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Velocity Specificity of Resistance Training: Actual Movement Velocity Versus Intention to Move Explosively

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summary

This article explores the question, which is more important in determining velocity-specific responses to resistance training: actual movement velocity or intention to move explosively?

Introduction

Velocity specificity is an important consideration when designing resistance training programs. It indicates that training adaptations (e.g., increased strength/power) are greatest at or near the training velocity (7, 17, 26). However, there exists a conflicting hypothesis that the intention to move a barbell, one's own body, or any other object explosively is more important than the actual movement velocity in determining velocity-specific responses of the neuromuscular system to resistance training (1). In other words, it is possible to improve high-velocity strength by attempting rapid movements against heavy loads, although the actual movement velocity is slow or even isometric. Such conflicting suggestions have led to a controversy among strength and conditioning (S&C) professionals and sports scientists. The question is, "Which is more important in determining velocity-specific responses to resistance training: actual movement velocity or intention to move explosively?" The answer to this question would dictate the appropriate selection of training loads and therefore is of great interest to S&C professionals. The purpose of this article is to review the research findings that this controversy is based upon and present the implications for the appropriate selection of training loads for high-velocity strength/power development.

Velocity Specificity

The training principle of specificity is an important consideration when designing resistance training programs. It is well known that different resistance training programs elicit different neuromuscular adaptations that are specific to the type of stimuli applied to the neuromuscular system in terms of muscle action type, movement pattern, magnitude and rate of force production, velocity of movement, and range of movement (27, 28). Velocity specificity is one such principle and indicates that training-induced adaptations (e.g., increased strength/power) are maximized at or near the velocity of training (2).

The majority of the past research on the topic of velocity specificity has been conducted with the use of an isokinetic dynamometer for both training and testing (6, 7, 17, 22). Results of such isokinetic research generally agree that high-velocity training elicits greater increases in strength/power at high-movement velocity than at low-movement velocity, whereas low-velocity training develops strength/power substantially at low-movement velocity with little effects on high-velocity strength/power, indicating the velocity-specific adaptations to isokinetic training (6, 17, 22). On the other hand, it appears that isokinetic training also causes increases in strength/power above and below the training velocity, although they diminish as the testing velocity deviates from the velocity of training (7, 20, 22).

Because isokinetic muscle actions are considered to be less specific to actual sport movements that typically involve acceleration and deceleration (i.e., changes in velocity), the practical application of the results from isokinetic research is somewhat questionable (9, 19). In terms of the external validity, isoinertial (i.e., constant mass) loading appears more specific to actual sport movements and would be more applicable (9). In isoinertial training with a given movement, the actual movement velocity is determined by the impulse applied by the musculoskeletal system and the magnitude of the external load, provided that the intention is to accelerate the load with maximum dynamic effort (21). Kaneko et al. (18), for example, found load-controlled velocity-specific adaptations in the elbow flexors with training loads of 0, 30, 60, and 100% of the isometric maximum voluntary contraction (MVC) force such that training with heavy load (100% MVC) mainly improved the high-force portion of the force-velocity curve, whereas training with light load (0% MVC) largely influenced the high-velocity portion. Moss et al. (23) showed similar velocity-specific responses of elbow flexors to isoinertial training with loads of 15, 35, and 90% of one repetition maximum (1RM), except that training with heavy load (90% 1RM) also improved power outputs at lighter loads (e.g., 15% 1RM). On the contrary, McBride et al. (21) and Jones et al. (16) reported a lack of apparent velocity specificity, so that peak velocity and peak power increased over a range of loads by training with light loads, whereas peak force increased over a range of loads by training with heavy loads. Therefore, it seems that the classic theory of velocity specificity supported by isokinetic research does not always hold true with isoinertial training. More research is necessary to elucidate the effects of isoinertial training methods on velocity-specific adaptations and in particular the relative contribution of neural versus muscular adaptations.

