Journal of Strength and Conditioning Research, 1996, 10(2), 131-136

Improving Vertical Jump Performance Through General, Special, and Specific Strength Training: A Brief Review

Daniel Baker

Southern Cross University, Lismore, NSW; and Australian Institute of Sport, Chandler, QLD, 4152 Australia.

Reference Data

Baker, D., Improving vertical jump performance through general, special, and specific strength training: A brief review. *J. Strength and Cond. Res. 10(2):131-136. 1996.*

ABSTRACT

Vertical jump ability is a requirement for success in a number of sports. This paper reviews three broad categories of strength training methods by which vertical jump ability is commonly improved. It examines a theoretical rationale for a strength training program by identifying the neuromechanical factors that affect jumping performance. The results of studies using general, special, and specific strength training exercises are also examined. The role and application of these different exercises for athletes of different abilities is discussed. Practical methods for analyzing jumping performance and their relevance to strength training are also discussed.

Key Words: athletic performance, stretch-shorten cycle, countermovement jump, squat jump

Introduction

As a necessary requirement for success in many sports, vertical jump ability is often what sets some athletes apart from others. It is a factor in sports as diverse as diving, wherein jumping ability is critical to overall success (6), and American football (15), in which it is a general measure of lower body power. Following are examples of jump-and-reach scores (4) for different athletes:

- Weight trained men, 49.7 cm
- Strength trained men, 53.3 cm
- Elite male divers, 63.8 cm
- Sub-elite male divers, 59.3 cm
- Elite female divers, 51.0 cm
- Sub-elite female divers, 44.5 cm

The objective of implementing strength training to improve vertical jumping ability for enhancing overall sport performance appears well-founded.

Strength training exercises can be classified as general, special, or specific depending on their biomechanical structure and effect on the neuromuscular system (3). As applied to the vertical jump, *general* strength training exercises are those aimed at increasing the maximal strength of the muscles involved in jumping. Examples would be squats, front squats, split squats, and power shrugs (with a very slow eccentric dip to the knee) (4).

Special strength exercises are those aimed at training for power, once strength levels have been increased. Examples would be jump squats (both optimal power jumping and variable load jumping), power shrug jumps, power cleans/snatches/pulls, and push presses (4). These have the effect of training to convert general strength to the special quality of power as relevant to jumping. These special strength exercises may be characterized by more rapid execution, higher power outputs, and loss of foot contact with the ground.

Specific strength exercises provide a training stimulus that is very similar to actual competition or an actual vertical jump. Examples would be (a) loaded jumps (e.g., small weights strapped to the waist); (b) repetitive jump training, with volume being the principle form of overload; and (c) depth jumps, with intensity via drop height being the principle form of overload. All these exercises closely mimic the jumping movement (4).

The purpose of this paper is to provide a theoretical rationale for strength training by identifying the neuromechanical factors that affect jumping performance, and to review the relative effectiveness of general, special, and specific training exercises. The role and application of these respective exercises for athletes of different levels will be discussed.

Factors Affecting Jump Performance

Vertical jump performance is dependent on the contractile properties of muscle as well as the augmentation to concentric work that occurs due to the stretch-shorten cycle (SSC) (24). A vertical jump that is preceded by a rapid stretch-shorten cycle is called a countermovement jump (CMJ), as opposed to a jump that is not immediately preceded by a prestretch, for example a squat jump (SJ). These two measures of jumping ability have been used to distinguish between the contractile (SJ) and SSC (CMJ) contribution to jumping (24).

A CMJ usually adds more height to a vertical jump over that of a squat jump, presumably through better utilization of elastic strain energy and the neural augmentation to the muscles (24). Thus it can be said that VJ performance is enhanced by training mainly the contractile elements of the muscle, or the efficiency of the SSC (6).

