SPECIFICITY OF STRENGTH DEVELOPMENT FOR IMPROVING THE TAKEOFF ABILITY IN JUMPING EVENTS

By Warren Young

WARREN YOUNG of the Australian Institute of Sport examines specific speed strength qualities in the four jumping events and provides sound practical guidelines for assessment of the qualities and training. Re-printed with permission from Modern Athlete and Coach.

The need for strength training for the jumping events is well accepted. However the specific strength qualities, or forms of strength, that are important are probably not so well known. The purpose of this article is to examine this and to provide implications for the training and assessment of jumpers.

The greatest strength requirement in jumping events is in relation to the takeoff phase. Although there are some distinct differences between the jumping events, there are also some common features relating to the takeoff. Firstly, the duration of the takeoff is always less than 200 ms (15). Secondly, the type of muscular contractions produced during the takeoff are common to all jumps. In the high and long jumps the centre of gravity of the body is usually lowered prior to the takeoff and rises immediately after the foot plant. Despite this, there is flexion or bending at the hip, knee and ankle joints (6). This results in lengthening or stretching of the leg extensor muscles (quadriceps, gluteals, hamstrings and calves); i.e. eccentric contractions. The leg then begins to extend or straighten as a result of a shortening of the leg extensors (concentric contractions). Therefore in all jumping events the takeoff consists of an eccentric-concentric contraction sequence or a stretch-shortening cycle (SSC).

LONG JUMP

In the long jump, better athletes achieve faster run-ups and produce greater takeoff forces in less time than less qualified athletes (12). Generally the greater the run-up speed, the greater the tendency for the takeoff leg to bend on impact as a result of the high eccentric or stretch loads imposed on the leg extensor muscles. Better athletes are able to tolerate these loads and avoid collapsing of the leg (2, 12), which could result in a loss of horizontal velocity and poor elevation. A recent biomechanical analysis of elite male long jumpers provided extra insight into the takeoff mechanism (11). A low body position prior to foot plant allowed the body to pivot over the takeoff leg, thereby generating vertical velocity as soon as the takeoff commenced. At the end of the eccentric phase, when the knee angle was reduced to 144 degrees, as much as two thirds of the final vertical velocity had already been generated. It was concluded that "...to ensure the pivot mechanism can operate there is a clear requirement for the body to resist flexion at touchdown... As approach speed increases, leg strength must also increase to be able to control the higher forces at impact" (11, p. 77).

TRIPLE JUMP

When landing from the hop and step, the impact forces are even greater than those encountered in the long jump, and can be over twenty times the bodyweight of the athlete (9). This is not surprising because the triple jumper has to absorb a large downward velocity before the upward concentric phase can begin. The athlete does not have the luxury of absorbing the impact forces by bending the knee and prolonging the takeoff time. If this were done, a large loss of horizontal velocity and a poor takeoff would follow.

The athlete could reduce the length and height of the hop to decrease the following impact loads, but this would obviously compromise the total distance jumped. A better strategy would be to improve the ability to tolerate the high impact or stretch loads imposed on the leg muscles. This would enable the jumper to hop further with less risk of the takeoff leg collapsing at landing. In fact, the ability to tolerate the impact forces on landings may be a limiting factor to triple jump performance (17).

HIGH JUMP

Using a faster run-up is potentially advantageous for a high jumper because it provides improved potential to apply greater vertical takeoff forces (4). Sotomayor and Kostadinova are examples of jumpers who successfully employ relatively fast run-ups (5). However, for a given athlete, increasing the run-up speed would only improve performance to an optimum speed, and then jump height would deteriorate at greater speeds. This relationship has been found with jumping to spike in volleyball (7) (Figure 1).

The decrease in performance at very high run-up speeds could be related to technical factors (e.g. poor body positioning). However, it might also be explained by neuro-muscular factors. For example, consider the performance of depth or drop jumps (DJ), which involves falling from a pre-determined height and then immediately jumping vertically. The higher the falling or drop height, the greater the downward velocity of the body on landing, and the greater the stretch loads imposed on the leg extensors. Often as the stretch load increases with increasing drop height, jump performance increases, but then falls off with very high stretch loads (3, 16) (Figure 2). This reduced jumping performance may be associated with a neuro-muscular inhibition (8).

