Training for Speed/Strength: Heavy vs. Light Loads

Warren Young
Sport Science and Sports Medicine Center
Australian Institute of Sport
Belconnen, Australia

Explosive movements are required in many sports and are typically performed at high speeds against resistance, such as the weight and inertia of the body or equipment. In these sports, the explosiveness or rate at which force can be applied may be more important than maximum force production capability (maximum strength) (65). The optimum resistance training method for developing fast force production is not as readily accepted. Coaches are faced with practical questions such as:

- How much resistance (load) should be used?
- How important is the speed of movement in resistance training?
- How important is it to simulate sports movements with resistance training exercises?

These questions will be answered by examining the arguments and research findings in support of methods that utilize light loads/fast movements and methods involving heavy loads.

Terminology

The explosiveness of the muscular actions produced in many athletic movements is often described as power. The formula for power is:

\[
\text{Work} = \text{Time} \times \text{Force} \times \text{Velocity}
\]

Speed/strength - a general term commonly used in Europe - will be used throughout this article. Speed/strength describes any capacity that contains both a force (strength) and speed component to the muscular actions. A distinction between speed of movement and speed of contraction will help clarify the term speed/strength. A muscle contraction can be defined as the state of a muscle when tension is generated across a number of actin and myosin filaments (36). Therefore, contraction speed is dependent on the rate of tension development, not the speed of external movement. In fact, an isometric contraction (zero movement speed) can be performed fast or explosively with maximum voluntary effort. Speed/strength encompasses all qualities related to fast-force production of a muscular action or contraction, both dynamic and static. The mechanical definition of power can be thought of as one specific form of speed/strength. In addition to power, speed/strength may also include:

1. Explosive strength. The maximum rate of force development (RFD) achieved in an explosive contraction (54).
2. Starting strength. The force achieved early in the contraction, e.g. the initial 30 milliseconds (61), and is considered to be important for accelerating light resistances.
3. Reactive strength. The ability to utilize the muscle pre-stretch in a stretch-shortening cycle (SSC) movement (54), and to quickly switch from an eccentric (stretching) contraction to a concentric (shortening) contraction (47).

Values for maximum, explosive and starting strength are identified from a force-time curve obtained from a maximum effort isometric contraction, and are indicated in Figure 1.

It may be difficult to accept that measurements from a static or isometric

Figure 1. Isometric force-time curve indicating maximum, explosive and starting strength.
contraction can describe speed/strength or explosiveness as it relates to athletic performance. However, Stoelhart (59) reported significant correlation coefficients of 0.74 to 0.82 between static and dynamic RFD with various loads during elbow flexion. Using an arm extension movement, Mueller and Buehrle (43) reported a close relationship (r = 0.83) between isometric and concentric RFD with a light load (4.30 kg), and concluded that isometric strength characteristics can be used as reliable predictors for performance of concentric contractions. Examination of muscle activation patterns (44) showed no difference between explosive isometric and fast ballistic concentric contractions. Studies (60, 64) have reported significant correlations between isometric RFD and athletic performance.

There are two approaches to this issue: one favors the use of light loads and corresponding fast movements, while the second emphasizes heavy loads. However, for the purposes of this paper, a light load is defined as 60 percent of the one repetition maximum (1 RM) or less, and a heavy load is 80 percent or more of the 1 RM.

**Light Loads/Fast Movements**

A discussion of light loads and fast movements was summarized in 1976 by swimming coach James Councilman. “For an exercise to have a beneficial effect on the speed at which the muscle can contract, it must be done at fast speed” (10). He argued that only fast movements activate the fast twitch muscle fibers (which possess greater force and speed capabilities), and heavy weights moved slowly recruit only slow twitch fibers (which have slower contraction characteristics). Recently, Michael Yessis, editor of Soviets Sports Review, added that training using 1 to 4 repetitions with heavy weights “...develops slowness, not quickness and speed” (67). Sale (51) also acknowledged that “...it is possible that a neural adaptation to high velocity training consists of an accentuation of the preferential activation of fast twitch motor units.”