Normative data from various studies (4, 20, 21, 24) indicate the following CMJ and SJ performance levels of male and female athletes from different sports:

- Physical education, M: CMJ = 40.3 SJ = 35.5
- Physical education, F: CMJ = 23.3 SJ = 19.2
- Volleyball: CMJ = 43.4 SJ = 37.2
- Untrained, M: CMJ = 29.1 SJ = 27.4
- National League netball, F: CMJ = 32.5 SJ = 30.2
- Elite divers, M: CMJ = 42.1 SJ = 35.6
- Elite weightlifters, M: CMJ = 48.7 SJ = 46.5

All SJ and CMJ tests were performed without an armswing, as opposed to a jump-and-reach VJ which utilizes an armswing.

Although interindividual variations affect the exact contributions of the relevant muscles, Hubley and Wells (22) have estimated that the knee, hip, and ankle extensors contribute 49, 28, and 23%, respectively, to the work done during a CMJ vertical jump. Jumps that also entail an armswing yield an extra benefit of 10 to 15% more height attained over that of a CMJ alone (21, 25, 28).

The total time for the CMJ ranges from 530 to 550 ms, with the concentric portion of the movement occupying 330 to 370 ms (18, 19, 21). In sport-specific jumps such as diving takeoffs, which demand great skill, the total jump time may be higher because of a lengthened eccentric phase of 350 to 450 ms (26). The vertical ground reaction forces developed during a CMJ without the armswing is on the order of 1,700 N, which is reached within 370 to 400 ms (21). More recently, Garhammer and Gregor (16) have theorized that better jumpers produce the forces involved much more rapidly, such that their impulse curve is shaped more like a "U" than a "V"; this implies a greater impulse or area under the force-time curve.

Consequently, vertical jumping is characterized by high force production in a short time and this distinguishes it from maximal strength activities. The fact that high forces in jumping must be produced by the lower body extensor muscle groups in a limited time frame of around 350 ms (concentric force production period) provides the rationale for implementing general, special, and specific strength training. Thus, a good strategy for improving VJ would be to periodize the introduction of exercises based on the biomechanics of muscle activity and time frames for concentric force production.

Effects of Strength Training

The effect of various resistance training programs on vertical jump performance has been researched extensively (7, 30, 31). While earlier research tended to focus on whether resistance training affected VJ ability, more recent research has attempted to identify the type of resistance training that was most effective in improving VJ (1, 10, 18, 19, 35).

It appears that the focus of this more recent research has been to determine the mechanisms by which VJ is improved and how they are affected by strength training variables or exercises from the three classifications. Concerning how to improve VJ ability, it may be theorized that *general* strength training aims to mainly improve the contractile capabilities of the muscle, *specific* strength training seeks a more efficient utilization of the stretch reflex and the use of elastic energy, and *special* strength training combines the contractile and stretch-shorten cycle mechanisms (4).

Both periodized and nonperiodized general strength training seem equally effective in improving VJ height when intensity is about equal and squats and clean pulls are performed (7, 30). However, when general strength training using squats was compared with other general strength training exercises such as Hydra-gym squats (9) or leg presses (29), squat training was found to be more effective in improving VJ. If strength training is of a general isometric nature, the transfer to jumping also appears limited when compared to general dynamic training (10, 27).

Certainly isometric strength or rate of force development measures do not correlate well with VJ ability (8, 38). Baker et al. (8) have postulated that these differences between isometric strength and a dynamic VJ would be due to the significantly different structural, neural, and mechanical attributes of the two activities.

This may indicate that, even in general strength training, certain exercises are more "specific" than others in improving VJ. The biomechanics of squat exercises and modified Olympic pulls aimed at developing maximal strength (clean and snatch pulls from the floor, blocks, or hang) may more readily transfer to jumping than do other strength training exercises (13, 16).

Variations in intensity and volume within general squat training do not appear to affect the improvements in VJ height in persons of low to intermediate strength levels (7, 30), although this is not fully supported by some research (31).

