POWER OUTPUT IN THE JUMP SQUAT IN ADOLESCENT MALE ATHLETES

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ABSTRACT

Dayne, AM, McBride, JM, Nuzzo, JL, Triplett, NT, Skinner, J, and Burr, A. Power output in the jump squat in Adolescent male athletes *J Strength Cond Res* 25(3): 585–589, 2011—The load that maximizes power output in the jump squat (JS) in college-aged athletic males has been reported to be 0% of 1 repetition maximum [1RM] squat strength) or in other words body mass. No data exist concerning adolescent athletic males. In addition, strength levels have been theorized to possibly affect the load that maximizes power output in the JS. The purpose of this investigation was to identify the load that maximizes power output in the JS in adolescent athletic men, and concurrently describe their strength level and its effect on the load that maximizes power output. Eleven high-school male athletes were tested on 2 occasions, first determining their 1RM in the squat (1RM = 141.14 ± 28.08 kg; squat 1RM-to-body mass ratio = 1.76 ± 0.15) and then performing JS testing at loads equal to 0% (body mass), 20, 40, 60, and 80% of squat 1RM. Peak power (PP), peak force, peak velocity (PV), and peak displacement were measured at each load. Jump squat at the 0% load produced significantly ($p \leq 0.05$) higher PP, PV, and peak displacement in comparison with the 40, 60, and 80% loading conditions. It was concluded that the load that maximizes power output in the JS is 0% of 1RM in adolescent athletic men, the same as found in college-aged athletic men. In addition, strength level relative to body mass did not affect the load that maximized power output. Practically, when devising a training program to increase PP, it is important to include JSs at body mass along with traditional strength training at heavier loads to increase power output across the entire loading spectrum.

KEY WORDS optimal load, jumping, velocity, force

INTRODUCTION

Power, the ability to produce force in an explosive nature, is crucial for optimal performance across a wide spectrum of sports (10). Some investigations have shown that the greatest potential for increasing muscular power comes from training with the load that maximizes power (8,22). However, other studies have shown that training with a variety of loading conditions may maximize power output development (3,21). The jump squat (JS) is a common lower-body exercise used for developing power and exercise testing. Optimal training loads for the JS come from percentages of a 1 repetition maximum (1RM) squat. The current literature shows optimal loads ranging from low-resistance (0–20% of 1RM (2,4,7,9,10,11,13, 14,15,16,19)) to heavy-resistance exercises (30–90% of 1RM 1,18,20). However, methodological flaws indicate that if calculated correctly power output is maximized at 0% of 1RM in the JS (2). However, no data exist on the load that optimizes power output in adolescent athletic men.

Variations in reported loads that maximize power output exist for multiple reasons, most notably variation in the type of exercise and methodology used to determine power. Some of these investigations, including the original study by Kaneko et al. (8), focus on maximizing upper-body power, whereas others have examined lower-body power. The methodology used to find the load at which peak power (PP) occurs is important to consider. Cormie et al. (4) and Dugan et al. (6) found that data collection and analysis procedures influence the power output calculated during dynamic lower-body movements such as the JS. The most current investigations that have used a combination of kinetic and kinematic equipment to obtain the most valid representation of lower-body power in the JS have determined the optimal load to occur at 0% of 1RM (2,4,14,15). Investigations that used only kinematic variables to calculate power may have incorrectly estimated power and, therefore, found the optimal load to include heavier resistances (1,18,20).

Varying strength levels of subject populations has also been indicated as a possible variable contributing to the different loads reported to optimize power output in the JS (1,5). However, several studies have reported no such observation (3,4,10). Variability in subject selection may be the cause of

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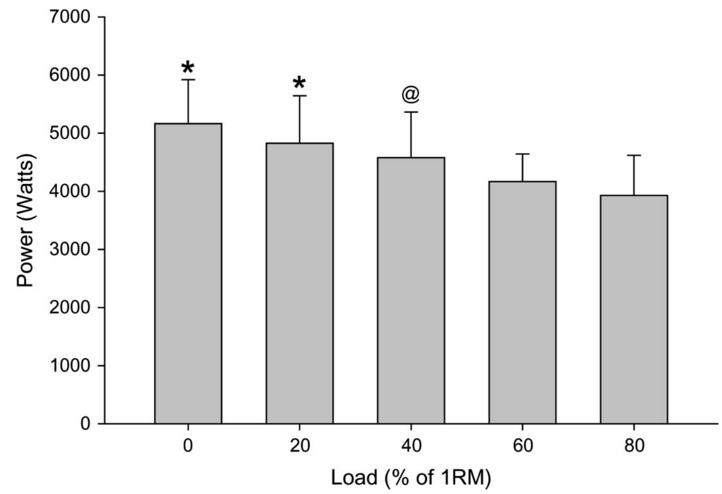

Figure 1. Power across the loading spectrum in the jump squat. *Significantly different in comparison with the 40, 60, and 80% loads ($p \leq 0.05$). @Significantly different in comparison with the 0, 20 and 80% load ($p \leq 0.05$).

differences in the load at which power is optimized. The majority of studies have tested subjects college aged and older, with only 1 recent study investigating children (14). It should be noted, however, that in children, who were presumably weaker than the college-aged subjects studied, still optimized power output at 0% of 1RM (14). Therefore, because there is still debate about the optimal load that maximizes power in the JS, the purpose of this investigation was to determine the optimal load for maximizing power output in adolescent athletic men.