Another theoretical basis in favor of light loads is based on recordings of human mechanical power output. It has been shown that maximum power output is achieved with a load of approximately one third of maximum isometric strength (15). Based on this, it has been argued that light loads that can be rapidly moved should be emphasized for power development (48). Hatfield (30) used a similar argument to use a load of 55 percent 1 RM for “ballistic training,” and claimed that loads greater than 80 percent 1 RM develop strength, not power (29).

**Research Evidence**

Much of the research evidence in favor of light loads is based on studies that required subjects to train on isokinetic (constant movement speed) devices either at relatively fast or slow speed. Six weeks of slow training at 36 deg/s (40) and seven weeks of training at 180 deg/s (38) resulted in significant gains in peak torque at or below the training speeds. No “transfer” of force generating ability was found at speeds greater than the training speed. Several studies (8, 16, 31, 46) have reported a velocity specificity effect of isokinetic training. Therefore, the greatest gains in peak torque or power occurred at or near the training speeds, and little transfer to other speeds was experienced. In a recent review of the research on velocity-controlled resistance training, Bell and Wenger (5) concluded that maximum increases in peak torque predominated the velocity used during training. These results imply that in order to best develop speed/strength qualities, it is necessary to train at high movement speeds.

Other studies have utilized various ways of observing strength gains at different speeds. For example, Hakkinen and Komi (11, 21) measured squat and countermovement jump heights (which are dependent on velocity of takeoff) with various loads on the back. Heavy resistance training produced modest gains in squat-jump height with no extra load (7 percent), compared to a 27 percent improvement with 100 kg loads, and failed to significantly increase maximum knee angular velocity (21). In contrast, explosive training with light resistances produced an improvement in squat-jump height (unloaded) of 21 percent and also produced a significant gain in maximum knee extension velocity (22).

Another way of evaluating different training methods is to compare fast or dynamic resistance training to the slowest possible method — isometric training where movement speed equals zero. For example, three months of training either dynamically with a load of about one third maximum strength or isometrically revealed greater gains in maximum force production from isometric training, but greater improvements in contraction speed from the dynamic program (13, 19). An isometric training study conducted by deKoning et al. (11) revealed that although maximum force production increased significantly and velocity increased with relatively heavy loads, maximum movement velocity and power did not significantly improve.

**Force-Time Curve**

A number of researchers have investigated the effects of strength training by examining changes in the isometric force-time curve (Figure 1). Subjects are instructed to apply a force as hard and fast as possible so that measures of strength and speed/strength can be obtained. Squat training with heavy loads (70 to 120 percent 1 RM) has been shown to induce significant improvements in squatting (20, 21) and maximum isometric strength (20, 23, 25). However, it failed to produce significant improvements in the isometric maximum rate of force production (23), or the time to various relative force levels (20, 23, 25). In contrast, jumping training with comparatively light resistances has been found to produce smaller gains in isometric strength (25), but significant gains in many speed/strength qualities as measured from the force-time curve (24, 25). In summarizing research findings, Hakkinen (26) stated that heavy resistance strength training with high loads and “slow
contraction velocities" leads to improvements primarily in maximum strength, and is demonstrated by specific shifts in the high force portions of the force-time curve. However, Hakkinen argued that power training that utilized high contraction velocities and low loads produces changes in the early parts of the force-time curve which is vital for sports involving short contraction times.

The primary issue for coaches examining research findings is the effect of resistance training on sport-specific activities or measures of performance. A number of researchers have adopted this approach. For example, vertical jumping ability is important for many sports and is often used as a general indicator of speed/strength of the leg extensors. The vertical jump has been tested with a preliminary dip or countermovement (CMJ), from a static squat position (SJ), and following a drop from various heights (DJ). Both CMJ and DJ involve muscle pre-stretching and can be considered tests of reactive strength. Table 1 indicates that jumping training involving light resistances (22) produced greater improvements in all the vertical jump tests than heavy squat training (21).

