SPECIFIC STRENGTH DEVELOPMENT IN THE HIGH JUMP

By Gary Bourne

Optimal strength development programs for high jumpers call for the inclusion of specific structural, as well as specific and direct functional training. In this article, based on an extract from the author's thesis for the Australian Track and Field Coaches Association's Level III coaching qualification, Gary Bourne discusses the specific development of structural and direct and indirect functional changes in the training of high jumpers. Re-printed with permission from Modern Athlete and Coach.

INTRODUCTION

High jump competitions are commonly won or lost by only one or two percent differences in the performance capacities of the competitors. The optimal development of muscular strength and transfer of this to the performance situation is therefore a crucial factor in the training of successful high jumpers. In this event, where the athlete encounters peak forces of between 5-8 times their own body weight on one leg during the takeoff, the structural and functional capacities of the musculo-tendinous and neuromuscular systems require optimal development.

Coaches need a good working knowledge of strength development theory and practice in order that their athletes may capitalize fully on the performance benefits offered through strength development programs. Ensuring an optimal transfer to performance of strength gained through supplementary programs requires careful attention to each of the facets of "applied strength" development.

STRUCTURAL CHANGES

In order to achieve the desired elements of structural changes in the jumper's muscles we need to induce selectively increases in the size of type IIb (fast fatigable, fast twitch) muscle fibers. This is because these are the fibers responsible for generating the peak tension, or maximum force output in the muscles, and are therefore the primary determiners of the muscular potential within the jumper to exert greater ground reaction forces during the takeoff.

There is general agreement amongst researchers that fast movements, such as encountered in plyometric activities, produce increases in muscular strength with little or no concurrent increase in muscle size. Relatively slow and controlled movements, such as those encountered with weight training exercises, on the other hand, produce increases in strength with concurrent significant increases in muscle size.

A program of selected specific weight training exercises employing the major muscle groups utilized in the event, in which the loads (in mature athletes) are designed to stress the muscles beyond 85% of their maximum voluntary contraction (MVC) through a slightly greater movement range (up to 15) than is encountered in the jump is therefore required.

The degree of change achieved in individual muscles or muscle groups will be determined partly by the total amount of work (weight x repetitions x sets x number of workouts) undertaken by the athlete and partly by the presence of appropriate levels of testosterone in the body. Because of this latter factor, the structural changes achievable by male high jumpers are likely to be greater than those achievable by females. Also, male jumpers with somatotypes higher in the mesomorphy element will achieve greater structural changes from a given amount of work because of their initial higher number of muscle fibres.

FUNCTIONAL CHANGES

The changes which we desire to induce in high jumpers here involve stimulating firstly increases of the frequency of messages sent via individual motor neurons to their attached muscle fibers so as to produce the maximum force output from these fibers and, secondly, to redefine the motor program in the brain, as well as the feedback loop mechanisms situated in the spinal cord, to send messages via more motor neurons in order to stimulate the maximum number of fibers to tetany in the muscle at the appropriate time.

Some of these changes occur as a result of weight training programs. In fact these types of neuromuscular changes are an essential precondition to the occurrence of the hypertrophic changes which are induced by weight training. The practical results of weight training alone for the high jumper, however, reveals that it provides only limited benefit for performance. This is because the functional muscular and neuromuscular changes which occur are velocity specific (Hakkinen & Komi 1985a & 1985b). Figure 1 reveals how weight training increases the maximum force output of the muscles at low limb velocities, while power training (plyometric exercises, skill drills and event practice) increases the maximum force output of the muscles at high limb velocities.

Weight exercises complete with relatively light weights and fast movements are ineffective in producing the high jumper’s desired velocity specific neuromuscular changes for a variety of reasons. Furthermore, these exercises fail to produce the necessary overload (> 85% of MVC) on the muscles throughout the movement, which is necessary to induce the desired structural changes to the type IIb fibers.

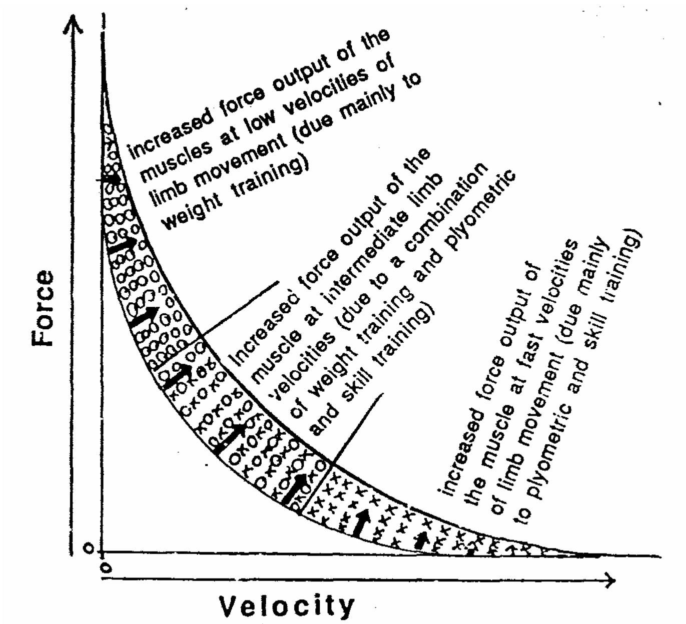

FIG. 1. The typical theoretical force-velocity curve reveals maximum force output by the muscle at varying speeds of movement. Arrows and shading suggest the ways in which different methods of strength training may be used to modify the performance of the muscle.

