NSA 2 81-89, 1986

THE PRACTICE OF STRENGTH TRAINING IN WOMEN'S HIGH JUMP

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"Strength is an essential factor of the jump and one which determines and limits performance... Strong muscles provide effective protection from overloading to the passive motor apparatus. Protection of this kind is absolutely essential considering that, during training and competition, athletes average around 10,000 take-offs and landings per year, with reactive forces 6 to 10 times their body weight. The author presents a training method involving both maximum strength training and elastic strength training."

Translation from the original German by Jürgen Schiffer

1. The significance of strength

The high jump is a disciplines that makes very high demands on the capacities of strength in the woman athlete. In this, strength has a two-fold function:

a) Strength is an essential factor of the jump and one which determines and limits performance.

Vertical take-off speed, which is a determinant dimension of the jump, is decisively influenced by the vertical acceleration thrust, together with the mass. The extent of this momentum depends essentially upon the strength of the athlete, as well as upon features of technique.

Fig. 1 shows an example of Force-time development during the jump-off phase of the High Jump.

It is clear from this diagram that within a ground-contact period of 170-200 ms in the phase of eccentric contraction, ground reaction forces of more than 5000 N develop.

Amortization of these forces must be brought about as rapidly as possible in order to create the greatest possible momentum in the concentric phase.

b) Strong muscles provide effective protection from overloading to the passive motor apparatus. With a total of something like 10,000 take-offs and landings per year in training and competition, (including horizontal and vertical jumps), and with reactive forces of 6 to 10 times of the athlete's body weight, protection of this kind is absolutely essential.

A further factor is that in the take-off for the Flop, as a result of the highly pronate position of the foot, the forces do not take effect in the direction of the anatomical axes.

Because point 2 is of equal importance to point 1, all forms of training must be considered not only from the point of view of their effectiveness in training but also that of the loading they cause to the passive motor apparatus.

2. Training the capacities of strength

As far as training method is concerned, a distinction can be made between the forms of maximum-strength training and of elastic-strength training.

2.1. *Maximum-strength training*

Maximum-strength training is carried out with various objectives, depending upon the period of training and the level of performance.

An increase in maximum strength can be brought about by

— the production of muscular hypertrophy, or by

— the improvement of intramuscular co-ordination.

Hypertrophy training is used during the period of general preparation, and depending upon the state of performance of the athletes, covers a period of 4-8 weeks, with a tendency towards the shorter period of time. With 6

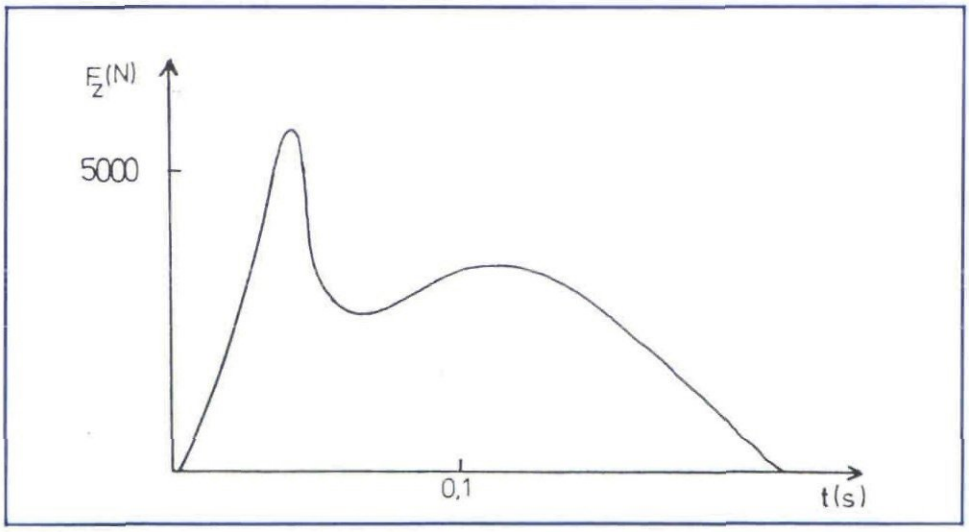

 Fig. 1 - Development pattern of vertical strength/time

sets and 80% intensity of loading, we do not exceed 8 repetitions per set.

The training of intermuscular co-ordination takes place in the special technique and competition cycle.

The number of repetitions is 4-1, with 6-8 sets and 90-100% intensity, which can mean up to 130 kg.