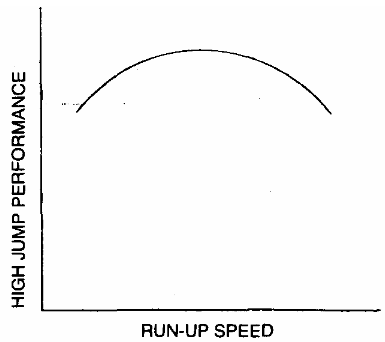

FIG. 1. Simplified diagram illustrating the expected relationship between run-up speed and high jump performance.

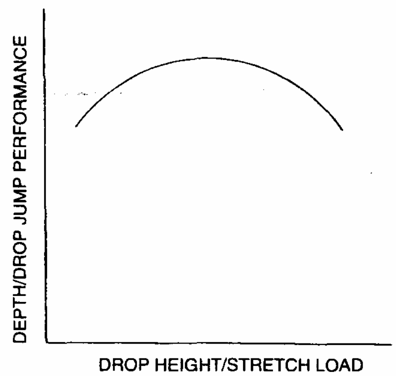

FIG. 2. Simplified diagram illustrating the relationship between drop height and DJ performance.

With reference to a fast run-up in the high jump, Dapena (5, p. 3310) states: “If the takeoff leg is not strong enough, it will be forced to flex excessively during the takeoff phase, and then it may not be able to make a forceful extension in the final part of the takeoff phase. In other words, the takeoff leg may ‘buckle’ under the stress...” The solution according to Dapena is to use some “extra strengthening” of the takeoff leg to withstand the impact loads.

POLE VAULT

The takeoff in the pole vault cannot be considered in the same way as the other jumping events. In the high jump the vertical propulsion is totally generated by the muscular forces during the takeoff. In the pole vault a greater run-up speed is used to transfer energy to the pole which is later released to propel the athlete vertically. Therefore, even though a vaulter may use a “pre-jump” takeoff technique (10), the strength qualities required for successful performance may be expected to differ from the qualities required for a ‘true” jumping action.

STRENGTH QUALITIES

The previous discussion reveals that for the long, triple and high jump takeoffs there are some common features:

- Large takeoff forces must be applied in a short time, therefore generating a high power output.
- Takeoff power is produced by SSC muscular contractions.
- Athletes must prevent excessive knee flexion during the eccentric phase. To achieve this, jumpers must be able to tolerate high stretch loads.

The ability to quickly switch from the eccentric to concentric phase in a SSC is described as reactive or elastic strength. According to Schmidtbleicher (14), this is a relatively independent strength quality. This means that an athlete may possess good general strength and power, but will not necessarily display good power capabilities in a SSC. Assessment of strength qualities of athletes at the Australian Institute of Sport (AIS) confirms this. The implication for the coach is that training methods that specifically develop reactive strength must be identified and prescribed. Traditional weight training exercises (e.g. squats, power cleans and snatches) are necessary for developing an optimum level of muscle mass, maximum strength and speed-strength abilities. However, once this foundation has been established, reactive strength training methods (i.e. plyometrics) play an increasingly important role in the specific strength development of jumpers.

Due to the principle of specificity of training, care must be exercised in the selection of plyometric drills. To illustrate this, the results of a study on four experienced jumpers is of interest (1). The athletes were analyzed while performing a high jump and a variety of plyometric exercises that they were accustomed to. These consisted of variations of hopping, stepping and depth jumping from single and double leg takeoffs. While the mean contact time for the high jump takeoff was 177 ms, the contact times for the plyometric exercises were generally greater than 250 ms. Furthermore, none of the exercises were able to match or exceed the neuromuscular demands of the high jump takeoff. Since the takeoff times of the plyometric exercises were significantly longer than the time available for force production in the high jump takeoff, the training effects of these exercises would not have been optimum.