The degree of general strength gained through squat training does not seem to affect the degree of change in VJ (2, 7). Baker et al. (7) reported that in trained athletes, the relationship between changes in performance in 1-RM squat strength and VJ consequent to training was also nonsignificant (r = 0.11). Similarly, Hakkinen et al. (20) found no correlation in elite weightlifters between maximal strength (clean & jerk) and jumping with only body mass. Furthermore, Alen et al. (2) reported no change in the jumping ability of elite strength athletes following 24 weeks of heavy squat training, despite a large improvement in 1-RM squat strength. Hakkinen et al. (20), who conducted a 1-yr study on elite weightlifters, also reported no change in overall CMJ performance, in spite of an increase in the SJ contribution to total jump height.

Compared to athletes with less strength, it is noteworthy that elite strength athletes do not seem to improve in VJ performance, despite large increases in maximal squat strength or a lengthy general strength training period. It may be that squat or general strength training alone is insufficient for improving VJ performance in elite strength athletes.

Consequently, while general strength training has improved VJ in beginners and others with low to intermediate strength levels, this improvement may be due to the strength training process per se, not to the degree of change in maximal strength. For elite strength athletes there may be a limit to the effectiveness of general strength training exercises in improving VJ. This may be due to differences in the biomechanical and/or neurophysiological attributes of heavy squats and vertical jumping that perhaps become more pronounced with increases in strength. In addition to leg strength, other mechanisms developed by general strength training exercises must also contribute to VJ ability.

The search for better ways to improve VJ has led researchers to compare other methods of strength training, both special (e.g., barbell squat jumps, cleans, snatches, Olympic lifting pulls) and specific (plyometric jump training). Early research (10) reported that special strength training, using squat jumps, was better than specific strength training in improving VJ in college-age men.

However, general squat training also led to similar improvements in VJ ability. As part of a wider investigation, Hakkinen and Komi (18) reported that general strength training, using heavy squats, resulted in improvements of 10.6 and 7.3% in CMJ and SJ, respectively, in experienced (though not elite) athletes. However, a combination of special (jump squats with up to 100 kg) and specific (plyometric jump training) strength training resulted in improvements of 17.5 and 21.2% in CMJ and SJ, respectively, in similarly trained athletes (19).

In a classical study that attempted to discriminate between the effectiveness of the three strength training classifications in trained athletes, Wilson et al. (35) compared general (squats), special (jump squats with the maximal power load), and specific (plyometric depth jumps) strength training. The special strength training resulted in improvements of 17.6 and 15.2% in CMJ and SJ, respectively, which was superior to the 5.1 and 6.8% improvements for the general strength training group and the 7.2% improvement in SJ for the specific training group. The specific training group reported a statistically similar improvement in CMJ as compared to the special training group.

These results indicate that special strength training is generally more effective than the other two methods, although specific strength training may improve the efficiency of the stretch-shorten cycle alone to a similar degree as special strength training.

Baker (4), reporting on a case study involving 5 rugby players, found that the degree of improvement in a special strength jump squat (with maximal power load) accounted for 78% of the change in a specific vertical jump test. Although the subjects in that study also performed general and specific strength exercises as well as the special strength jump squats, the fact that an increase in maximal jumping power as measured with a barbell jump squat could account for so much of the change in performance in a specific jumping test with armswing is of considerable interest.

The above research and observations would tend to favor the use of special strength training in improving VJ—if exercise classifications are to be considered in isolation. Theoretically, however, the use of combined general strength and specific strength may bring similar results by predominantly training the contractile and stretch-shorten cycle elements relatively independently.

A number of studies have compared the use of general, specific, and combined methods in improving VJ. Adams et al. (1) compared general (squat) and specific (plyometric jump) and reported equal improvements in VJ, as did Clutch et al. (14). However, Adams et al.'s combined training group (general + specific training) had twice as much improvement as either single-method training group. This lends support to the theory of improving VJ by enhancing both the contractile and stretch reflex properties of the muscle rather than undertaking unidirectional training alone.

