Resistance training is widely regarded as an effective supplemental tool to the modern athlete's preparation for competition. With competition growing at all levels of athletics, coaches, athletes, and exercise professionals alike are constantly searching for new and better ways to enhance performance. It has been well established that the repetitive performance of resistive exercises with external loads improves muscular force, production, or strength (4, 5, 8, 11, 13).

But great athletes are not built on strength alone. More recently, resistance-training protocols that address velocity of movement have been developed to enhance muscular power rather than strength. Power is defined as the amount of work done over time, whereas work is the force required to move a load a given distance. As such, power improves with an increase in force production much like strength does; however, power also improves with a decrease in time in which a given amount of work is done. Because velocity is often important in the performance of sport-related skills, power would appear to be a much more applicable measure of potential athletic performance than strength alone.

The regular performance of ballistic, power exercises is now commonplace in many weight rooms. Of the 2 components of power, force and velocity, force is much easier to regulate. Because much of the resistance training that takes place uses free weights, controlling external loads is quick and easy. As such, a great deal of research on muscular power has been performed with the goal of determining the most appropriate load when seeking maximal gains (8, 10, 15, 16). Although these exercises are performed with the intention of moving a given load as fast as possible, actual movement velocities are often far below maximum. This paper will discuss the potential benefits of emphasizing movement velocity rather than load in power training. Rationale is provided for the performance of resistance exercises with high movement velocities as a supplement to be performed as part of a comprehensive resistance-training program.

**Velocity Specificity**

The biggest argument for including high-velocity training in an athlete's resistance-training program deals with the concept of specificity. This concept states resistance-training programs will best produce positive effects on activities or tasks that closely mimic the training that is performed (2, 4, 6, 8, 15). In other words, resistance training undertaken to improve a specific sport should be similar in movement pattern, duration, and intensity to the various movements performed during competition.

This concept holds true with respect to the velocity of training as well. In a recent review by Pereira and Gomes (12), numerous studies involving velocity of movement during resistance training were analyzed. By examining research...
involving isokinetic exercise equipment, which controls for velocity of movement rather than resistance, these authors made it clear that training effects are most prominent at the specific velocity at which a person trains (12). Therefore, training that is undertaken to produce performance gains at the high movement velocities seen during athletics may need to include movements performed at or close to the actual velocities seen during competition.

With this in mind, it may be as appropriate to vary movement speed as it is to vary load when training. Because sports are often performed at a spectrum of different velocities, a comprehensive training program should include appropriate exercises performed at a range of velocities.

**Force-Velocity Relationship**

Before one can have an intimate understanding of power training, one must first examine the relationship of its 2 components. Through studies involving isokinetic exercise, in which velocity of movement was strictly controlled, it has been well established that force and velocity of human movement are inversely related (3, 7, 14). That is, as speed of movement increases, the amount of force one can produce decreases. This relationship can clearly be seen by examining the force-velocity curve in the Figure.

This produces some inherent problems with training at high velocities and may be why resistance training has traditionally been performed toward the slower end of the velocity spectrum. Much of the benefit of resistance training can be attributed to providing the neuromuscular system with an overload stimulus, in which muscles adapt to being required to move under greater loads than those they encounter during everyday activities (9–11, 16). Because movements at high velocities require lower amounts of force compared with movements at low velocities (Figure), it would appear that there is a very different type of muscular overload. In the authors’ opinion, this might result in less muscular hypertrophy.

**Velocity-Specific Adaptations to Exercise**

Although there is low muscular overload in terms of force production with high-velocity exercise, it still may have an appropriate place in a resistance-training program. In fact, the benefits of high-velocity exercise have been reported for many years. As early as 1975, Pipes and Wilmore (13) were able to conclude that high-velocity isokinetic exercise was more effective in producing strength gains than was low-velocity isokinetic or isotonic training. A group of 36 men (age 20–38 years) underwent 8 weeks of resistance training in which they performed bench press, bicep curl, leg press, and bent-over row exercises 3 times a week. Those participants who trained with high-velocity isokinetic movements recorded higher mean strength increases during subsequent testing than did those who trained with low-velocity isokinetic or isotonic movements.