ASSESSMENT OF REACTIVE STRENGTH

The AIS has recently established a laboratory strength assessment system that is specific to sprinting and jumping movements. Although it can be used to measure maximum strength, speed-strength, reactive strength and strength-endurance qualities of the leg extensors to obtain athlete profiles and monitor training, the following discussion will be limited to reactive strength as it relates to jumpers.

A DJ may be thought of as an indicator of reactive strength because it requires a reversal of the downward movement into a concentric action to jump vertically. However, if an athlete is required to jump for maximum height and no other instructions regarding jump technique are provided, the contact times produced are generally long (over 400 ms). In this situation, the athlete bends the knees to about a 90 degree angle so that a long time can be used to absorb the impact forces and generate upward propulsion. This is clearly not specific to the takeoff conditions encountered in the jumping events. A more specific measure of reactive strength that is used at the AIS takes into account both jump height and contact time. The objective is to maximize jump height, minimize contact time and therefore maximize the jump height/contact time ratio. The athlete receives feedback about these parameters immediately after a jump so that the optimum combination of jump height and contact time can be easily achieved. An example of a test result for a female long jumper is shown in Figure 3.

....*REACTIVE STRENGTH (DROP JUMP)*.....

Drop Height (cm)	Jump Height (cm)	Contact Time (sec)	Reactive Strength Performance (Jump height/time)
30	36.2	0.145	250
45	37.3	0.144	259
60	41.2	0.143	288
75	39.4	0.157	251

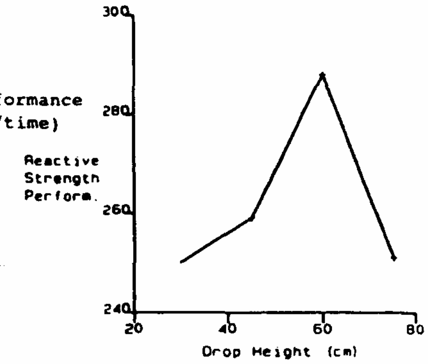

FIG. 3. An example of a reactive strength test result.

The typical range of contact times produced by this method is approximately 125-180 ms, which is very similar to those used in the jumping events (15). This test also involves a relatively small knee flexion and high stretch loads, which are similar to the jump takeoffs. Due to the specificity of this test, results obtained at the AIS have confirmed that it is a better predictor of the ability to jump for height from a run-up than a test involving a long contact time (DJ for height only or vertical jump). AIS testing has also shown that sprinters and jumpers attain similar results on a variety of measures of power, but jumpers are generally superior in reactive strength. This makes sense because although sprinters also require fast SSC contractions, they do not have the need to tolerate very high stretch loads.

The reactive strength test is conducted with a contact mat and a portable computer which calculates and displays jump height, contact time and reactive strength performance immediately after a jump. The drop heights used are 30, 45, 60 and 75 cm, and DJ are always performed with the hands placed on the hips. The results are graphed to enhance the interpretation of the test (Figures 3 and 4).

IMPLICATIONS FOR TRAINING

There are various ways to interpret the results. Firstly, the best reactive strength performance score (e.g. 393 for the high jumper in Fig. 4) is compared to athlete norms. This gives information about an athlete’s current level of reactive strength and determines the need to further train this quality. If the result is relatively poor, a greater emphasis should be placed on reactive strength training methods. Ideally, this result should be examined in conjunction with other tests results of different qualities, since it is only one component that influences performance.