As standard forms of training, we use squats and cleans, as well as special forms of exercise for strengthening the muscles of the calf. The squats are not carried out to the point of full extension, so that in this way, the total period of tension is extended. We aim for the exercise to be performed without the heels being raised, so that at the same time, the Achilles tendon is stretched. A bench behind the athlete serves solely as a means of orientation.

In those forms of exercise for strengthening the calf muscles, care must be taken to ensure that the *m. gastrocnemius*, as a bi-articular muscle, and the *m. soleus*, as a mono-articular muscle, are trained separately.

An assessment of maximum-strength training leads to the following conclusion:

1. Maximum-strength training is an irreplaceable component in the training of the High Jump athlete.

2. From the point of view of injuries resulting from overloading, there are no problems whatever in its use, providing the following previsions are fulfilled:

— technically correct performance;
— strengthened trunk muscles;
— the accompaniment of an extensive program of gymnastics for stretching.

3. For healthy athletes, work with dum-bells is always to be given preference over work on the machines.

2.2. *Elastic-strength training*

With regard to elastic-strength training, we distinguish between non-reactive and reactive forms of training.

Non-reactive forms of training are undoubtedly less problematical, but on account of their rather slight effectiveness in training, they are given only minor importance in our training programme.

An exception to this is the exercise "knee-joint jumps with additional loading".

The distinct isometric phase leads to these exercises being classified as "non-reactive jumps", and yet the strong development of tension in the eccentric phase proves to be highly effective in training.

This training form is not suitable for beginners.

The reactive forms of training can be subdivided into four groups:

a) Reactive knee-bends or reactive squats

Two variants have to be distinguished: *"t-squat"*. Starting position with contracted leg and trunk muscles and slightly bent knees. Performance of movement: maximum fast bending of knee-joint up to 110 degrees; concentration to fast return of movement (down-up-down-...) with accentuating the extending phase (concentric phase). The t-squat does not lead to a complete extension of the knee-joint, the movement downwards is attached immediately.

Contrary to this the *"r-squat"* leads to a full extension of the knee-joint inclusive ankle joint. After a short phase

of concentration the next single repetition follows, again starting from the above mentioned starting position with pre-tension of the muscles.

A common feature of both forms is that the athlete must endeavour to carry out the reversal of the movement as rapidly as possible.

This is because of the requirements of the take-off that are mentioned above. However, in the case of the t – squat, when there is a sequence of several repetitions, a constant or uniform tempo establishes itself, since otherwise counter-momentum in the barbell comes into play. In order to avoid this levelling-out of the speed, the repetitions are carried out individually, with additional stretching of the upper ankle joint.

For the same total weight of athlete plus dumb-bell (here 130 kg), the following quantities are characteristics:

t-squat: F_{MAX}: approx. 300 N: duration of phase: 200 ms.

r-squat: F_{MAX}: approx 4000 N: duration of phase: 160 ms.

Assessment of the reactive squats leads to the following conclusion:

— very effective for training;

— virtually no problems for the passive motor apparatus;

— very often, the retaining function of the muscles of the trunk is the factor that limits the load.

b) Horizontal jumps

Here it is basically a question of bounds with and without run-up strides. The difference in these values serves at the same times as a means of directing training.

If in the case of women performing the sequence of 5 jumps, the value obtained with 6 run-up strides exceeds that without a run-up by more than 4 m, the reactive strength capabilities based on the available muscle system are fully utilized.

Assessment has shown that Horizontal jumps are:

— effective in training, but

— liable to cause problems if carried out incorrectly (the foot should not be placed down with a sluggish or dragging action) or if the jumps are practised frequently on synthetic surfaces.

c) Vertical jumps

Fundamentally, vertical jumps include the various variations on hurdle-rebound jumps (see Fig. 2-4). The vertical forces produced are in the region of 2500 N for the take-off and some 4000 N for the landing, with a ground-contacta duration of 170-210 ms depending upon the manner of execution.

Single-leg hurdle jumps are performed with one, three and five intermediate strides, depending upon the training objective.

Hurdle jumps, carried out correctly, can be assessed as relatively problem-free, providing the muscles are appropriately prepared and the passive motor apparatus is effectively supported.

d) Ankle jumps

These are jumps with an additional dumb-bell load, which are carried out almost exclusively from the ankle-joint. These jumps represent a highly effective form of training, but one which is certainly problematical.

It is advisable to use this form in very strctly measured amounts and exclusively with top-class athletes.