In a unique approach, Venable et al. (32) compared general strength training (squats) to a combined method of squats and electrical stimulation. Both methods yielded an equal improvement in VJ. Bauer et al. (9) reported similar improvements between general (squat), combined squat + plyometrics, and combined Hydra-gym + plyometrics training; all proved more effective than either specific training (plyometrics) or Hydra-gym general training alone. The somewhat anomalous results of this study as compared to other combined-methods studies may perhaps be due to the low strength level of the subjects. Nonetheless, it does indicate the relative effectiveness of squat training over Hydra-gym training if these exercises are the only ones used.

Contrary to the above results, Verhoshanski and Tatyan (33) reported that for experienced speed-strength athletes, a more intense form of specific strength training (depth jumps) was more effective in improving VJ than the combination of general (squats) and specific (in-place vertical jumps) strength training exercises. In the depth jump, foot contact time is less than in a normal VJ. This places more emphasis on the speed of the contraction and the utilization of elastic energy, which decays exponentially as a function of the length of the pause between the eccentric and concentric phases (34).

It may be that the experienced speed-strength athletes in Verhoshanski and Tatyan's study had an adequate general strength base and that the faster execution of the depth jump led to a greater improvement in jumping performance via a better use of elastic energy and the neural augmentation to the concentric phase of the movement. Conceivably, elite athletes who are already experienced in strength and power training may benefit more from training with faster contraction velocities or with greater stretch loads, to further enhance their use of the elastic and neural augmentation that occurs during the stretch-shorten cycle (18, 19). This may not be the case for athletes with lower strength levels who may respond adequately to virtually any form of training (17).

The studies cited above, while apparently revealing certain anomalies, indicate that various forms of resistance training act to improve VJ ability perhaps through different mechanisms. For athletes with low strength levels, general strength training yields reasonably large improvements in VJ. It may be theorized that the role of general strength training is to initially condition the neuromuscular system to the high level of forces (e.g., 3 to 5 times body mass) that occur with jumping.

However, the degree of change in maximal strength is unrelated to the degree of change in VJ (7), and in elite strength athletes general strength training such as in heavy squats may not gain any further positive adaptation in jumping ability. Certain morphological changes may occur within the muscles of athletes with low to intermediate strength levels, leading to enhanced VJ performance due to an increased contractile contribution to total force production, as assessed by the SJ measure. The ability to efficiently use the augmentation of the stretch-shorten cycle [(CMJ – SJ/SJ) × 100] may remain unchanged as a result of general strength training (18).

When general strength levels are adequate, a more efficient use of the stretch reflex and elastic energy, brought about through general and specific strength training, may offer a more appropriate training stimulus. In this regard, special strength training, such as in jump squats, appears to be the most effective form of training. In studies by Berger (10) and Wilson et al. (35), the special strength jump squats appear to offer the best single method of training.

Theoretically, a combination of methods would lend themselves to a greater transfer of effects by enhancing the contractile and stretch reflex/elastic properties of the muscle. We must also consider the specific patterns of motor unit recruitment, temporal sequencing, and firing frequency when performing specific plyometric jump training to allow for a transfer to sport-specific jumping (12).

In support of this theory, recent work by Bobbert and Van Soest (11) suggests that an increase in strength alone may actually retard VJ ability if the ability to "control" the new levels of force has not been improved. Bobbert and Van Soest constructed a VJ model based on elite volleyball players and examined the effects of equal improvements in strength in the various muscles of the lower body, with and without enhanced neural control (temporal sequencing and specific patterns of motor unit recruitment and firing).

