Academy *of* PHYSICAL MEDICINE

Research Paper Review

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Developing Maximal Neuromuscular Power – Training Considerations for Improving Maximal Power Production

Sports Medicine 2011; 41(2): 125.146

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ABSTRACT

This series of reviews focuses on the most important neuromuscular function in many sport performances: the ability to generate maximal muscular power. Part 1, published in an earlier issue of Sports Medicine, focused on the factors that affect maximal power production while part 2 explores the practical application of these findings by reviewing the scientific literature relevant to the development of training programmes that most effectively enhance maximal power production. The ability to generate maximal power during complex motor skills is of paramount importance to successful athletic performance across many sports. A crucial issue faced by scientists and coaches is the development of effective and efficient training programmes that improve maximal power production in dynamic, multi-joint movements. Such training is referred to as 'power training' for the purposes of this review. Although further research is required in order to gain a deeper understanding of the optimal training techniques for maximizing power in complex, sports-specific movements and the precise mechanisms underlying adaptation, several key conclusions can be drawn from this review. First, a fundamental relationship exists between strength and power, which dictates that an individual cannot possess a high level of power without first being relatively strong. Thus, enhancing and maintaining maximal strength is essential when considering the long-term development of power. Second, consideration of movement pattern, load and velocity specificity is essential when designing power training programmes. Ballistic, plyometric and weightlifting exercises can be used effectively as primary exercises within a power training programme that enhances maximal power. The loads applied to these exercises will depend on the specific requirements of each particular sport and the type of movement being trained. The use of ballistic exercises with loads ranging from 0% to 50% of one-repetition maximum (1RM) and/or weightlifting exercises performed with loads ranging from 50% to 90% of 1RM appears to be the most potent loading stimulus for improving maximal power in complex movements. Furthermore, plyometric exercises should involve stretch rates as well as stretch loads that are similar to those encountered in each specific sport and involve little to no external resistance. These loading

conditions allow for superior transfer to performance because they require similar movement velocities to those typically encountered in sport. Third, it is vital to consider the individual athlete's window of adaptation (i.e. the magnitude of potential for improvement) for each neuromuscular factor contributing to maximal power production when developing an effective and efficient power training programme. A training programme that focuses on the least developed factor contributing to maximal power will prompt the greatest neuromuscular adaptations and therefore result in superior performance improvements for that individual. Finally, a key consideration for the long-term development of an athlete's maximal power production capacity is the need for an integration of numerous power training techniques. This integration allows for variation within power meso-/micro-cycles while still maintaining specificity, which is theorized to lead to the greatest long-term improvement in maximal power.

ANALYSIS

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Background Information

Developing maximal power is influenced by a variety of neuromuscular factors, including muscle fiber composition, muscle diameter and length, pennation angle and compliance, just to name a few. Additionally, power can be increased by enhancing neural drive, motor unit recruitment, firing frequency, muscular synchronization and intermuscular coordination. Power is also affected by the time to develop force, storage of potential/elastic energy and the type of muscle contraction utilized (i.e. concentric vs. eccentric). The purpose of this article is to review the relevant scientific literature concerning the development of effective training programs for the purposes of improving power production.

PERTINENT RESULTS

The Role of Strength in Maximal Power

There is a direct correlation between strength and power; meaning that in order to develop maximal power, one must first be sufficiently strong. One of the reasons why this relationship exists is because stronger individuals possess the neuromuscular characteristics that are fundamental in superior maximal power production. After years of training, these strong individuals typically have considerably greater muscular cross-sectional area, pennation angle and fascicle length. Also, neural drive, as well as inter/intra-muscular coordination would be far greater. These characteristics would shift the muscular force-velocity relationship so that any force generated would be greater for any velocity of shortening, and as a result maximal power would be far superior. Thus, training to enhance maximal strength is inherently important in designing training programs to maximize muscular power.

Movement Pattern Specificity

The nature of the movement involved in a sporting task is integral in the ability to generate maximal power. Thus, the exercises chosen in a power-training program may influence the degree of performance improvement.