**Heavy Loads**

Some evidence on the effectiveness of heavy load training for speed/strength is anecdotal in nature. For example, some Olympic weightlifters have produced excellent results in vertical and horizontal jumps (28), and many strength athletes, such as weightlifters and shotputters are so outstanding in short sprints that they could beat world class sprinters (30).

Some of the following points are actually counter-arguments against the benefits of light load methods, rather than direct evidence for heavy loads. As mentioned earlier, an argument for light loads/fast movements is based on a belief in preferential recruitment of fast motor units. In opposition to this view, Tidow (61) and Young (68) suggest that heavy loads may be at least as effective as light loads for stimulating fast motor unit activity. The rationale underlying this claim is based on motor unit activation (MUA) patterns. The fiber type activated in a muscular contraction depends on the force of contraction. Slow motor units are recruited for low force contractions and as the force required increases, fast motor units become active as well (50). Therefore, it is logical to expect that activation of the fastest high threshold motor units may require the use of high loads since only heavy loads guarantee a maximum voluntary contraction (55).

Although there are contradictions to this principle (12), an extensive review of the subject (51) concluded that the majority of evidence from human studies indicated that in high velocity contractions the recruitment order of slow and fast motor units is not reversed, and there is no selective activation of fast motor units in high speed activities. Therefore, both fast and slow motor units are active during maximum high resistance training, regardless of the speed of movement (18). As a result of these findings, Young (68) advised coaches not to feel compelled to use light loads exclusively for fast movements in an attempt to develop speed/strength.

**Power Output**

Light loads were recommended earlier, based on the premise that they allow the generation of maximum mechanical power output. A case against this argument is that mechanical power (force x velocity) output is not necessarily the most crucial strength quality for successful performance in many sports. It must be remembered that mechanical power is only one specific form of speed/strength and that forms defined earlier may be of equal or greater importance. Coaches must identify the specific speed/strength requirements of their sport and then devise the most appropriate resistance training methods. For example, in the long, triple and high jump events, take-off ability is vital, and is strongly influenced by reactive strength and explosive strength (64). Therefore, speed/strength methods targeted at these qualities (plyometrics) may be more appropriate than attempting to specifically target development of maximum mechanical power capabilities.

Another argument against low load training is that "...there are several strategies available" to move these loads (62). This means it is possible to produce submaximum efforts if the athlete is not motivated appropriately. The use of heavy loads compels the athlete to achieve maximum voluntary activation (61). For example, a sub-maximum effort cannot be produced when attempting to lift a load of 90 to 100 percent 1 RM.

As mentioned earlier, isokinetic training effects have been found to be greatest near the speeds of movement used in training. Caiozzo et al. (8) reported that fast training at 240 deg/s produced significant gains in peak torque only at 145 to 240 deg/s, but not at speeds of 0 to 240 deg/s. However, slow training at 96 deg/s induced significant improvements at a wide range of speeds from 0 to 240 deg/s. The improvement at 240 deg/s was 8.8 percent for the 250 deg/s training group and 5.5 percent for the 96 deg/s training group. This suggests that relatively slow training can produce a significant transfer to faster speeds. Other isokinetic training studies (4, 17, 62) have also reported a lack of velocity specificity. Kanelisa and Miyashita (32) reported that a slow (60 deg/s) training group improved power at a wide range of testing speeds, whereas a fast training group (300 deg/s) showed no improvement at slow speeds. In addition, the biggest absolute improvement

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<th>Table 1. Percent improvement in vertical jumps from light load jump and heavy load squat methods (Hakkinen and Komi, 21, 22).</th>
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<td><strong>Vertical Jumps</strong></td>
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**Table 1.** Percent improvement in vertical jumps from light load jump and heavy load squat methods (Hakkinen and Komi, 21, 22).
in power at any speed was obtained by the slow training group. If slow isokinetic training can be equaled with heavy load strength training, there would be substantial evidence that this training method can improve force production capabilities at relatively high movement speeds.