METHODS

Experimental Approach to the Problem

To investigate whether populations other than college-aged males and children express maximal power output at 0% of 1RM (body mass), 11 high-school male athletes were tested in the JS. A 1RM in the squat was determined for each subject. Because some previous investigations have shown maximal power output to occur at loads heavier than 0% of 1RM, each subject was tested at various loads across the loading spectrum in the JS using 0, 20, 40, 60, and 80% of 1RM.

Subjects

Eleven high-school male athletes (age: 15.63 ± 0.52 years; height: 177.39 ± 4.93 cm; weight: 80.55 ± 16.39 kg; squat 1RM: 141.14 ± 28.08 kg; and squat 1RM-to-body weight ratio: 1.76 ± 0.15) involved in an off-season football weight training program participated in this investigation. Written informed consent was obtained from all participants, along with parental consent. Prior approval was given by the Institutional Review Board at Appalachian State University.

Study Design

This acute study consisted of 2 testing sessions. Subjects were instructed not to train for at least 72 hours before the first session in which they performed a 1RM squat test to assess maximal strength. After 48 hours of rest, the second session consisted of a JS familiarization, followed by JS testing at different prescribed loads based upon percentages of their 1RM results.

Squat 1 Repetition Maximum Testing

Squat 1RM testing was completed at Watauga High School as part of the subjects' off-season training program. Previous squat 1RMs were used to determine warm-up loads. The warm-up protocol consisted of 10 repetitions at 50% of previous squat 1RM load, 2–4 repetitions at 70% 1RM, and 1 repetition at 90%. Subjects then completed up to 4 attempts to achieve their 1RM. All squats were performed to a depth of a 100° knee angle as measured by a goniometer. Three minutes of rest was allowed between each set of squats.

TABLE 1. PP, PF, PV, and PD using different loads (% of 1RM) during the jump squat.*

% 1RM	PP (W)	PF (N)	PV ($m \cdot s^{-1}$)	PD (m)
0%	5,162.10 ± 757.26	1,837.92 ± 373.12	3.33 ± 0.34	0.46 ± 0.15
20%	4,827.40 ± 816.31	2,149.01 ± 439.06	2.68 ± 0.16	0.37 ± 0.04
40%	4,578.38 ± 785.30	2,401.05 ± 474.73	2.25 ± 0.16	0.30 ± 0.04
60%	4,167.74 ± 473.47	2,680.55 ± 539.21	1.91 ± 0.16	0.25 ± 0.03
80%	3,926.64 ± 692.79	3,049.71 ± 679.88	1.59 ± 0.13	0.20 ± 0.02

*PP = peak power; PF = peak force; PV = peak velocity; PD = peak vertical displacement.

Jump Squat Testing

The second session began with instruction of correct JS technique. Subjects were instructed to hold a bar of negligible weight on their shoulders in a back squat position. Performance of the JS involved lowering the bar to the point where the knee angle was approximately 100° as measured by a goniometer. After reaching the bottom of the movement, subjects were instructed to immediately jump upward as fast as possible with their feet leaving the floor while holding the bar tightly to the shoulders. Each subject was allowed multiple practice repetitions with constant feedback from the investigators to ensure safe and proper technique. After a rest period, and before actual JS testing, subjects performed a 5-minute warm-up on a cycle ergometer at 1 kilopod. The JSs were performed in a randomized order at loads equal to 0% (body mass), 20, 40, 60, and 80% of their recorded squat 1RM. Three trials at each load were performed with 1-minute rest between trials and 3 minutes rest between different loading conditions. Reliability and validity of method have been reported previously (2,3,4).