A later study by Wilson et al. (16) also addressed speed of movement during resistance training. Their study was undertaken to determine the optimal training load with which to enhance athletic performance. Participants were tested for gains in various sport-related skills, such as sprinting and jumping, after 10 weeks of resistance training. The authors reported that those participants who performed exercises with relatively light weights at high speeds performed significantly better on posttests than did those who engaged in traditional heavy-load resistance training or those who performed plyometrics.

The participants who trained at high velocities used a load that was one-third of their 1 repetition maximum (1RM). This load was chosen because it is largely agreed upon to be optimal for creating maximal power output during exercise performance (10). In other words, a load of one-third of 1RM is heavy enough to require a significant force output but light enough to be moved at a relatively high velocity. Thus, a combination of moderate loads and high movement speeds yields the most mechanical power. This can be seen clearly when the relationships between force and velocity and between power and velocity are viewed together in the Figure. The peak of the power–velocity curve is seen at relatively high velocity and low load, with respect to given maximums.

Furthermore, Morrissey et al. (11) performed a study in which participants
performed squats with a load of 8RM. Experimental groups differed only in the velocity with which the exercise was performed. After 7 weeks of training, the fast-velocity group showed a greater improvement in standing long-jump distance (44%) than did the group who performed the same exercise at a slower velocity (31%). Because training loads were similar between groups, performance differences were attributed to the actual velocity with which the weight was moved. Hammett and Hey (4) also reported significant improvements in physical performance as a result of increasing movement speed during training. Half of the participants in their study incorporated a ballistic exercise into their regular off-season training program. After 4 weeks of training, participants who engaged in the ballistic training demonstrated significantly greater decreases in 40-yard sprint times than did participants who did not engage in the ballistic training.

Jones et al. (8) agree that there is evidence to support the notion that training effects tend to be velocity specific. Participants in their study performed basic core exercises for 10 weeks with either heavy (70–90% 1RM) or light (40–60% 1RM) loads. Although differences between groups were not reported to be statistically significant, the low-load group presented strong trends toward greater increases in peak power and velocity of movement. Because both groups were attempting to move as quickly as possible, perhaps the actual speed with which the exercise was performed allowed for differences in training effect. Other authors may contend that the lack of statistically significant differences supports a belief that the intention to move a heavy load quickly produces similar training effects as moving a light load quickly.

**Intended Versus Actual Movement Velocity**

Behm and Sale (1) performed a study to determine if actual movement at a high velocity was necessary to produce a velocity-specific training effect. After 16 weeks of training, they concluded that isometric exercise performed with the intention of moving quickly produced similar training effects to exercise actually performed at a high velocity. Therefore, it was reported that attempting to move a heavy load at a high velocity produced significant high-velocity adaptations. Behm and Sale (1) argue that it is the attempt to move quickly, and not the actual velocity of movement, that is responsible for velocity-specific training gains. However, these results may be limited in their applicability to resistance-training programs, as ankle dorsiflexion and plantar flexion were the only joint movements performed. Furthermore, results were reported in terms of strength gains only with no attention given to the ability to produce greater velocity.

McBride et al. (10) were unable to support the findings reported by Behm and Sale (1). Participants in their study performed jump squats with either a heavy (80% 1RM) or light (30% 1RM) load. Both groups were instructed to perform the lifts as quickly as possible. After 8 weeks of training, the low-load group was able to produce significantly higher movement velocities whereas the high-load group was not. These results indicate that the actual velocity of training is important when the goal of training is to be able to produce faster movements.