Isometric (constant joint angle) training can be considered as an extreme type of heavy loading since maximum force production can be even greater than that produced in a dynamic 1 RM lift. Since the resistance is immovable, movement speed is zero. Due to this static nature, it is often denied that isometric training can produce improvements in fast force production (41). Some studies have examined the effects of isometric and various combinations of isometric and dynamic training on strength qualities. Kaneko et al. (33) compared four loading methods of training the elbow flexors: zero load (unresisted), 30 percent of maximum voluntary contraction (MVC), 60 percent and a 100 percent MVC load (isometric). As expected, the biggest improvements in movement speed were demonstrated by the unresisted training group, and the best gains in isometric strength came from the isometric training group. However, isometric training also produced a significant increase (10 percent) in movement speed. All groups improved maximum power production and interestingly, the isometric group improved more (22.4 percent) than the unresisted or speed training group (13.8 percent). The fact that the isometric training group obtained a bigger gain in isometric force production (27 percent) than the unresisted or speed training group achieved in maximum movement speed (16.8 percent), suggests that strength may be more trainable than speed. If this is the case, heavy load training can be expected to be more effective than low resistance methods that emphasize speed for development of mechanical power.

The findings of another training study (63) lend support to this notion. In addition, isometric training studies have found significant increases in movement speed (9, 58) as well as superior gains in power development when compared to light dynamic training (13). Analysis of isometric force-time curves has revealed favorable changes in speed/strength as a result of heavy resistance training. A cross-sectional study that compared elite bodybuilders and powerlifters with physically active males and females found the strength trained individuals to be significantly better on maximum rate of force production (49). In addition, although sprinters have been found to possess higher levels of explosive strength of the leg extensors than endurance athletes and powerlifters, the advantage over the powerlifter was not statistically significant (27). Hakkinen et al. (20) also showed that heavy strength training not only increased strength but also significantly decreased the time to reach a force of 2000 N, increased jumping height and produced fast twitch fiber hypertrophy.

One training study directly compared the effects of heavy (90 percent RM), light (45 percent 1 RM) and hypertrophy (70 percent 1 RM) methods (56). A number of variables were analyzed, including the max RFD (explosive strength) and the rate of activation of the muscles, as recorded from electromyography. After 12 weeks of training, the biggest improvements in these speed-strength measures were obtained from the heavy load group. Schmitzlecker (55) explained these findings in terms of neural adaptations. He claimed that although using fast contractions with heavy or light loads involves activation of motor units with high firing rates, only heavy loads involve contractions "long enough to develop a complete mechanical efficiency" for fast motor units. (Behm and Sale (3) offer a recent review of the scientific literature on velocity specificity of resistance training and the associated neuro-muscular mechanisms.)

A number of studies (1, 20, 21) have found heavy squat training to be effective for improving vertical jumping ability. Others (53, 57, 58) have reported that either heavy or isometric training produced significant gains in arm movement speed. When heavy/slow training was compared to light/fast training, gains in movement speed were either similar (9, 35) or superior for the heavy load training (53). A study by Napier (45) investigated the effects of five weeks of strength training incorporating seven exercises on 20m sprinting speed. One group was required to train with sets of 8 repetitions at 40 to 50 percent 1 RM (light) as fast as possible, while another group performed sets of 1 to 3 repetitions at 80 to 90 percent 1 RM.

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<th>Table 2. Proposed advantages and disadvantages of heavy and light load methods for development of speed-strength.</th>
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(heavy). While the training with the heavy loads resulted in a significant improvement in the 20m sprint time, the light/fast training failed to do so. Based on these results, the investigator questioned the apparent emphasis now being placed on light load training by sprint coaches.