Intention to Move Explosively

The concept of the intention to move explosively being more important than the actual movement velocity became widely known among S&C professionals and sports scientists after publication of an article by Behm and Sale (1), which is one of the most cited research articles on this topic. In this study, male and female physical education students trained both of their legs unilaterally in order to investigate the effects of different resistance training modes on velocity-specific responses of ankle dorsiflexor muscles. The foot of one leg was restrained so the ensuing muscle actions were isometric, while the foot of the other leg was subjected to isokinetic concentric muscle actions at 5.23 $rad \cdot s^{-1}$. Subjects were instructed to attempt to move as rapidly as possible with both legs so that the neural intent to make rapid movements was the same with both legs but the actual movement velocities differed. The results of the study indicated that both isometric-trained and isokinetic-trained legs showed similar high-velocity–specific responses when tested on an isokinetic dynamometer at various joint angular velocities (0–5.23 $rad \cdot s^{-1}$). Thus, training-induced increases in dorsiflexion torques were greatest at the highest velocity tested and were progressively smaller at lower velocities for both legs. Additionally, similar training adaptations were found between both legs in voluntary as well as evoked isometric force-time curve characteristics. The authors concluded that the principal stimuli for the high-velocity-specific responses to resistance training are the intention to move explosively and the subsequent high rate of force development (RFD) and that the external load and the actual movement velocity are less important. They further suggested that attempting to move a heavy load quickly may be the best method to improve high-velocity strength performance because the use of heavy load allows higher force production.

Such a suggestion is in contrast to the classic theory of velocity specificity, which indicates that it is necessary to perform explosive resistance training with light loads and at high movement velocity to improve high-velocity strength/power performance (14, 18, 27). Such contradictory claims have created confusion regarding which training loads are best for high-velocity strength/power adaptations and dynamic performance enhancement. The following section examines the opinions, research evidence, and possible underlying mechanisms that support each school of thought and attempts to clarify a controversy over "actual movement velocity versus intention to move explosively."

Which Is More Important: Actual Movement Velocity or Intention to Move Explosively?

Before comparing two different schools of thought, it might be appropriate to state that the intention to move explosively at a given load is important regardless of the training loads used. Fielding et al. (13) compared two different training groups, both of which trained at 70% 1RM, but one group emphasized the intention to move explosively (fast training), while the other group completed repetitions in a slow, controlled manner (slow training). They found that the fast training group increased muscular power significantly more than the slow training group, although increases in maximum strength were similar for both groups. Additionally, Young and Bilby (30) found a trend that the training group that emphasized the intention to move explosively (fast group) achieved a greater improvement in fast force production (i.e., maximum RFD) than the other training group, which emphasized slow, controlled movements (slow group). Both groups used the same relative training intensities (8–12RM), and thus the actual movement velocity/power of training was higher for the fast group than for the slow group. The results of these studies indicate that when using the same relative training loads, training with the intention to move explosively is superior to training with slow, controlled movements in terms of development of explosive strength and fast-velocity strength/power. Therefore, the following discussion will focus on whether the intention to move explosively by itself is enough of a stimulus to elicit high-velocity strength/power adaptations or whether the actual movement velocity controlled by external loads also contributes to consequent neuromuscular adaptations as an important stimulus.

During a resistance training program, training stimuli trigger certain neuromuscular adaptations, which can then manifest themselves in increased strength and power (Figure). Behm and Sale (1) suggested that the principal stimuli that elicit high-velocity-specific training adaptations are (a) the motor command and characteristic motor unit activation pattern associated with the intention to move explosively and (b) the high RFD of ensuing muscle actions. Behm and Sale (1) purported that if training includes the intention to move explosively, the stimuli are the same regardless of the subsequent movement type or velocity because rapid ballistic movements are preprogrammed so that new motor commands or proprioceptive feedback from sensory organs cannot modify the motor unit discharge (2, 11). On the basis of such contention and their research results, which showed similar responses between isokinetic- and isometric-trained legs, Behm and Sale (1) concluded that actual movement velocity or actual muscle shortening does not provide a crucial stimulus to high-velocity-specific responses of the neuromuscular system.

However, there exists contrary research evidence to indicate that the actual movement velocity could also influence the velocity-specific responses to resistance training. For example, McBride et al. (21) investigated the effects of training with either heavy- (80% 1RM) or light-load (30% 1RM) jump squats, both with the intention to move explosively, and found that training responses were different between the training groups. Light-load training increased peak velocity, peak power, and jump heights during the jump-squat test against light load (30% 1RM), while heavy-load training did not. Similarly, Kaneko et al. (18) found that training elbow flexor muscles with various loads, all with the intention to move explosively, elicited different neuromuscular adaptations as previously described. Because these training studies both emphasized the intention to move explosively regardless of the training loads used, different training adaptations found between training conditions should be due to different training loads used and thus the actual velocities of training. Therefore, the findings of McBride et al. (21) and Kaneko et al. (18) provide evidence that the actual movement velocity during training could play a significant role in determining velocity-specific responses to resistance training. In other words, training with light loads with the intention to move explosively would provide different training stimuli and elicit different training adaptations than training with heavy loads with the similar intention to move explosively. However, it is still unclear whether training at heavy or light loads would provide the greatest transfer of adaptation to actual sports performance.