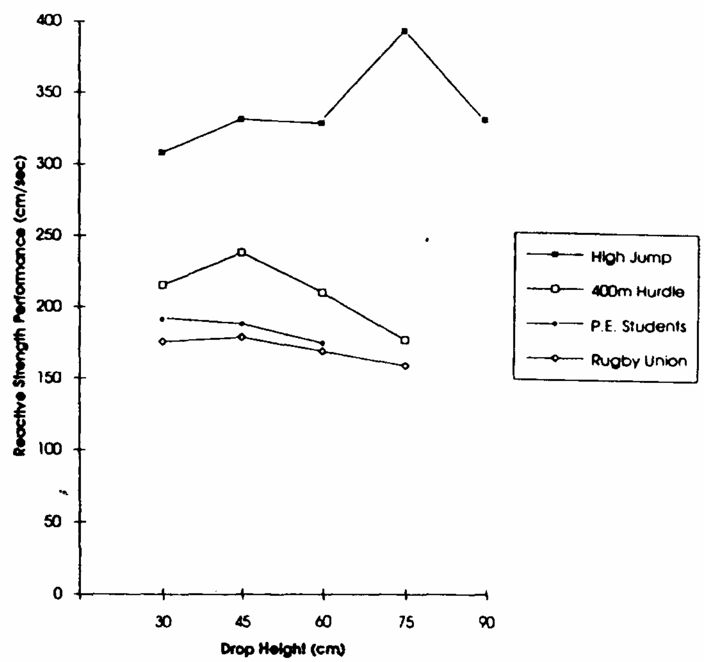

FIG. 4. Examples of reactive strength test results for different athletes.

Secondly, the drop height yielding the best performance provides information about the ability to tolerate stretch loads. The higher the drop height, the better this ability. Untrained people, or athletes that don't require high levels of reactive strength, will generally achieve their best performances from a 30 or 45 cm drop height. On the other hand, jumpers may achieve their best result from a 60 or 75 cm drop height, indicating a superior tolerance to stretch loads (Fig. 4).

In addition, DJ training has been shown to reduce the neuro-muscular inhibition that may be associated with high stretch loads (13). If the tolerance to stretch loads can be improved, a long or high jumper may be able to utilize a faster run-up without negative effects and a triple jumper may be able to hop further without collapsing on the landing going into the step phase.

The reactive strength test can also be used to determine what drop height the athlete should use for training. In the example of the high jumper (Fig. 4), drop heights of 30 to 60 cm produced a sub-maximum performance. From a 75 cm drop the performance was maximized, probably due to an optimum use of the stretch reflex and the storage and utilization of elastic energy by the neuromuscular system. The most powerful contractions would most likely occur from this drop height and therefore would be expected to produce the best training stimulus. With drop heights greater than 75 cm, performance declined, presumably due to a neuromuscular inhibition. Therefore the recommended training drop height for this athlete is 75 cm. An advantage of using this test result to prescribe the training drop height is that it is individualized, which helps to ensure that athletes are not exposed to drop heights that are either too low or excessive.

It should be remembered that as the drop height increases, so does the impact or stretch load. The intensity of this training method is inherently high and therefore relatively low volumes should be used e.g. 4-5 sets of 5-8 reps, 2-3 times per week. The rest between sets should be complete (e.g. 3 minutes or more) to prevent fatigue of the nervous system and deterioration of performance from one set to the next.

Athletes with a history of injury, especially in the calf muscle, achilles tendon and shin areas, should perform this type of DJ with caution. DJs should be performed on a firm but forgiving surface e.g. firm grass, synthetic track, timber floor. Extremely soft surfaces (e.g. sand, gymnastics mats) absorb too much of the landing impact and may change the timing of the movements. Running shoes with good shock absorbing qualities are preferable to running/ jumping spikes for minimizing the risk of injury from intense DJ training.

Experience at the AIS has shown that for one jumper, the addition of two sessions per week of DJ training over two weeks were able to produce an improvement in reactive strength performance of over 15%. It should be noted that some of these training sessions were performed with the aid of the contact mat/computer system so that immediate feedback was provided. This feedback may in fact be quite important for ensuring that the “correct” contact times are being performed and for motivation. The portability and inexpense of this system makes it viable as a routine procedure for monitoring plyometric training as well as for testing.

DJ is only one form of plyometric training. A limitation of DJ is that it involves a double leg takeoff. This movement pattern is not as specific to jumping events as plyometric exercises that utilize a single leg takeoff and encourage the use of the free limbs e.g. bounding. The advantage of the DJ training method described here is that the individual optimum stretch load and specific contact times can be used and controlled. A combination of DJ and other specific plyometric exercises would be ideal and is recommended for developing the reactive strength component of jumpers.

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