Their results suggest that a 20% increase in strength would translate to an improvement of 7.8 cm in VJ if the jumping skill were also optimized. The same increase in strength would lead to a decrement of 2 cm if the neural control of the new levels of force production were not optimized to the jumping skill. Bobbert and Van Soest concluded that "muscle training exercises should be accompanied by exercises in which the athletes may practice with their changed muscle properties" (p. 1019). In effect this lends support to the use of general strength training to increase the strength of the muscles, and special and specific training to "fine tune" the control of the jumping muscles.

The Relevance of Jumping to Strength Training

The contribution of the contractile and stretch-shorten elements to jumping may be used as a diagnostic tool for prescribing individual training to improve VJ (6, 36). Well-trained jumpers tend to display differences of 15 to 20% between SJ and CMJ measures, as noted for volleyball players and divers in the bulleted list (see p. 132). If the difference between SJ and CMJ are small (<10%), this may indicate inefficient use of the stretch-shorten cycle. If the differences are large (>20%), this may indicate that jumping can be improved by more emphasis on training the contractile elements of the muscles.

In the above scenarios, the former would benefit from greater emphasis on the special and specific strength exercises while the latter would benefit from greater emphasis on general exercises (6). For a VJ preceded by a run-up, it has also been proposed that the relationship between the height from a depth jump and its foot contact time could be used to monitor and prescribe strength training (37). Such procedures, currently used by a number of elite athletes and sports teams, may provide both the athlete and coach with more objective data on the effects of strength training on jumping. However, the validity of this method of prescribing strength training requires further substantiation.

The Overall Training Plan

The nature of the sport, periodization of the training year, and the athlete's training age and individual needs may all dictate what combination of strength training exercises is most appropriate (23). The difficult task for the strength and conditioning coach may be to decide the exact manipulation of training variables for an athlete, given the complexities of the training process and the number of training variables (5, 23).

While all the exercises cited in the Introduction may help improve jumping performance, an increase in maximal strength itself may not directly correlate to an increase in jumping height (7). Therefore a strength coach should realize that an increase in squat or leg strength will not necessarily improve jumping.

The transfer of the effects of general strength training may be spurious at best. An increase in jumping height may occur through the strength training process, which brings about neural disinhibition and other neural or morphological adaptations, but a very large increase in maximal strength does not necessarily equate to a large increase in jumping height. Consequently, it appears necessary to proceed beyond the usual fare of general strength exercises into the special and specific strength exercises. This may be especially true for more advanced athletes or those already quite experienced in strength training.

Conceptually, there would appear to be a continuum of exercises for the use of strength training in jumping, proceeding from general to specific. A strength training continuum for improving VJ by utilizing squats, squat jumps, and specific loaded jumping exercises would be as follows:

General		*Special*		*Specific*	
Squats →		Jump squats →		Specific loaded jumps	
10 reps (light)	3–4 reps (heavy)	light (20 kg)	optimal power (40–60 kg)	heavier (5–10kg)	lighter (1–5kg)

Obviously, other exercises from the three classifications could also be implemented into the training continuum at various stages.

Practical Applications

A rationale for general, special, and specific strength training to improve VJ ability has been provided, based on the neuromechanical factors influencing jump performance and how these factors may be affected by different exercises. The athlete's training age may dictate to what degree an exercise is appropriate in this context.

Several findings or underlying recommendations applicable to strength and conditioning coaches can be gleaned from the reviewed literature.

1. The vertical jump of beginners can be increased with general strength training exercises such as squats. Elite strength athletes may not record VJ improvements if they only perform general strength exercises such as squats and very heavy weightlifting exercises.
2. Combined methods of strength training seem to offer the greatest training stimulus by training the contractile and neural/elastic components, perhaps relatively independently.
3. If not implementing a combined approach, the single best method appears to be special strength jump squats, ideally with a load that approximates maximal power load.
4. The role of periodization, especially over the long term, remains unclear; elite athletes undergoing periodized strength training over longer periods have not demonstrated improvements in VJ performance.
5. It may be prudent to use lighter jumping squat loads before introducing maximal power loads within a training cycle to reduce the possibility of injury.
6. Use light loads (1–5 kg for most athletes) for the specific loaded jump exercises. Larger loads tend to alter the biomechanics of the jump, reducing the "specificity" of the specific strength exercise. For depth jumps, low drop heights and/or a good strength base (1-RM squat equivalent to 150–200% of body mass) may be necessary upon introduction to training.
7. Strength training programs can be based on an analysis of the SJ and CMJ scores.
8. Individuals with orthopedic disorders or injuries should obtain medical approval prior to beginning any of the training techniques reviewed in this article.

