3,839.31
Exercise (*F*)	1.11 ($p = 0.303$; ES = 0.046)			
% of 1RM (*F*)	301.75 ($p < 0.001$; ES = 0.929)			

*Values are given as mean ± *SD*.
†Significantly different ($p < 0.001$) from 90% of 1RM.

(ICC = 0.990; *SEM* = 0.55). So the accelerometer is capable of providing accurate data.

The data were processed thereafter, using Pasco Capstone software (Version 1.1.5; PASCO Scientific), and barbell peak power outputs were calculated from acceleration according to the methodology explained by Thompson and Bemben (35). Data analysis included only the vertical acceleration attained by the barbell that was lifted, but only up to the highest point of the bar path before the catch position of the exercises assessed. It should be noted that the lifter's body weight was not included in the calculations, so that the power calculations recorded the work done against the bar by the lifter. The exclusion of the body weight in the calculations gives more important information about weightlifting performance because the success of weightlifting depends on the power applied to the barbell, which moves independently of the body and how high the lifter can pull (in the snatch and clean) or drive (in the jerk) the barbell regardless of the lifter's body mass (19,20,22,27). In that sense, to measure specifically, the power applied to the barbell may be the primary outcome measure when assessing weightlifting performance (19,20,22,27).

To ensure the maximum effort from subjects for every load, in both testing sessions strong verbal encouragement was given to all participants to motivate them to perform each lift to the maximum and as powerfully as possible.

Statistical Analyses

The SPSS statistical software package (version 18.0; SPSS, Inc., Chicago, IL, USA) was used to analyze all data. Normality of distribution was tested by means of the Kolmogorov-Smirnov test. Standard statistical methods were used to calculate the mean and *SD*. Power-related effects and the differences between exercises were assessed using 2-way ANOVA with repeated measures (exercise × load). When a significant *F* value was achieved through Wilks' lambda, Scheffe's post hoc procedures were performed to locate the pairwise differences. The Bonferroni correction for multiple comparisons was applied. The significance level was set at 0.05. Effect size (ES) statistics was assessed using Cohen's *d* (6). Cohen classified ESs as "small" (0.2–0.3), "medium" (0.4–0.7), and "large" (>0.8). In addition, for the power output of each exercise, the reliability of measurements was calculated using the ICC.

Results

The Kolmogorov-Smirnov test suggested that all variables were distributed normally ($p > 0.05$). Jerk and back jerk peak power increased from 30 to 90% of 1RM. Table 2 shows the data for both exercises in every test. The ICC was 0.97 for jerk and 0.89 for back jerk. The back jerk elicited a greater peak power than the jerk for all the loads assessed (Figure 2), but ANOVA revealed no significant exercise × load interaction effects for them ($F = 1.111$; $p = 0.303$). Pmax occurred at a relative intensity of 90% of 1RM for the jerk (3,103.34 ± 616.87 W) and the back jerk (3,400.23 ± 691.07 W). However, these were not significantly different from the peak power produced with 80% of 1RM for the jerk (3,019.66 ± 629.08 W; $p > 0.05$, ES = 0.06) and 80% of 1RM for the back jerk (3,248.4 ± 737.84 W; $p > 0.05$, ES = 0.11). Therefore, the