Research Findings

Strong arguments can be made for either heavy or light resistance training methods for development of speed/strength. This is unfortunate for the coach or practitioner who is concerned with identifying optimum training methods. Why is it that heavy load training appears to be a superior method for developing speed/strength qualities in one study (56) but light load training yields better results in another study (23)? When attempting to answer this question, remember that the rate of muscular tension development can be independent of the external movement speed. In addition, the maximum rate of force reduction (explosive strength) and motor unit activation in a maximum effort contraction is relatively constant for an individual, and is generally not influenced by the external load or speed of movement (7, 52). Therefore, the assumption that training with heavy loads (producing relatively slow movements) is always associated with slow rates of tension development (37) is incorrect.

This clarification may explain the large gains in speed/strength measures from heavy load training observed by Schmidtbacher and Buhle (56). Both heavy and light load groups were specifically instructed to produce explosive contractions in training. In other studies involving heavy load training that failed to produce impressive gains in speed/strength (23, 25), no instructions were given regarding explosiveness of training efforts. In fact, this heavy training also included some eccentric-only repetitions, which must be performed with slow contractions. Therefore, the main difference between the heavy load methods that produced different effects may have been the speed of rate of tension development. As a result of these observations, it has been argued that a key stimulus for development of speed/strength qualities is the maximum voluntary effort to develop force as fast as possible, not the speed of movement (68). Support for this notion came from a Soviet study which compared different training regimens on strength, speed/strength and speed qualities (39). It was shown that an isometric training group improved in a speed/strength measure by 13.5 percent and in speed by only 0.25 percent. However, another isometric training group required to perform contractions explosively improved in the speed/strength measure by 43.2 percent and in speed by 17 percent. Unfortunately, detailed methods were not described so conclusions can not be confidently drawn from these findings.

Further support for this concept was provided by Behm and Sale (2). Subjects were required to perform 5 sets of 10 repetitions, three times per week for 16 weeks on an ankle dorsiflexion exercise. Subjects were instructed to attempt to produce fast ballistic contractions with both feet. One foot was allowed to move at high speed (300 deg/s) but the other foot was held static so that the contraction was isometric. This design allowed a comparison of fast contractions/fast movements with fast contractions/no movement, with contractions from both sides being a result of the same neural input and lasting about 0.5 seconds. The training produces significant increases in peak torque development, but there were no significant differences between the contraction methods. In other words, both methods were equally effective for development of the speed/strength measures. The investigators concluded that the intent to produce ballistic contractions was responsible for the high velocity-specific training effect, not the speed of movement. They also suggested that an advantage of heavy load training performed with explosive contractions is that it should be effective at inducing hypertrophy of fast motor units.

A mechanism that may explain the value of high load training was offered by Tidow (61). Even though both light and heavy load training with explosive contractions may require a high degree of neural input, the high resistance efforts must result in slower movements and, therefore, a longer duration of muscular tension. The near maximum loadings compel the motor neurons to fire high frequency impulses for comparatively long times. This may be a superior training stimulus for speed/strength development.

A possible conclusion is that speed/strength development may be achieved using heavy loads as well or better than using light loads that rely on speed of movement, when contractions are performed as explosively as possible. A practical consideration for the coach is that ability to produce explosive contractions with heavy loads requires a high degree of concentration, which should be constantly monitored by the coach (69). Also remember that the explosive effort should only be performed during the concentric contraction phase (raising the weight) of a weight training exercise. The eccentric contraction phase (lowering the weight) should always be performed under control to maintain tension in the dipping action in jerking movements (e.g., push press) where a fast descent is desirable to achieve a high rate of muscle pre-stretching. For example, the recommended approach for the bench press is to lower the bar slowly and at the instant of contact with the chest, the explosive effort is made to raise the bar. Contact with the chest can be thought of as a trigger to initiate the explosive effort. The use of weight training with near maximum loads performed explosively involve very high muscular forces. Therefore, beginners are advised to progress with action before attempting such high intensity efforts.