References

1. Adams, K., J.P. O'Shea, K.L. O'Shea, and M. Climstein. The effect of six weeks of squat, plyometric and squat-plyometric training on power production. *J. Appl. Sport Sci. Res.* 6:36-41. 1992.
2. Alen, M., K. Hakkinen, and P. Komi. Changes in neuromuscular performance and muscle fiber characteristics of elite power athletes self-administering androgenic and anabolic steroids. *Acta Physiol. Scand.* 122:535-544. 1984.
3. Australian Strength & Conditioning Association. *Level 1 Coaching Course Syllabus.* Toowong, Brisbane: ASCA, 1993.
4. Baker, D. Improving vertical jump performance: The application of general, special and specific strength training. In: *Proceedings of the National Coaching Conference.* Canberra: Australian Coaching Council, 1994a. pp. 13-18.
5. Baker, D. Specific strength/power training for elite divers. Case study from the Australian Institute of Sport. *Strength & Cond. Coach* 2(1):20-27. 1994b.
6. Baker, D., and S. Foley. Measuring the jumping capabilities of divers. *Strength & Cond. Coach* 2(2):16-19. 1994.
7. Baker, D., G. Wilson, and R. Carlyon. Periodization: The effect of manipulating volume and intensity. *J. Strength Cond. Res.* 8:235-242. 1994a.
8. Baker, D., G. Wilson, and R. Carlyon. Generality versus specificity: A comparison of dynamic and isometric measures of strength and speed-strength. *Eur. J. Appl. Physiol.* 68:350-355. 1994b.
9. Bauer, T., R. Thayer, and G. Baras. Comparison of training modalities for power development in the lower extremity. *J. Appl. Sport Sci. Res.* 4(4):115-121. 1990.
10. Berger, R. Effect of dynamic and static training on vertical jumping. *Res. Quar.* 34:419-424. 1963.
11. Bobbert, M., and A. Van Soest. Effect of muscle strengthening on vertical jump height: A simulation study. *Med. Sci. Sports Exerc.* 26:1012-1020. 1994.
12. Bosco, C. Stretch-shortening cycle in skeletal muscle function and physiological considerations on explosive power in man. *Atleticastudi.* 16(1):7-13. 1985.
13. Burkhardt, E., and J. Garhammer. Biomechanical comparison of hang cleans and vertical jumps. *J. Appl. Sport Sci. Res.* 2(3):57. 1988.