The maximum loads on the quadriceps muscles in high jumping occur in the eccentric phase of contraction which happens in the time interval between the takeoff foot striking the ground and the maximum lowering of the jumper's centre of gravity, commonly called the amortization phase of the takeoff. This muscle group is primarily responsible for partially blocking the forward momentum of the jumper, reducing the horizontal velocity by between 3.5m/s and 4.8m/s (male Olympic finalists, Seoul 1988) and 2.7m/s and 3.6m/s (female Olympic finalists, Seoul 1988), [Conrad, A. & Ritzdorf, W., 1988].

Maximum loading is in the period of maximum deceleration of horizontal velocity (Bourne, 1982). This occurs in the early stages following the foot plant, or when the limb velocity (hip and knee joints) is still relatively high. The maximum force output by the hamstring and gluteal groups of muscles, on the other hand, occur in the early stages of the vertical acceleration of the jumper, or at relatively low limb velocities (these muscle groups are primarily responsible for hip extension).

The horizontal blocking which occurs in the amortization phase of the takeoff can facilitate the storage of large amounts of elastic energy in the quadriceps group of muscles and their associated tendons. This energy is re-utilized in the next phase of the takeoff, which partially involves knee extension by the quadriceps muscles in the generation of vertical velocity y the high jumper. For effective horizontal blocking to take place, the quadriceps group of muscles must be capable of withstanding very large forces in the eccentric phase of contraction (estimated at between 5-8 times the body weight of the jumper) in very short periods of time as the amortization phase lasts between 0.07-0.10 seconds (Bourne, 1982).

The development of the capacity within the high jumper's neuromuscular system to withstand these very high forces will require the use of plyometric exercises as well as jumping practice. Training must include activities which engage the quadriceps in similar loads and similar speeds (± 15%) to those encountered in the event itself. These activities will invoke the central nervous system to reprogram the responsible motor program in the brain to provide it with the capacity to send appropriately strong electrical impulses at a greater frequency to type II fibers and to a maximum number of these fibers.

This type of training produces very little hypertrophy in the muscles. The changes which occur in force output are greatest at fast limb velocities and are minimal at low limb velocities. Increases in force outputs which do occur, and these can be quite considerable toward the top end of the force velocity curve, (Hakkinen & Komi, 1985b) appear to be due almost solely to direct functional neuromuscutar changes.

To develop this system optimally the coach or athlete needs to select a range of appropriate drills and exercises. Activities which will engage the muscles in similar loads, speeds and movement patterns (i.e. comply with specificity requirements) include:

- Double leg jumps down a short hill or bank, seeking maximum height and distance (knee bend on landing not exceeding 130°).

- Single leg hops down hill, attempting to break forward velocity on each landing (similar knee and hip angles on landing). Only a small number of hops on each leg in each set, i.e. 3 x L, 3 x R, 3 x L, 3 x R, because of fatigue factors.

- Hurdle hopping from a run-up over two hurdles with increasing heights, spaced to allow for only one landing in between.

- Pop-ups into a long jump pit from a run-up only slightly faster than the high jump final velocity, emphasizing blocking, lead knee drive and maximal vertical height.

The outlined activities are primarily designed to induce changes in the quadriceps and gluteal muscle groups in their eccentric phases of contraction, as will be encountered in the amortization phase of the takeoff. Specific exercises also need to be included in the program which will target the hamstring, gluteal and calf groups of muscles in their concentric phase of contraction which will be encountered in the extension or vertical acceleration phase of the takeoff.

Dynamic stretching of these muscles and their associated tendons is required during their eccentric and isometric contraction during the amortization phase. This is essential to facilitate maximum force output from both the contractile components within the muscle and the series elastic components within the muscles and their associated tendons during the subsequent concentric action in the extension phase.

To facilitate the important pre-stretching of these muscles, while still imposing the greatest load on the muscles during the early stages of extension (performance specific muscle loading), activities with a run-up approach should be utilized. Maximal activation of these muscles can be achieved by introducing an overload on the hip, knee and ankle extensors and by having the athlete perform these activities up a gradient.