The research of Duchateau and Hainaut (12) may help to explain these apparent contradictions. They removed the confounding variable of neural innervation and only considered contractile changes within the muscle. Subjects completed 12 weeks of training using either voluntary dynamic contractions with a resistance of 30% of MVC or isometric contractions of the adductor pollicis muscle. Both groups were tested using electrically stimulated contractions against 6 loads ranging from 0 to 100% of MVC. The dynamically trained group produced increases in maximum contractile speed (0% load), whereas the isometrically trained group did not, but rather increased velocity in conditions of higher mechanical resistance. Duchateau and Hainaut (12) noted that speed of movement for small loads is essentially related to the rate

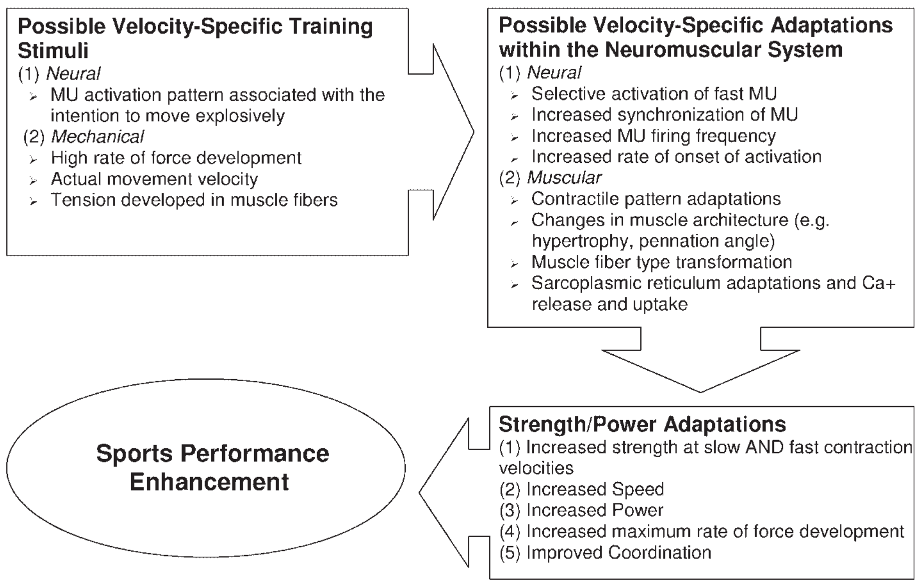

Figure. Process of resistance training and neuromuscular adaptation. MU = motor unit.

of rise of force development (mRFD), whereas for heavy loads it is closely related to maximal force capability. Both types of training were seen to augment muscle power for different loads, but the peak power increase after isometric training was higher than the peak power increase after dynamic training (51 versus 19%). Furthermore, only isometric training shifted the muscle optimal power peak towards heavier loads. Duchateau and Hainaut (12) speculated that the isometric training produced increases in muscle cross-sectional area, resulting in increased maximal force. The dynamic training may have increased myosin ATPase activity and/or calcium release from the sarcoplasmic reticulum. Also, the quantity and/or quality of the sarcoplasmic reticulum may have been improved. Whether the actual shortening velocity of the muscle fiber or the frequency of neural input is the stimulus to these adaptations in force production at specific velocities remains speculative. Clearly both neural and muscular adaptations contribute to the resulting shifts in the force-velocity-power relationship, and the conflicting results of different studies may be more a reflection of training experience. That is, in studies (e.g., Behm and Sale [1]) using subjects with no resistance training experience or a muscle that is not normally resistance trained (e.g., dorsiflexors), the adaptations are predominantly neural and so actual movement speed is of less consequence. However, in studies involving already strength-trained muscles (e.g., McBride et al. [21]), adaptations within the muscle become more important and so training contraction velocity effects are observed. This is clearly a distinction of importance for the preparation of athletes.

There is also evidence supporting movement velocity-specific changes in muscle architecture (3). In as little as 5 weeks, Blazevich et al. (3) demonstrated that when the load used in training is light (e.g., sprint and jump training with body weight only), the fascicle angle decreases pre- to postintervention, which is an architectural adaptation favoring increased speed of muscle shortening. However, in the groups that completed resistance training movements combined with sprinting and jumping training, the fascicle angle increased, which is an architectural adaptation favoring higher force production, possibly at the cost of contraction speed. Interestingly, all participants were instructed to try and move as fast and explosively as possible so the specific changes were stimulated by the actual movement speed used in training and/or the level of tension developed in the muscles.