Since both loading methods can produce positive gains in speed/strength, the earlier questions concerning the prescription of training loads are unanswered. However, answers can be found by closely examining some neural
adaptations to strength training, which leads to a model that suggests a way both heavy and light load methods can be integrated into a periodized program.

**Neural Adaptations**

It is well accepted that neural adaptations can account for strength gains when there is minimal hypertrophy (34, 42). Neural factors that influence the force and rate of force production and are trainable can be classified into two categories (70):

1. **Intra-muscular coordination.**
   This is dependent on the extent of motor unit activation within a muscle and is determined by:
   a. Recruitment – the number of active motor units.
   b. Firing rate of motor units — the frequency of impulses that activate the motor unit.
   c. Synchronized motor unit firing – the extent to which motor units fire simultaneously.
   d. Stretch reflex input – e.g. from muscle spindles and golgi tendon organs.

2. **Inter-muscular coordination** – the coordination between muscles and muscle groups (skill) and influenced by such factors as:
   a. Activation of synergists - muscles that work together with the prime mover or agonist (stabilizer, assistant mover).
   b. Co-contraction of antagonists – the extent of antagonistic muscular activity which influences the effect of the prime mover or agonist.

Some potentially desirable neural adaptations to resistance training include improved recruitment, an increased ability to fire motor units at higher rates, increases in motor unit synchronization, increased net excitatory input from stretch reflexes, synergistic activity and decreased co-contraction of antagonist muscles. For sports that require a high level of strength in relation to body weight (relative strength), neural adaptations with minimal weight gain from muscle mass is an advantage (26). Development of intra-muscular coordination indicates an improved ability to activate the available mass of individual muscles. (28).

To achieve a high transfer of training to an athletic movement, the ability to coordinate the individual muscle capabilities (inter-muscular coordination) is vital (70). Therefore, the optimum training effect would involve improvements in both intra- and inter-muscular coordination. A model can now be presented that indicates the neural adaptations that can be expected from heavy and light load training.

**Light Load Training**

Intra-muscular coordination can be developed with either heavy or light load methods, although it has been suggested that heavy loads are superior (56). Unfortunately, when evaluating neural adaptations, it may be impossible to clearly distinguish between the intra- and inter-muscular coordination factors. Nevertheless, since development of inter-muscular coordination is basically skill or coordination training (54), it could only be well trained by the use of exercises specific to the competition movement in terms of both movement speed and pattern. Therefore, with the exception of Olympic weightlifting movements, development of inter-muscular coordination can only be optimized by using relatively light loads that encourage an execution of the skill that is very similar to the competitive skill.

For example, assume a volleyball player is interested in improving vertical jumping ability for blocking. A barbell half squat exercise is specific to the vertical jump in terms of the major muscle groups involved and the range of motion. However, some non-specific aspects of the squat are the lack of ankle plantar flexion (and therefore calf muscle involvement), the lack of an arm swing, the relatively slow movement and the acceleration of the body towards the end of the movement.

While a vertical jump takeoff phase lasts less than 0.5 second, a complete repetition of a half squat can take several seconds. Therefore, while the squat may be an excellent exercise for developing the basic strength and speed-strength qualities of the muscles involved (intra-muscular coordination), the transfer to the skill of vertical jumping (inter-muscular coordination) may be limited. In agreement, a training study involving half squats (72) revealed that an improvement in the 1 RM squat of approximately 20 percent was accompanied by an improvement of less than 10 percent in the vertical jump.