**Increasing Acceleration of Movement**

The benefits of high-velocity exercise may also have to do with the body’s ability to reach top speed rather than its ability to produce greater force. Brown and Whitehurst (2) recently determined that high-velocity training improves one’s ability to reach a given velocity of movement more quickly. These authors had 2 groups of participants train at either a fast or slow velocity. After just 2 days of training, participants were able to decrease the rate at which they were able to achieve their training velocity. In other words, a significant neural adaptation occurred in the fast-training group, which allowed them to accelerate to their desired speed more quickly. These findings may have particular applications to athletic activities that require speed, agility, and quickness. If we can train a muscle to achieve a faster limb movement more quickly, perhaps we can train athletes to have faster movements during competition.

**Program Ideas**

It is clear to see from the power–velocity curve that peak power is achieved at approximately one-third of peak force (7) (Figure). Thus, it is thought that training with a load near 30% of 1RM will produce the greatest gains in muscular power (10, 11, 16). It is also clear when examining the Figure that the peak of the power–velocity curve occurs near one-third of peak velocity as well. Therefore, if the goal of resistance training is to improve high-velocity activities, an athlete may be better served by training at a velocity higher than one-third of his or her peak. Perhaps training at the high-velocity end of the power–velocity curve would allow for a shift of the peak upward and to the right. Then, the athlete would be able to produce more muscular power at velocities closer to those of the movements seen during competition.

This is not to say that resistance training performed at slow velocities trains athletes to be slow and should be eliminated all together. In contrast, improved muscular strength should continue to be the stable base on which any resistance-training pyramid is built. The idea here is to begin to get exercise professionals to think of movement velocity as an appropriate marker in which to gauge exercise performance rather than to strictly look at load.
The difficulty lies in that without the use of sophisticated computerized equipment, exercise velocity is very hard to set constant. Furthermore, each athlete possesses his or her own maximum velocity for a given movement. Therefore, it may not be as important to know precisely how fast an exercise is performed but rather that it is being performed as quickly as possible. Qualitatively, each athlete should perform the given exercise with maximal velocity. It may be pertinent to create a volume scheme that utilizes a set load lifted multiple times at or near peak velocity. Because attaining high velocity of movement would be the goal, very low percentages of RM (<30% 1RM) would need to be used. Table 1 provides a proposed high-velocity workout in which movements would be performed at each individual’s peak velocity.

A final problem lies in the prescription of an actual exercise volume. The effects of high-velocity exercise have been studied in detail, but currently there is no consensus in the literature regarding appropriate training volume (12). In theory, high-velocity exercise may be likened to high-intensity, heavy-load exercise with the goal of recruiting primarily type 2 muscle fibers. Instead of performing at the end range of a given athlete’s force spectrum, though, exercise is performed at the end range of the athlete’s velocity spectrum. High-velocity exercise may require fewer repetitions per set and more rest between sets in order to be effective.

Periodization

High-velocity exercise may have an appropriate place in a periodized resistance-training program designed for athletes who require speed and quickness. Attempting to make gains in these areas just before the onset of a competition phase may help these athletes achieve peak performance. For instance, incorporating 1 or 2 “speed” days during a strength and power microcycle, in which athletes performed power, core, and some assistance exercises with low loads and very high velocities, might help produce limb movement that reaches peak velocity more quickly. Table 2 provides a sample strength and power microcycle, which includes high-velocity days. If this microcycle were placed just before an athlete’s competition phase, it might help create a peak in speed and quickness.

Conclusion

Resistance training has become one of the modern athlete’s primary tools with which to prepare for competition. Exercise professionals are constantly in search of new and different training stimuli to enhance performance. Applying attention to the velocity of exercise performed in addition to the load may be a way to promote gains in speed and quickness. Exercise performed in the highest ranges of an athlete’s velocity spectrum may not produce significant muscular overload but may instead improve his or her ability to increase movement velocity and reach this velocity more quickly. With this in mind, exercise in which velocity of movement is kept near its peak may be appropriate to include just before the competition phase for athletes who require speed and quickness more so than shear strength. All resistance-training models should be predicated on the foundation of improving muscular strength. However, the inclusion of velocity-specific exercises may be appropriate when further sport specificity is desired.

References

2. BROWN, L.E., AND M. WHITEHURST. The effect of short-term isokinetic training on force and rate of velocity

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