Does an Optimal Load Exist for Power Training?

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Column Editor

SUMMARY
MECHANICAL POWER CONTRIBUTES TO SUCCESS OF MOVEMENTS RANGING FROM ACTIVITIES OF DAILY LIVING TO SPORT TASKS. RESEARCHERS HAVE ATTEMPTED TO DETERMINE THE LOAD THAT MAXIMIZES MECHANICAL POWER. HOWEVER, DOES TRAINING AT THIS LOAD MAXIMIZE POWER ADAPTATIONS?

PRO
Power training using different loads causes specific changes to the force-velocity relationship that creates variability in the degree to which power output is improved. Several investigations have indicated that training with the load that maximizes power output is more effective at improving maximal power production and athletic performance than either lighter or heavier loading conditions (5,7,8). Kaneko et al. (7) examined 4 loading conditions; 0% of maximum isometric strength (Po), 50% Po (the load that maximized power output), 60% P∞, and 100% P∞. After 12 weeks of elbow flexor training, maximal power production was improved in the 30% Po group significantly more than both the 0% Po and 60% Po groups (26.1% versus 13.8% and 21.7%, respectively) and to a greater extent than the 100% Po group (22.4%). Thus, training with the load that maximized power output promoted all-round improvements to the force-velocity relationship (i.e., increased both maximum velocity and maximum force output), which translated into the most pronounced improvement maximal power output (7). Similarly, Häkkinen et al. (5) reported that explosive body weight jump training (load equivalent to approximately 30% of maximal dynamic strength—the load that maximizes power output in the jump squat [3]) resulted in a 21% increase in jump height after 6 months of training, whereas heavy resistance training (70–120% of 1RM in the squat) resulted in a significantly lower improvement of 7%. Although no doubt exists that increasing an athletes strength level through heavy resistance training directly impacts the ability to generate high power outputs, little evidence exists demonstrating that heavy resistance training is more effective at increasing maximum power than training with 0% and 30% of Po (19.5% versus 10.0% improvement, respectively) (10). It is unclear whether similar results would be observed in trained athletes or if the combined training program was compared to single-load training at the load that maximized power output (30% of Po). It is important to note that no evidence of work performed by the different training groups was provided in either investigation and thus it is difficult to delineate whether the loading conditions or the magnitude of the stimulus applied contributed to these observations. Furthermore, the impact of combined training has yet to be examined in a trained subject population where the potential for increasing maximal strength is diminished.

Although the exact physiological mechanisms underlying superior adaptations after power training to a greater extent than single-load programs. Harris et al. (6) compared the effects of high-force (80–85% of 1RM), high-power (30% of P∞), and combined (30% of P∞ and 80–85% of 1RM) lower body training programs. After 12 weeks of training, the high-force group displayed no change in vertical jump peak power or jump height whereas a significant training effect existed for both the high-power and combined groups. No differences existed between the adaptations of the high-power and combined groups, with very similar improvements observed in peak power (2.5% and 2.6%, respectively) and jump height (2.3 cm and 1.8 cm, respectively). Furthermore, an examination of the elbow flexors in untrained males revealed that combined training using 100% and 30% of Po resulted in a significantly greater improvement in maximum power than training with 0% and 30% of Po (19.5% versus 10.0% improvement, respectively) (10). It is unclear whether similar results would be observed in trained athletes or if the combined training program was compared to single-load training at the load that maximized power output (30% of Po). It is important to note that no evidence of work performed by the different training groups was provided in either investigation and thus it is difficult to delineate whether the loading conditions or the magnitude of the stimulus applied contributed to these observations. Furthermore, the impact of combined training has yet to be examined in a trained subject population where the potential for increasing maximal strength is diminished.

Although the exact physiological mechanisms underlying superior adaptations after power training with a specific load remain unidentified, it is theorized that the load that maximizes power output provides a stimulus that elicits the greatest improvement in power production due to specific adaptations in neural activation patterns (5,7,8). Several investigations have observed increases in muscle activity to occur at the specific load and movement
velocity used in training (5,8). This suggests an increase in neural drive through the selective recruitment of high threshold motor units, increased firing frequency, and/or synchronization of motor units. Because adaptations are most pronounced at the load used in training, the load that maximizes power output provides the best stimulus to elicit the physiological changes necessary to increase maximal power output. Changes in muscle fiber contractile properties have also been postulated to contribute to adaptations following power training however little evidence to this effect currently exists.

A major obstacle to the identification of an optimal load has been the variety of methodologies used to measure power output (2,4). As a consequence, large disparities in the optimal load have been reported leading to ambiguity surrounding the load-power relationship (1,9). Methods reliant solely on kinematic (e.g., linear position transducer [LPT]) or kinetic (e.g., force plate) data have limitations when used for the determination of power output in various movements (2). The combination of kinetic and kinematic equipment (i.e., force plate and LPT) should be used to obtain the most valid representation of muscle power generation during dynamic movements (2,4).