A resistance training exercise that more closely mimics the demands of a vertical jump in volleyball is a jump with added light weights attached to the body, such as a weighted jacket or vest. This exercise involves the calf muscles as well as the leg extensors, allows an arm swing and a similar movement speed to the competition skill. Therefore, improvement in jumping ability from this exercise may be due to improvement in inter-muscular coordination. A general exercise for the leg muscles using a heavy load is relatively

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*Table 3. Periodization of strength training incorporating the use of heavy and light load methods (modified from Bompa, (6)).*
more effective for development of intra-muscular coordination than inter-muscular coordination, whereas the reverse may be the case for vertical jumping with a weighted jacket.

Adding light weights to equipment is one way of achieving maximum specificity of training exercises. Examples are weighted golf clubs, bats, throwing implements and weighted sleds and tires for resisted sprinting. Movements should be performed as explosive contractions rather than simply executing the sport. Care must be taken with this approach to avoid using excessive loads that prevent proper execution of the movement pattern or skill. Too much training with an altered technique could potentially damage the normal sport skill (66).

Plyometric exercises (involving muscle pre-stretching or stretch-shortening cycles) are typically performed at high speeds, and can be designed to simulate the movement patterns of many sports actions. For example, sprint bounding is considered highly specific to sprinting at top speed (71). Since resisted equipment and plyometric training methods (involving light loads) can be very specific to many sports movement patterns and speeds, they can be considered as potentially beneficial for the development of inter-muscular coordination. Weight training exercises performed with barbells, dumbbells, machines and pulleys are not as effective for this purpose. A fast bench press requires a rapid deceleration of the bar towards the end of the range of motion. This causes a reduction in the muscular activation near the fully extended position (14) which is non-specific to an explosive activity like throwing. Plyometric or weighted implement exercises do not cause this reduction. Indeed, they allow the athlete to use “compensatory acceleration” which is a technique of exploding all the way through the range of motion (30). It could be concluded that the weight room is ideal for heavy load training (that develops intra-muscular coordination), whereas light load methods performed in field conditions are ideal for development of inner-muscular coordination.

**Applications**

If different neural adaptations can be expected from heavy and light load training methods as previously suggested, both methods should be combined for the optimum training effect. This concept was supported by the findings of Adams et al. (1) who reported that vertical jumping ability was increased in a heavy squat training group (3.3 cm) and a plyometric (light load) training group (3.81 cm), but the biggest gain resulted from a group that combined both squats and plyometrics (10.67 cm).

The way in which both loading methods should be combined for the optimum results is not yet known, but Table 3 suggests one possibility.

No time scale is shown in Table 3 because the duration of each phase is dependent on the competition schedule and individual needs of the athlete. It is also important to realize that the methods and neuro-muscular factors listed are intended to be emphasized, not used exclusively, throughout the period shown. Therefore, during the preparation phase it is appropriate to prescribe some exercises or period that is directed to the development of speed/strength and neural factors. Likewise, some short cycles (2 to 3 weeks) of hyper-trophy methods can be used during the pre-competition phase. In relation to heavy and light load training methods, heavy loads would be emphasized during the late preparation and pre-competition phases, whereas light loads would be emphasized during the pre-competition phase.

**Conclusions**

Light load resistance training:

1. Can be effective for the development of various speed/strength qualities.
2. Should include highly sport-specific exercises to maximize the potential benefits. These exercises are usually performed better in the field than in the weight room.
3. Yield relatively minor fast twitch fiber hypertrophy but good development of inter-muscular coordination, and therefore, good transfer to the specific sports movements.
4. Emphasis during the pre-competition phase in an attempt to convert general strength and speed/strength qualities to the specific speed/strength qualities required in the sport.

Heavy load resistance training can be:

1. Effective for the development of various speed/strength qualities.
2. Incorporated with a voluntary effort to produce explosive contractions, regardless of external movement speed, if maximum speed/strength development is expected.
3. Expected to produce increases in fast twitch fiber size as well as neural adaptations, especially intra-muscular coordination.
4. Heavy load training should be emphasised during the late preparation and pre-competition phases.

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