14. Clutch, D., M. Wilton, C. McGowan, and G. Bryce. The effect of drop jumps and weight training on leg strength and vertical jumps. *Res. Quar.* 54:5-10. 1983.
15. Fry, A.C., and W.J. Kraemer. Physical performance characteristics of American football players. *J. Appl. Sport Sci. Res.* 5:126-138. 1991.
16. Garhammer, J., and R. Gregor. Propulsion forces as a function of intensity for weightlifting and vertical jumping. *J. Appl. Sport Sci. Res.* 6:129-134. 1992.
17. Hakkinen, K. Factors influencing trainability of muscular strength during short term and prolonged training. *NSCA Journal* 2:32-37. 1985.
18. Hakkinen, K., and P.V. Komi. Changes in electrical and mechanical behaviour of leg extensor muscles during heavy resistance strength training. *Scand. J. Sport Sci.* 7(2):55-64. 1985a.
19. Hakkinen, K., and P.V. Komi. Effect of explosive type strength training on electromyographic and force production characteristics of leg extensor muscles during concentric and various stretch-shortening exercises. *Scand. J. Sport Sci.* 7(2):65-75. 1985b.
20. Hakkinen, K., P. Komi, M. Alen, and H. Kauhanen. EMG, muscle fibre and force production characteristics during a 1-year training period in elite weightlifters. *Eur. J. Appl. Physiol.* 56:419-427. 1987.
21. Harman, E., M. Rosenstein, P. Frykman, and R. Rosenstein. The effects of arms and countermovement on vertical jumping. *Med. Sci. Sports Exerc.* 22:825-833. 1990.
22. Hubley, C., and R. Wells. A work-energy approach to determine individual joint contributions to vertical jump performance. *Eur. J. Appl. Physiol.* 50:247-254. 1983.
23. King, I. Plyometric training: In perspective. *SPORTS* 13(6):1-12. 1993.
24. Komi, P., and C. Bosco. Utilization of stored elastic energy in leg extensor muscles of men and women. *Med. Sci. Sports* 10:261-265. 1978.
25. Luhtanen, P., and P. Komi. Segmental contributions to forces in vertical jump. *Eur. J. Appl. Physiol.* 38:181-188. 1978.
26. Miller, D., E. Hennig, M. Pizzimenti, I. Jones, and R. Nelson. Kinetic and kinematic characteristics of 10-m platform performances of elite divers: 1. Back takeoffs. *Int. J. Sport Biomech.* 5:61-88. 1989.
27. O'Shea, P., and K. O'Shea. Functional isometric weight training: Its effects on dynamic and static strength. *J. Appl. Sport Sci. Res.* 3(2):30-33. 1989.
28. Shetty, A., and B. Etnyre. Contribution of armswing to the force components of a maximum vertical jump. *JOSPT* 11:198-201. 1989.
29. Silvester, L., C. Stiggins, C. McGowan, and G. Bryce. The effect of variable resistance and free-weight training programs on strength and vertical jump. *NSCA Journal* 3(6):30-33. 1982.
30. Stone, M.H., H. O'Bryant, and J. Garhammer. A hypothetical model for strength training. *J. Sports Med.* 21:342-351. 1981.
31. Stowers, T., J. McMillan, D. Scala, V. Davis, D. Wilson, and M. Stone. The short term effects of three different strength-power training methods. *NSCA Journal* 5(3):24-27. 1983.
32. Venable, M., M. Collins, H. O'Bryant, C. Denegar, M. Sedivec, and G. Alon. Effect of supplemental electrical stimulation on the development of strength, vertical jump perrformance and power. *J. Appl. Sport Sci. Res.* 5(3):139-143. 1991.
33. Verhoshanski, Y., and V. Tatyan. Speed-strength preparation of future champions. *Sov. Sports Rev.* 18:166-170. 1983.
34. Wilson, G., B. Elliott, and G. Wood. The effect on performance of imposing a delay during a stretch-shorten cycle movement. *Med. Sci. Sports Exerc.* 23:363-370. 1991.
35. Wilson, G., R. Newton, A. Murphy, and B. Humphries. The optimal training load for the development of dynamic athletic performance. *Med. Sci. Sports Exerc.* 23:1279-1286. 1993.
36. Young, W. A simple method for evaluating the strength qualities of the leg extensor muscles and jumping abilities. *Strength & Cond. Coach* 2(4):5-8. 1994.
37. Young, W. Specificity of strength development for improving the takeoff ability in jumping events. *Mod. Athl. & Coach* 33(1):3-8. 1995.
38. Young, W., and G. Bilby. The effect of voluntary effort to influence speed of contraction on strength, muscular power and hypertrophy development. *J. Strength Cond. Res.* 7:172-178. 1993.