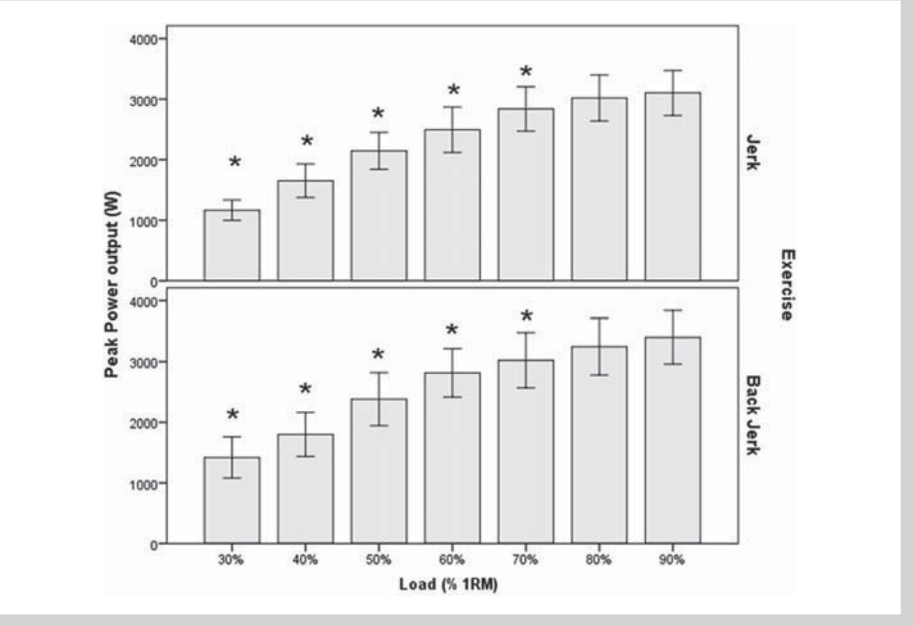

Figure 2. Peak power output at loads of 30–90% of one repetition maximun (1RM) during jerk and back jerk. *Significantly different from 90%.

Pmax load (optimum load) and OPS in both exercises were achieved with 90% of 1RM and between 80 and 90% of 1RM.

For the jerk, Scheffe's post hoc tests revealed differences between 90 and 30% ($p < 0.001$, ES = 4.04), 40% ($p < 0.001$, ES = 2.66), 50% ($p < 0.001$, ES = 1.70), 60% ($p < 0.001$, ES = 0.983), and 70% ($p < 0.001$, ES = 0.71). However, for the back jerk, the differences were noted between 90 and 30% ($p < 0.001$, ES = 3.20), 40% ($p < 0.001$, ES = 2.52), 50% ($p < 0.001$, ES = 1.47), 60% ($p < 0.001$, ES = 0.88), and 70% ($p < 0.001$, ES = 0.53).

Discussion

The purpose of this research was to determine the optimal load (Pmax load) to achieve maximal peak power output (Pmax) and the OPS in the jerk and back jerk exercises in competitive weightlifters. In this particular population, the Pmax load was achieved at 90% of 1RM for both exercises tested. However, the load of 80% of 1RM was not statistically different compared with 90% identifying the OPS between loads of 80 and 90% of 1RM for both lifts (Figure 2 and Table 2).

Training in weightlifting focuses on generating high levels of muscular power during the lift and to transfer that power to the bar in a short period (4). During weightlifting exercises, such as snatch, clean, jerk, and variations of these movements, the center of gravity of the barbell and that of the system (bar plus body mass) do not move in parallel (9–11,19,20,24,27). According to this, a weightlifter's interest is moving an external object, the bar plus weight, as fast as possible because the success of weightlifting depends on the power applied to the barbell (17,20,27). Taking into account only the power applied to the barbell, Pmax load during weightlifting exercises and their derivatives have been reported ranging from 80 to 100% of 1RM (17,20). The results obtained in the current study using back jerk and jerk located Pmax load at 90% of 1RM and the OPS at the top of the power load curve, between 80 and 90% of 1RM. It would seem that to date nobody has attempted to establish the Pmax load and OPS for jerk and back jerk exercises. Thus, the results obtained in this work confirm the trend shown in the literature (14,33) toward achieving Pmax load with a high percentage of 1RM during weightlifting exercises and their variations.

In the present study, Pmax load was achieved with a 90% of 1RM in the jerk and back jerk. Although no previous pieces of research have tested these exercises, the high percentages found in the present study might be influenced by the strength profile of the subjects (competitive weightlifters). Thus, it has been suggested that the level of experience and proficiency of the subject could be expected to shift the percentage of maximum strength at which the highest power is produced either upward or downward (23). In this way, the strength level of the subjects might be a factor that makes matters less clear (25). For example, in line with the current study, Stone et al. (32) found that in squat jumps, weaker subjects produced the maximal power output at a lower relative load than did stronger. The same trend was reported by Kilduff et al. (25) using hang power clean exercises with professional rugby players. However, there is no uniform agreement between researchers, and contradictory results were reported by Baker et al. (2,3), suggesting that stronger athletes used lower percentages of 1RM than weaker to maximize power output during jump squats and bench press throws.