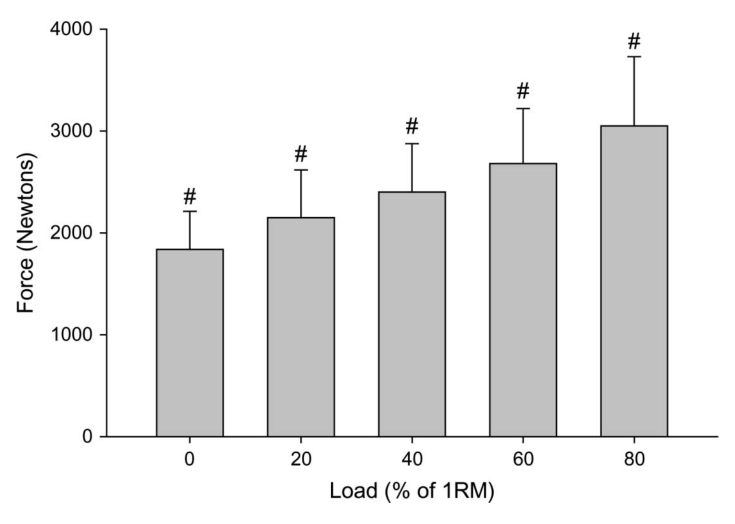

Figure 2. Force across the loading spectrum in the jump squat. #Significantly different in comparison with all the other loads ($p \leq 0.05$).

Data Collection

All subjects performed JS testing on a force plate (AMTI, BP6001200, Watertown, MA, USA) with the barbell attached to 2 linear position transducers (LPT; Celesco Transducer Products PT5A-150, Chatsworth, CA, USA). As described previously (2), the 2 LPTs allowed for measurement of horizontal movement affecting vertical displacement. Through the use of trigonometry, vertical displacement was determined and combined with time to calculate vertical velocity that was then coupled with the vertical force data to calculate power. Previous data indicate that a combination of kinetic (FP) and kinematic (LPT) equipment must be used to obtain the most valid representation of PP generation during dynamic movements (2). Data were collected at 1,000 Hz using a BNC-2010 interface box with an analog-to-digital card (National Instruments, NI PCI-6014, Austin, TX, USA). All data were recorded and analyzed using customized software (LabVIEW, National Instruments, Version 7.1). Peak vertical displacement (PD), peak force (PF), peak velocity (PV), and PP were determined for each trial with the best value for each condition used for analysis.

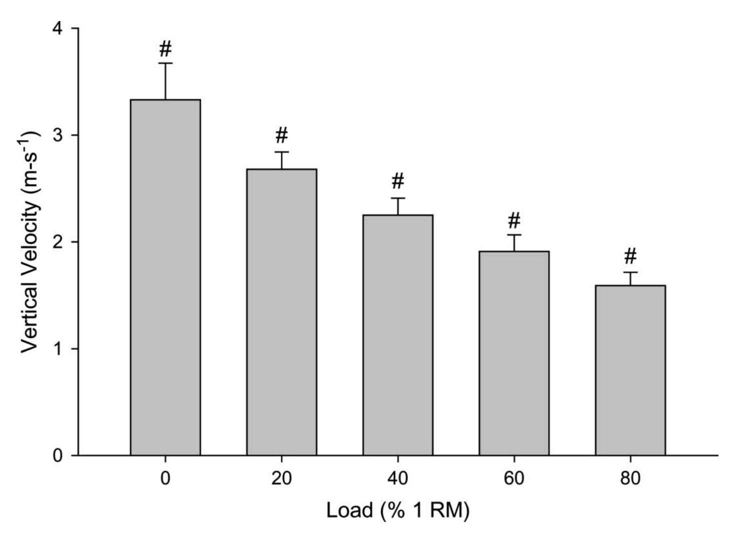

Figure 3. Vertical velocity across the loading spectrum in the jump squat. #Significantly different in comparison with all the other loads ($p \leq 0.05$).

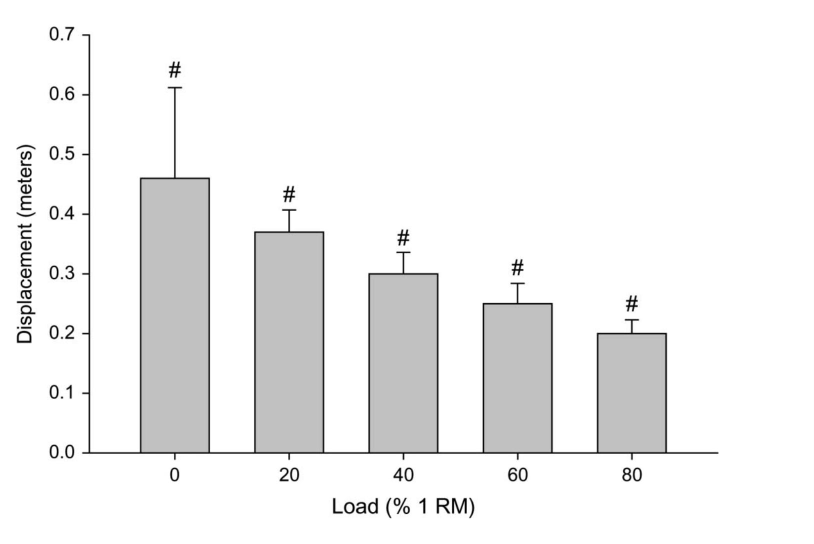

Figure 4. Displacement across the loading spectrum in the jump squat. #Significantly different in comparison with all the other loads ($p \leq 0.05$).