To sum up, we can say:

Fig. 2

Fig. 3

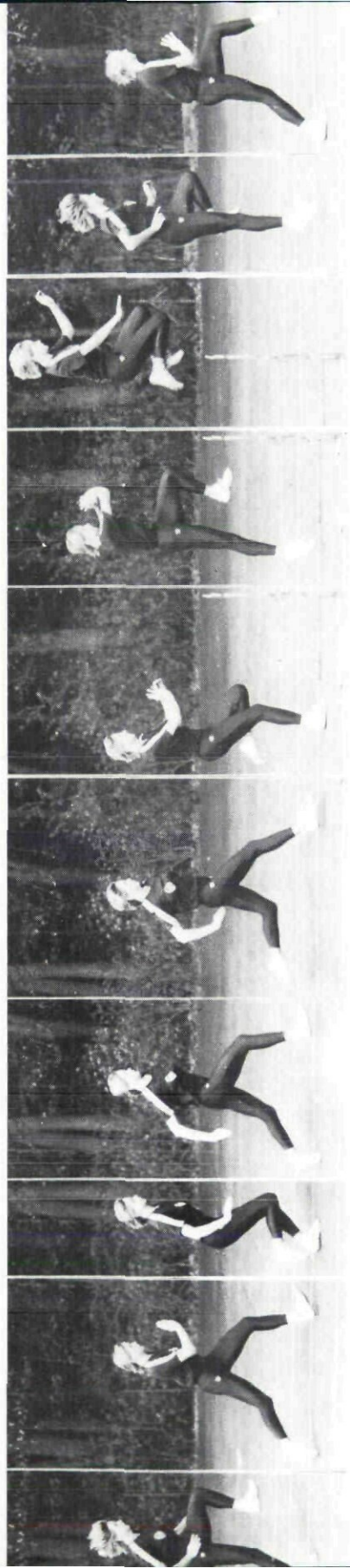

Fig. 4

There exists no shortage of highly effective forms of training to improve the capacity of reactive strength, which is a factor of particular interest for the High Jump.

Reactive forms of training cannot be replaced by anything of equal value!

However, the unprepared or premature use of these forms of training is not without its problems, especially for the passive motor apparatus.

Depending upon individual weak points, the effects of overloading manifest themselves in the lower ankle joint (fatigue fracture), knee joint or lumbar vertebral region.

Consequently, it is essential that there should be early, systematic gymnastic strengthening of the muscles of the foot and trunk in particular. Appropriate forms of training are a daily component of the training carried out by our women team athletes.

In respect of injuries to the Achilles tendon as a result of overloading, our experience is somewhat different.

Problems arise less as a result of reactive forms of training, but rather of inadequate stretching of the muscles and the tendon in the phases of Maximum-strength training. Our own subjective impression is that adaptation in the tendon tissue does not measure up to the altered strength capacity of the muscles, so that as a result, when rapid movements are made, susceptibility to injury is greatly increased.

3. Training method

3.1. *Maximum-Strength Training*

a) Hypertrophy training

Training forms: squats, cleans.
Series: 6-8.
Repetitions per series: 8.

Intensity: 80%.
Period: General cycle.
Training units per week: 2-5.

b) Intramuscular co-ordination training

Training forms: squats, cleans.
Series: 6-8.
Repetitions per series: 1-3.
Intensity: 100-90%.
Period: special cycle, technique cycle.

3.2. *Elastic strength training*

a) Non-reactive

Training form: knee-joint jumps.
Series: 6-8.
Repetitions per series: 6-8.
Intensity: 20-40 kg.
Period: special cycle, technique cycle.
Training units per week: 2-3.

b) Reactive squats

Training forms: t-squats; r-squats.

Series: 6-8.
Repetitions per series: 6-10.
Intensity: 100%-150% of body weight.
Period: special cycle, technique cycle, competition cycle.
Training units per week: 1-3.

c) Vertical jumps

Training form: Hurdle jumps.
Series: 6-10.
Repetitions per series: 14-30.
Number of hurdles: 2-6.
Height of hurdles: 70-110 cm.
Period: special cycle, technique cycle, competition cycle.
Training units per week: 1-3.
Example: 8 x (6x6) hurdles, 70 cm, at start of special cycle - 8 x (6x2) hurdles, 110 cm, in competition cycle.

d) Ankle-Jumps

Series: 6-8.
Repetitions per series: 6-10.
Intensity: 20-40 kg.
Period: technique cycle, competition cycle.
Training units per week: 1-3.

3.3. *Supplementary points*

In our opinion, the strength of the muscles of the trunk and foot are of particular importance.