Traditional Resistance Training Exercise

Exercises where load is decelerated towards the end of a range of motion, such as a squat or a bench press, are inherent in traditional resistance training exercise. Research has shown that during the bench press, deceleration has been reported to last for 23% of the total duration of a one-repetition max (1RM) test. This figure can be increased to 52% of the duration of the test when the load is reduced to 80% of 1RM. Thus, if light loads are lifted rapidly, the added deceleration component integrated into the movement results in movement velocities that are slower than would be expected in sport-specific movements such as jumping or throwing. Also, the deceleration phase is associated with a decrease in muscle activation of the agonist muscles (prime movers) and possibly an increase in the activation of the antagonist muscles to decelerate towards the end of the movement. This results in a reduction in the transfer of the exercise to the training effect desired (i.e. an increase in performance).

However, traditional resistance training exercises have been proven to successfully improve maximal power output in sports-specific movement, despite the reduction of resultant desired training effect. This mode of training has shown an increase in power output in untrained subjects with low-to-moderate strength levels and potentially, in elite athletes who specialize in endurance events. This is because these exercises result in an increase in cross-sectional area of muscle and neural drive – the two major physiologic means of increasing power and strength.

Ballistic exercises

Exercises such as the jump squat and bench press throw require the athlete to accelerate throughout the entire range of motion and do not incorporate the deceleration phase that is seen in the traditional resistance training exercises. These exercises are most often performed using a variety of loading conditions, from 0-80% of 1RM. As a result of the huge acceleration required, range of motion, velocity, force, power and muscle activation are greater during ballistic movements in comparison to traditional exercises. As a result, many coaches and trainers incorporate this style of training into training regimens in hopes of demonstrating a significant improvement in maximal power output during a variety of sporting tasks. The precise mechanisms behind this are not well understood; however it is theorized that this type of training creates adaptations in neural drive and the rate of neural adaptation in addition to inter-muscular coordination that more closely resemble sport movements. These adaptations likely create a greater rate of force development, leading to higher power outputs in shorter periods of time.

Plyometrics

These exercises are characterized by incredibly rapid muscular stretch-shorten cycles. Exercises such as medicine ball throws, push ups, hopping and jumping, or variations therein, are categorized as plyometrics. These differ from ballistic exercises, in so much as they utilize little to no external resistance. Also, increasing the muscular challenge is accomplished via decreasing the stretch shortening cycle and/or the stretch load (i.e. increasing the height while performing box jumps). These exercises can be designed to train movements that are shorter in duration and require a shorter stretch-shorten cycle (ie. a sprint) or movements that are longer in duration, which require a longer stretch-shorten cycle (i.e. throwing or countermovement jump). This adaptability makes plyometric exercises specific to a variety of sport-specific movements and functions to improve maximal power output.

Weightlifting Exercises

Exercises such as the snatch, clean and jerk and their variations are commonly utilized in power training programs. These require the athlete to accelerate through the entire lift, causing projection of the barbell, or sometimes the body, into the air. However, these exercises do require some deceleration at the end of the lift. Incorporation of these exercises has the potential to facilitate greater power output and entrainment of motor patterns that are similar to sport tasks (such as jumping or sprinting). However, few articles exist in the primary literature on the efficiency of power training weightlifting exercises. Because weightlifting exercises can improve maximal output against heavy loads, these exercises are ideal for those who are required to produce high velocities against heavy loads (ie. wrestlers, rugby, football linemen).

Load Specificity

The ability to generate maximal force is also dependant on the load applied to the movement. Power output will change as the load required to accelerate during the movement changes. The current literature shows that a range of loading conditions elicit improvements in maximal power output.

Heavy loads

Training with heavy loads (greater than or equal to 80% of 1RM) can improve maximal power output. This is because strength increases associated with lifting heavy loads are correlated with increases in power output. Additionally, the high-threshold motor units which innervate type 2 muscle fibres (those responsible for power movements) are only utilized while performing exercises that require near maximal force output. This relationship is particularly pronounced in weaker individuals, while in strong and experienced athletes, the magnitude of the change in power output is much smaller. While more research is required to determine the exact mechanism of performance improvements, this type of training is considered ideal for athletes who require high power outputs against heavy loads.

Light loads

Ballistic and/or plyometric exercises performed with loads ranging from 0-60% of 1 RM are often used in power training programs. These loads permit individuals to train at velocities which are similar to those used in sporting tasks, which can result in an increase in maximal power output. In fact, the performance of ballistic or plyometric exercises with light loads will result in the increase in maximal power output during sport specific movements. It has also been shown that maximal power tends to improve to a greater degree while utilizing light loads compared to heavier loads. It is recommended that athletes who are required to generate high power outputs while performing fast movements against low external loads utilize lighter loads while training. There is one caveat: the use of lighter loads while performing traditional resistance training exercises is not recommended, because that type of training does not provide an adequate enough force and velocity stimuli for adaptation.