The current literature indicates the load that maximizes power output in a specific movement is the optimal training load to elicit improvements in maximal power output. This optimal load provides a stimulus that results in the greatest improvement in maximal power output due to velocity specific increases in neural drive. Although training with a combination of intensities may improve power output across a greater portion of the force–velocity relationship, the degree at which maximal power output is increased remains unclear. Further examination is necessary to elucidate if improvements to maximal power output and athletic performance differ between single-load and multiple-load training programs in which the total work performed in both programs is equivalent.

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Power is an instantaneous quantity derived from the product of force and velocity. Velocity refers to the speed of the moving body, not how quickly force is developed. Because of the inverse, nonlinear relationship between force and velocity during concentric muscle actions (as force increases, power decreases and vice versa), maximum power occurs at neither maximum force nor maximum velocity—but an optimal interaction between the 2. A prevalent training theory, backed by some early research, suggests that training at loads that produce the highest power outputs will lead to the greatest increases in ability to produce power during athletic performance (6). The optimal load for developing power has, as a result, in many ways become the Holy Grail of resistance training programs. However, there are at least 4 compelling reasons to give up this quest.

First, there is no definitive answer as to what the optimal load to develop power ought to be. There is considerable variability in the load found to maximize power output. Maximal power outputs have been reported to occur at loads as low as 10% of a 1 repetition maximum (1-RM) (8) to as heavy as 70% of a 1-RM (1). This large variability may be explained by the potential problems associated with measuring peak power and even the very nature of mechanical power in human movement itself.

Methodological inconsistencies associated with identifying loads producing peak power outputs are abound (3). Power can be calculated using displacement-only data, force-only data, or a combination of the two; each method has its own errors and limitations. Decisions to treat the subject and the external resistance as either a single system or 2 separate systems, to analyze all planes or just the predominant plane of movement, and even the determination of which/how many loads to use, have not been standardized and prevent a clear relation between load and peak power from being ascertained.
Even if a clear relationship between load and peak power can be identified, it is unlikely that a single load will produce peak power that is substantially greater than all others. Power is the instantaneous product of force and velocity. Theoretically, power may be the same for two different loads because the movement velocity would be higher for the lighter load, yet lower for the heavier load. Practically, there were no significant differences between power outcomes achieved during jump squats with loads between 48% and 63% of 1-RM (2). Similarly, there was no difference in power outputs during hang power cleans performed with loads between 50% and 90% of 1-RM (5). These results suggest that there may be no optimal load, but rather a range of resistances that maximize peak power. Second, even if there were a single load that maximized peak power, it may be irrelevant because peak power may be an inappropriate parameter to try to maximize during training. Peak power represents a single instant in time during the movement, and may not be reflective of the demands of the movement as a whole. There is a low correlation between peak power and the time taken to complete speed repetitions during the squat (4). After a period of training, peak power in a jump squat may increase without a concomitant increase in jump height (7). While there is some evidence to the contrary (3), average power has a high correlation with tasks performed at a high rate of speed and may be more reflective of demands during the entire movement.

Third, the load that produces maximum power may not provide the greatest transfer to tasks that have different load or velocity requirements. Most athletes (with the exception of weightlifters and power lifters) use resistance exercise as a means to an end—improvement in their chosen sport. Power is the product of force and velocity. For some activities, force may be the dominant contributor to power generated; for others, it may be velocity. Since the greatest improvements in power are specific to the resistances used in training (6), the goal of training should not be to maximize power, but to maximize power output at the resistances found in an athlete’s sport. Certain athletes may need to develop power against heavy resistances (e.g., football linemen), whereas others may need to develop power against lighter resistances (e.g., baseball pitchers). And some athletes may need to develop power across a wide spectrum of resistances (e.g., mixed martial artists). Surely, these athletes need to be trained differently.

Fourth, an optimal load for developing power (if one exists) may vary from one person to the next, even if they play the same sport. Improving maximum strength using heavy loads may be the best method for improving power in a relatively weak individual (8), whereas a relatively strong individual may need to switch to more explosive training at lighter resistances to improve power. This information will never be ascertained by examining group mean data resulting from training studies: the “most effective” program is rarely “one size fits all.” Group mean data need to be generalized only to a population that is homogenous with the sample.

In conclusion, there is no compelling scientific evidence to suggest that there is a single, optimal load to develop power. It has been generally accepted for many years that there is no “optimal” load to develop strength. Rather, a variety of training loads should be used in a periodized fashion to elicit superior strength gains. Why should power development be any different?

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