The muscles of the trunk are specially important for the following reasons:

— the action of bringing forward and fixing the hip during the take-off represents one of the most significant factors in the performance of a jump;

— dumb-bell work with high loads and/or reactive exercise makes extremely high demands on the muscles of the trunk and on their retaining or holding function.

The following points apply to the muscles of the foot:

— the feet, as the terminal members of the kinetic chain are the first to be subjected to the very high forces produced in all jumps, so that their bony structures (especially the plantar arches) have to be specially protected;

— the final stretch in the take-off is a stretching of the upper ankle joint; this extension is one of the decisive factors in competition performance.

For these reasons, training forms aimed at strengthening the muscles of the foot and trunk hold a special position and are carried out throughout the whole year.

In addition to a large number of gymnastic exercises, sit-ups and trunk raising on the box are some of the standard forms of training for strengthening the muscles of the trunk.

Strengthening of the foot muscles is achieved by a special gymnastic programme.

In all forms of strength training, special importance is attached to extension or stretching, since the shortening of the muscles that results from the increase in strength involves two negative effects:

— mobility is limited;

— tension loadings on the tendons (particularly the patellar tendon and the Achilles tendon) is increased, and the result is an increased danger of injury.

These effects can be counteracted by a systematic programme of stretching.

4. The systematics of strength training in the long-term training structure

Many authors maintain repeatedly that there should be no attempt to achieve muscular hypertrophy before puberty. Even if a degree of doubt can be expressed here (it seems unlikely that the markedly muscular profile of children who have undergone strength training is exclusively the results of a reduction in the subcutaneous fatty tissue), the clarification of this question is irrelevant as far as basic training in track and field athletics is concerned, since in no case would the aim be to bring about muscular hypertropy in school children of the B/A group (11-14 years). But this does not mean that all strength training is inappropriate in school-age children. It is our opinion that the gymnastic strengthening of the overall motor apparatus represents a necessary pre-requisite for later competitive training.

As already mentioned, special importance is attached to the strengthening of the trunk muscles and muscles of the feet.

In addition to the gymnastic strengthening of all groups of muscles, we consider a second focal point of strength training in young men and women jumpers to be the acquisition of the correct technique of dumbbell/barbell training.

Here, in some cases, quite considerable deficiencies can be observed. In order to prevent injuries and to achieve the desired effect of training, it is necessary in every case that these techniques should be learned perfectly (e.g. with the aid of a horizontal bar), before work is started with additional loads. With young athletes, strength training must be monitored and corrected just as carefully as exercises in technique.

Ignorance of or failure to observe these facts has led (especially in the case of women jumpers) to a serious consequence: no dumb-bell training, since it is thought to be too dangerous, but in order to develop the necessary jumping strength, jumps in all their variations carried out very extensively (up to 400 hurdle or multiple jumps per week). In our opinion, both parts of this argument are false.

In cases where no orthopaedic irregularities or negative indications exist, and where there is appropriate. preparation of condition and technique, the risk of injury as a result of dumbbell training is extremely slight. On the other hand, the extensive use of multiple jumps (horizontal and verti-

cal) involves the production of very high forces in the amortization phase (see above), and as a result, represents a much greater source of danger to the (passive) motor apparatus, unless it is adequately prepared, that is, given protection by the muscles.

Within the framework of jumping exercises, depth-jumps certainly have a place. As a result of high peaks of force produced, the possibility of injury inevitably and automatically exists for anyone who has had no strength training, because he has at his disposal less relative and absolute strength, and so the peaks of loading are intercepted by the skeletal and ligamentous apparatus, and less by the muscle.

On the basis of these considerations, we start out from the following system in the long-term development of strength, and in doing so, the paramount goals are the long-term preparation of top level performances and the avoidance of injuries from overloading.

Children (13/14 years)

— Gymnastic strengthening with special attention to muscles of the trunk and feet.

— Preparation in the technique of dumb-bell training.

— Horizontal and vertical jumps (both legs) of slight extent and slight intensity.

— Hopping on the spot (both legs and one-legged).

Juniors B (15/16 years)

— Beginning of dumb-bell training (squats, snatches, cleans); no ankle-jumps with dumb-bells.

— Further gymnastic strengthening.

— Horizontal and vertical jumps of medium extent and intensity.

— Boundings with technical improvement as target.

— Jumps over low obstacles (40-50 cm).

— Light one-leg hops.

Juniors A (17-18 years)

— Compete dumb-bell training.

— Two-legged and single legged hurdle jumps.

— Take-off jumps over hurdles.

— Bounding for distance and time.

— Further gymnastic strengthening.