The Optimal Load

This is defined in primary literature as the load that results in the maximal power production while performing a specific movement. The results should be most pronounced at the load utilized while training. Maximal power is ascertained at approximately 30% of 1RM in single-joint movements.

However, in multi-joint, sport-specific movements, the load that maximizes power varies depending on the type of movement performed, the strength level and training history of the athlete. While some research has shown that the optimal load occurs at a higher absolute load in individuals with greater maximal strength, this concept is argued extensively in the literature – this trend may not actually be true. However, the optimal load which provides the unique stimulus resulting in the most optimal power adaptations is theorized to be due to the increased rate of neural activation. It is hypothesized that power training using these optimal loads that are detailed in the primary literature are a potent stimulus for improving maximal power outputs in specific movements.

Velocity Specificity

Adaptations are hypothesized to be maximized at speeds used during training. Another theory exists in which training adaptations are thought to be more greatly influenced by the intention to move explosive, despite the actual movement velocity. Thus, development of the most effective power training programs must include actual and intended movement velocity during exercise.

Actual movement velocity

Some research exists which found a velocity-specific response to training, with isokinetic exercise. This body of literature shows that high-velocity training produces greater improvement in force and power at high movement velocities. On the other hand, training with low velocity shows increased force and power at low movement velocities.

Intention to move explosively

One investigation has shown that training with high velocity movements is not necessary to elicit a high velocity-specific improvement in performance. Improvements are driven by the high rate of neural activation and rate of force development required to produce such powerful contractions regardless of the resultant isometric or dynamic movement. However, these findings have not been replicated in another study. We should also consider that the majority of primary literature on velocity and its relationship with power indicates that velocity-specific improvements in maximal power are likely to be more suitably elicited by the actual velocity used during training. The authors recommend that athletes should incorporate loads that allow for similar movement velocities that are encountered in their sport and movement velocities that allow them to be as explosive as possible.

Integration of Power Training Modalities

Periodizing workouts involves the use of scheduling and cycling of intensity, volume and specificity of strength training to achieve specific program goals. This type of training is theorized to work because the body is constantly bombarded with new stressors. This allows the athletes to continuously adapt to training without becoming exhausted. The integration of hypertrophy training, basic strength and power training are commonly used to elicit the greatest long term improvements in maximal strength and sport performance. For instance, one cycle can involve the use of traditional resistance training with heavy loads to develop strength at slow velocities. Then ballistic training with light loads can be implemented to enhance high-velocity strength. After that, plyometric exercises can be utilized to improve the stretch shortening cycle performance and sport-specific technique. However, it is imperative that the design of the periodized program target different components of the athlete's sport, while taking the overall demands of the activity into consideration.

CLINICAL APPLICATION & CONCLUSIONS

- The maintenance of high maximal strength is important in the development of maximal power output (1,3)
- Traditional resistance exercises using heavy loads are important components in an athlete's training program (1)
- Power training must involve movement patterns, loads and velocities that are specific to the sport (4)
- Plyometric, ballistic and weightlifting exercises are multi-joint, dynamic and sport-specific exercises that can be used within power training programs to develop maximal power output (2,3).
- Ballistic exercises utilizing loads ranging from 0-50% of 1RM and/or weightlifting exercises using 50-90% 1RM appears to be the most adequate loading stimulus for increasing maximal power in complex movements.
- Plyometric exercises should be designed utilizing stretch shortening cycles that are similar to those featured in sport-specific movements and should offer little-to-no external resistance.
- Integrating a number of power training techniques is essential because it allows for variation in training while maintaining sport specificity. These techniques lead to the greatest long term improvement in power output (5).

STUDY METHODS

The authors utilized three databases to search for relative literature: PubMed, MEDLINE and SportDiscus. They used a number of textwords and MeSH terms, such as 'maximal power', 'muscular power' and 'power training.' Each article's reference list was scanned for additional sources.

STUDY STRENGTHS / WEAKNESSES

Weaknesses

- One of the major limitations of most of the literature surrounding this topic is the fact that the interventions typically represent an isolated mode of training monitored over a short period of time. It may take more time and more than one intervention to succeed optimally.
- A discussion of the different types of periodization training would have been optimal.

Strengths

- A very comprehensive review
- The authors searched a number of databases

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