Fatigue curves (Bourne, 1991) indicate that effective maximum force outputs of the leg extensor muscles under these conditions can be sustained for between 4-8 repetitions. With type IIb fibres being convertible to type IIa fibers through speed endurance and endurance training, (Saltin and Gollnick, 1983), [with a corresponding reduction in their maximal force output from 100% to 80%], it is important to ensure that the number of repetitions of exercises employed remains within these limits to avoid possible reductions in maximum power output with corresponding unhelpful gains in the endurance capabilities of the muscles.

With the above in mind, selected activities may include:

- Successive single leg hops (4-8) from an 8-10 stride approach up a gradient for maximum distance.
- Successive alternate bounds (4-8) from the same run-up up a gradient for maximum distance.
- Successive skip jumps for height (4) up a gradient, using high jump run-up speed.
- Successive side skips (4) up a gradient for distance from a six-stride approach.
- Single leg hopping for speed up a limited number of stairs.
- Single leg hurdle hops (as described).

INDIRECT FUNCTIONAL CHANGES

The indirect functional neuromuscular changes are essentially modifications to the motor program which controls the jump takeoff, with a view to improving both the intra-and inter-muscular coordination of contraction during this phase. The effects-which the high jumper seeks to induce through appropriate training activities are a reduction in the activity (tension) of antagonist muscles during the takeoff sequence of movements and improved intra- and inter-muscular coordination of contraction by the contributing muscles, which will lead to a greater overall summation of muscular forces during the takeoff.

It is just as important to ensure appropriate development and training of the coordinative mechanisms responsible for maximizing force output of the muscles, as it is to ensure that all factors in strength development are accounted for in the high jumper's training program. The changes to the maximal force output of the jumper ensure that the available (developed) strength becomes "applied strength" in the execution of the jump. This aspect is often not well recognized by coaches and may be neglected in training.

Development of the coordinative neuromuscular systems are most effectively achieved in pre-pubertal children (Tittel, 1988). Physical educators should know, and coaches and athletics administrators must come to realize, that limits will always be placed on the development of these systems in athletes where appropriate broad based development, involving exposure of the young high jumper to a wide range of related and specific jumping activities, has not occurred in the pre-pubertal years.

Unfortunately, most high jump coaches do not have access to their protégés until some years after they have attained puberty. This is a problem which needs to be addressed in this country through middle and upper primary school and junior secondary school physical education and sport programs.

While the ultimate potential for development of these coordinative mechanisms may be limited through neglect in the early stages of a high jumpers growth and development, significant changes can still be induced by the implementation of appropriate activities into the training program. A range of related and specific running and jumping activities need to be introduced so as to improve the motor control of the limbs during these movements.

General improvement in the neuromuscular coordinative mechanisms may be induced by the activities outlined earlier in this text, as well as a wide range of other running and jumping drills to improve general control and timing of the movements of the lower and upper limbs and inter-muscular fiber recruitment.

Specific coordinative improvements in the neuromuscular system, which are influenced by the motor program responsible for the high jump take-off, will require the employment of specific event-skill drills and principally and most importantly, practice of the event itself. It is important to understand that the use of event related activities will have a negative effect by incorrectly modifying the motor program responsible for the high jump takeoff. This applies particularly to the two activities mentioned, because of the similarities in the overall movements, but unique and subtle differences in the timing of limb movements which are crucial to an efficient flop takeoff.

The longer leg swing and greater lean back in scissor drills [despite attempts to counter this] will have a negative skill transfer effect on the fast bent knee drive and more vertical body position of the takeoff in the flop. Similarly, short approach flop jumps allow for less speed at the takeoff in comparison to a normal jump, thus having a negative effect on the training of intra-and inter-muscular fiber recruitment patterns. There is also a negative effect on the body angles at the foot plant (more vertical) and the takeoff (greater lean in towards the bar). This may lead to the development of incorrect special perspective in relation to the correct takeoff point.

Overuse of these types of activities, which incorporate similar movement patterns, but in which the pattern of intra-and inter-muscular fiber recruitment differs due to subtle differences in the torques encountered in more extended levers, and in the demands placed on the muscles by the load-speed-angle characteristics of the movement, will interfere with or adversely modify the motor program for flop high jumping if repeated too frequently.

The suggestion here is not that these activities should be avoided altogether, but that they form only a small proportion (i.e. up to 25%) of the jump takeoffs practiced by the high jumper. In this way the positive aspects of these activities may be capitalized on, while the negative effects are minimized.

IN SUMMARY

Optimal strength training programs for high jumpers require a multifaceted approach. A number of these distinctly different but inter-related facets have been identified here. While there are some cross-training effects which occur in other facets when we specifically target one facet for development, the optimal development of all facets of strength requires that each receive specific attention in the training program. Only in this way will the athlete achieve optimal “applied strength” or “strength transfer to performance” as a result of the program.

In concluding this paper it is important to qualify the above, by pointing out that apart from an understanding of the requirements of strength development programs, the total picture, including the chronological age, developmental level (biological age) and training age of the athlete need to be considered in detail before finally determining the appropriate strength development program, including the types of activities, exercises and specific training loads for an individual athlete.

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