Statistical Analyses

A general linear model with repeated measures and Bonferonni post hoc tests were performed to test significance of difference between and within each of the variables (PD, PF, PV, and PP). An estimate of effect size $\eta^2 = 0.984$, 0.948, and 0.989 at an observed power level of 1.0, 1.0, and 1.0 for PD, PF, and PV, respectively, was determined. Statistical significance for all analyses was defined by $p \leq 0.05$. All statistical analyses were performed through the use of a statistical software package (SPSS, Version 15.0, SPSS Inc., Chicago, IL, USA).

RESULTS

Peak power in the JS was significantly higher during the 0% of 1RM load (5,162.1 ± 757.26 W) in comparison with the 40, 60, and 80% of 1RM load JS (Figure 1, Table 1). Peak power during the 20% of 1RM load was significantly higher than the loads of 40, 60, and 80% of 1RM. Peak power during the 60% of 1RM was also significantly different from the 80% load. Peak force was significantly different between all loading conditions (Figure 2, Table 1). Peak velocity was significantly different between all loading conditions (Figure 3, Table 1). Peak vertical displacement was significantly different between all loading conditions (Figure 4, Table 1).

DISCUSSION

Peak power in the JS was maximized at 0% of 1RM as observed in previous investigations (2,4,10). Loads greater than 0% of 1RM produce a trend of decreasing PP output that became significantly different ($p \leq 0.05$) at 40, 60, and 80% of 1RM. Comparing the results of this study with upper-body power exercises, such as the bench press throw, indicates that loads immediately greater or lesser than the load at which PP was maximized do not significantly alter PP output (1,5). Therefore, even though PP was optimized at body mass, JSs at 20% did not significantly alter PP production. Similar to the current investigation, Stone et al. (19) found that PP in the JS was optimized at a low-resistance load. It was observed that the optimal load was 10% of 1RM, but they failed to test the JS at 0% of 1RM. Had the investigation tested a body mass JS, power may have been optimized at 0% of 1RM, as the data showed a trend in that direction.

It is important to consider the nature of the exercise when comparing optimal power. The results of this study contradict previous literature recommending higher percentage of maximal load to optimize PP (5,12,17,20). However, these heavier resistances (30–90% 1RM) were found to optimize power for upper-body exercises, which must be considered when comparing results with lower-body exercises such as the JS. Training loads should be differentiated between upper- and lower-body movements, and more specifically prescribed according to the biomechanics of the movement. For example, among lower-body power exercises, optimal load for PP output in the JS is different than the optimal load for a squat and, likewise, differs from the optimal load for the power clean (2,4). Lower-body exercises such as the JS require the athlete to move his or her entire body mass and the external load. Upper-body exercises involve only the load and the arms. In the squat, the feet never lose contact with the ground. However, in a JS, the entire body leaves the ground; thus, a different optimal load may be required.

Another aspect to consider is the methodology used in determining power output. It has been shown recently (4,6) that using 2 linear position transducers and a force plate in measuring PP is the optimal method because vertical and horizontal displacements and force measures are included. Kinematic data without actual measurement of force output (i.e., force plate) often underestimate PP output as observed in the literature (1,22), and therefore, it is difficult to determine optimal loads based upon misrepresented PP output. The importance of correct methodology (i.e., kinematic–kinetic methods) must be adequately emphasized because the sole use of either kinematic or kinetic data to estimate power output is fraught with assumptions and issues of validity. There is still no consensus in the literature as to what the acute variables such as sets, repetitions, recovery, and intervals in power-training programs should be. Despite the differences in optimal power outputs among the research, the literature agrees that there is indeed an optimal load for training for power in the JS. Using the most valid measurement techniques, this study adds more weight to the recent literature (2,4,14,15) and agrees that power output is maximized at body mass (0% of 1RM). In addition, given the lower strength-to-body mass ratios of the current subjects, it appears that strength levels do not alter the load at which PP is optimized in the JS.

Practical Applications

Body mass or 0% of 1RM is the optimal load at which power output in the JS is maximized in adolescent athletic men. Strength and conditioning coaches can use this knowledge when devising training programs for athletes. When training for power, JSs at body mass are an important aspect and thus recommended for inclusion in a training program. As shown in a previous training study (3), performing JSs at body mass will increase power production at loads on the light end of the loading spectrum only. However, along with power training at light loads, it is important to include strength training at heavier loads in the same program to increase power output across the entire loading spectrum (3).

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