Velocity-Specific Adaptations and Transfer of Training Effect

Of interest to S&C professionals should be the effects of resistance training programs on sports performance rather than on neuromuscular adaptations. Therefore, in this section, we will review research findings that investigated the effects of training with various loads on sports performance. Wilson et al. (29) found that jump squat training at the load corresponding to about 30% MVC produced significantly greater gains in vertical jump performance compared with heavy squat training (6–10RM). However, this finding was probably more related to the ballistic movement's more closely matching the jumping force- and velocity-time profile compared with squats, in which the latter phase of the movement involves reduced muscle activation, force, and velocity. An explanation of this phenomenon is provided by Newton et al. (25). In an attempt to compare training movements with similar characteristics but differing only in load used, McBride et al. (21) reported that jump squat training with 30% 1RM achieved a borderline increase in short sprint performance, while jump squat training with 80% 1RM significantly decreased sprint performance. Therefore, it seems that light-load training with the intention to move explosively is more effective than heavy-load training in improving sports performance that requires maximum movement speed of athletes. However, when the practice of sport movement is combined with resistance training, training response seems somewhat different and research results are inconsistent.

Bobbert et al. (5) suggested that resistance training should be accompanied by the practice of actual sport movement to take full benefit of training-induced neuromuscular adaptations. It is also more realistic that resistance training is combined with sports practice. Thus, it would provide more meaningful and practical information to S&C professionals to review research findings in which both resistance training and practice of sport movements were incorporated. Cronin et al. (8) compared the effects of upper body resistance training with 80 and 60% 1RM, both with the intention to move rapidly. Explosive netball passes were also performed as sport-specific motion training within the same training session. They found similar improvement in netball throw velocity by both training groups and suggested that the repeated intent to move explosively coupled with practice of sport-specific movement is important regardless of the external loads and movement velocity of resistance training. However, this finding should be viewed with caution because the subjects had no previous weight training history. Blazevich and Jenkins (4) reported similar findings with elite junior sprinters who had previous resistance training experiences. Resistance training at 30–50% 1RM and at 70–90% 1RM, both of which were performed with the intention to move explosively and coupled with sprint running practice, produced significant but similar improvements in sprint performance. On the contrary, Delecluse et al. (10) found high-velocity training with light or no external loads improved 100-m sprint performance significantly more than heavy resistance training when both training groups performed accompanying sprint running workouts. Therefore, there is a lack of consensus as to which is more effective in improving sports performance, light- or heavy-load training both coupled with the intention to move explosively as well as the practicing of sport movements.

There exists another possible implication that training using a range of loads is superior to training with either light or heavy loads alone. Newton et al. (24) showed that ballistic jump squat training against 30, 60, and 80% 1RM improved vertical jump performance of elite volleyball players significantly more than squat and leg press training with 6RM loads. Subjects in both groups also completed the usual on-court volleyball practice, which involved a large volume of jumping activities. Harris et al. (15) support this idea by showing the superiority of a combination of heavy- and light-load training to either training method alone in improving a variety of sports performance in football players. Accordingly, athletes may benefit most from resistance training using a range of loads with the intention to move explosively coupled with practicing of the actual sport movement.

Summary and Practical Application

In summary, we conclude that (a) classic theory of velocity specificity may not necessarily apply to isoinertial training; (b) both the intention to move explosively and the actual movement velocity are important and crucial stimuli that elicit high-velocity-specific neuromuscular adaptations to resistance training; and (c) athletes are recommended to use a range of training loads and attempt to lift a given load as quickly as possible, which should be coupled with the practice of actual sport movements to maximize the transfer of training effect. We also recommend the use of resistance-training movement profiles that maximize the acceleration phase throughout the range of movement and minimize the deceleration phase. Examples of such exercises include weightlifting movements (e.g., clean, power snatch) and ballistic training exercises (e.g., jump squat, bench press throw) (25). ♦

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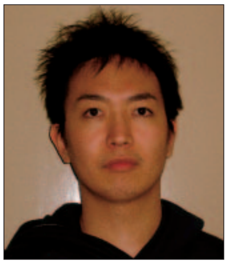

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