The Pmax obtained in the present work are significantly lower than those previously reported by Stone (31) or Garhammer (14). These discrepancies might be attributable to variations in the methodological procedures used (10,11,19,20,27,33), like how to collect and analyze power output, the body mass of the subjects, and the conditions for data collection. In the current study, the body mass of the sample was 72.15 $\pm$ 9.88 kg, in comparison with the 100 and 125 kg of the weightlifters studied by Stone (31) and Garhammer (14), respectively. In addition, the methodology used in these works to estimate the Pmax was video analysis under competition conditions, unlike to the evaluation carried out in training conditions in the current study. According to Garhammer (14), horizontal component during the jerk is negligible for skilled lifters, so the jerk analysis of Garhammer only included the work done vertically on the barbell and center of mass (CM) of the lifter. Thus, during the current study, horizontal work was rejected; however, the power output because of lifting body's CM was not included in the present study. The power output because of lifting body's CM during the study by Garhammer (14) was 689 W, which accounted for 15% of total power generated by the lifter (4,570 W). These methodological differences could well be decisive in explaining the variability reported in the power values in these studies.

The results of the present study, taken together with the details given above, suggest that weightlifting movements and their variations (including jerks and back jerks) require a higher percentage of loads to maximize power output. According to Lake et al. (26), this might be explained by the fact that, although ballistic, load projection must be performed under control and within technical patterns, which may prevent achieving maximum power outputs with lighter loads.

As hypothesized, the results of the present research noted that the back jerk elicited a greater peak power than the jerk for all the loads assessed (Figure 2). As it was previously indicated, this may be explained by the nature of the movement involved developing high force and high velocity (9–11), with no obstacles during the trajectory of the barbell upward permitting to apply greater power values in a movement with easier technical patterns than the jerk. Under the influence of Bulgarian method (16), the back jerk is not usually an exercise scheduled in many weightlifting training programs, but according to our results, the back jerk can be considered as valid as the jerk to improve power development. Moreover, the back jerk is one of the best variations among weightlifting exercises to improve the jerk phase of clean and jerk (16).

The findings of this study should be considered in light of a few limitations. First, the peak power is referred only to the bar, although according to McBride et al. (27), little differences exists whether calculating the bar, body, or system (lifter-plus-bar) power during weightlifting movements. Second, the findings of this study are mainly applicable to sports where to move an external mass as fast as possible is the main goal (e.g., throwing or weightlifting); thus, it does not apply to other sports like sprinting or jumping (27), in which power production against one's own body is crucial to achieve high performance. And finally, power against 100% of 1RM was not assessed so we cannot conclude definitely that 90% is the Pmax load. Future studies may identify roundly the Pmax load, including the evaluation power at 100% of 1RM.

In conclusion, the results of this study provided new information about mechanical power output during jerk and back jerk exercises. They indicated that relative intensity had a significant effect on peak power during the jerk and the back jerk, and that Pmax were obtained working against an external load equivalent to 90% of 1RM. Furthermore, they identified OPS between 80 and 90% of 1RM in both exercises. In addition, future studies should consider differences either from other weightlifting exercises (e.g., snatch, clean power snatch, or power clean) carried out by the same group of subjects or from the same exercises undertaken by other athletes (e.g., sprinters, jumpers, or throwers). Likewise, it would be worth exploring how the kinematic differences observed between jerk and back jerk may affect the kinetic values. These would provide helpful knowledge for athletes and coaches so that they could improve performances.

Practical Applications

It is important for coaches to be aware of the Pmax load for peak power production and OPS. The results of this study indicate that the Pmax during jerk and back jerk is maximized with a resistance of 90% of 1RM, with the OPS between loads of 80 and 90% in both lifts. The findings showed that peak power in the back jerk is higher than in the jerk across the whole spectrum of loads, suggesting the use of back jerk in the battery of training exercises for competitive weightlifters, focusing on improving their muscular power production and clean and jerk performance. Therefore, because no statistically significant differences in peak power were noted between 80 and 90% of 1RM, when setting out training programs to improve the power output, it is suggested that loads between 80 and 90% of 1RM in the jerk and the back jerk may be the most advantageous to improve power production during the exercises assessed by the weightlifters.

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This manuscript is original and not previously published, nor is it being considered elsewhere until a decision is made as to its acceptability by the JSCR Editorial Review Board. Informed consent was obtained from all participants, in keeping with the guidelines established by the University of León (Spain) Ethics Committee which approved the author's study.

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