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Is there a crisis in the horizontal jumps?

Having coached long jumpers for many years, including one or two world-class performers, the horizontal jumping events remain close to my heart. When I am able to attend a championship or meeting you will most likely find me in the seats close to the runway, preferably in line with the take-off board, so that I can keep an eye on today’s long and triple jumpers. If asked to give an overview of these disciplines, I would have to say that, unfortunately, performances have plateaued and regressed in recent years and that the situation could even be termed a crisis.

Of the top 20 outdoor long jumps by men in history, just two have been recorded after the year 2000 and since the start of the current Olympic cycle in 2009 only Dwight Phillips (USA) has come within 30cm of Mike Powell’s 1991 world record of 8.95m, something the likes of Carl Lewis (USA), Larry Myricks (USA), Ivan Pedroso (CUB) and Powell himself were all able to do on multiple occasions in the 1980s and 1990s. Phillips has dominated the last two outdoor world championships because he is the only athlete who has been able to jump close to 8.50m when it counts.

On the women’s side, the situation is worse. Some will argue that improved doping controls and education have had an effect on performance levels in general and that in principle this must be a good thing for the sport. But the fact is that competition for today’s top championship performer, Brittney Reese (USA), has been unusually sparse as in the first three years of the current Olympic cycle we have seen a total of just nine jumps outdoors over 7m, and four of these were by Reese herself. Lack of strong competition or rivalries make it unlikely that marks will improve or that audiences will be attracted to these events.

Things are only a little better in the triple jump. Both the men’s and women’s outdoor world records date from the 1995 IAAF World Championships in Athletics in Gothenburg, more than a quarter of a century ago. The women’s event is still relatively new on the international competition programme and this is reflected in that 18 of the top 20 performances have been since turn of the century. But we have not seen more than two jumpers over 15m outdoors since 2008 and there were none in 2011. The one ray of hope is with the men, where these days there is a lot of talent around, including Teddy Tamgho (FRA), who has taken the indoor record to 17.92m, indoor and outdoor world championships gold medallist Phillips Idowu (GBR) and the 2011 World Champion Christian Taylor (USA), who have all been within 50cm of Jonathan Edwards’ (GBR) 18.29m world mark. In addition, there are the recently crowned world indoor champion Will Claye (USA) and a number of good jumpers from Cuba, Russia and even Italy.

At the IAAF World Indoor Championships in Istanbul I discussed this situation with former world record holder and three-time European champion in the long jump Igor Ter-Ovanesian, who also helped to coach the current women’s long jump world record holder Galina Chistyakova (URS). Our conclusion was quite simple: The technique of the long jumpers we observed, including Reese, who jumped an exceptional 7.23m, is just not good enough to consistently go much further.

From my point of view this is largely an issue of coaching. I don’t have the space here to go into more detail but there is some interesting reading in this issue’s Special Topic section, including an extensive biomechanical analysis of the horizontal jumping events from the 2009 IAAF World Championships in Athletics. I am making it my personal mission to build on what is published here to create an international project to address the crisis by discussing how we can better prepare our horizontal jumpers. I will start by looking to stage, as soon as possible, an international conference of coaches of top-level long jumpers and scientists, mainly biomechanists, to see how we can revitalise these disciplines. Be sure to check the IAAF website for further details as they become available.

Finally, let me conclude by thanking you for your patience in accepting the publication delays accumulated in the past two years but still recognising the quality of information and insight provided by NSA. As always, I look forward to your thoughts and comments on both NSA and the IAAF Development Programme.

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Horizontal Jumps

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The Horizontal Jumps

by Jürgen Schiffer

Introduction

This article aims to provide a summary drawn from the current literature of the main aspects of the horizontal jumping events in track and field athletics as a general guide and a starting point for further study.

The horizontal jumping events can be defined as those disciplines where the athlete tries to jump as far as possible, whereas in the vertical jumps the athlete aims to jump as high as possible. Although this definition may seem trivial, it is important to point out that, from a purely technical or biomechanical point of view, the jumping action in the pole vault is not so much vertically directed but rather it is horizontal into the bending pole, as it were, giving the event a common characteristic with the two disciplines that will be covered below – the long jump and the triple jump. But because the goal of the pole vault to clear as great a height as possible it is classified as a vertical jump.

In the sections below we will look first at the most important commonalities between the two horizontal jumps and then at the two disciplines in some detail including basic descriptions, technique, teaching procedure and training.

Common Characteristics

The basic physical qualities required for success in either the long jump or the triple jump are:

• high sprinting speed or acceleration ability;
• above average eccentric and reactive strength;
• high take-off ability, i.e., the ability to convert forward velocity to vertical lift, or the ability to use explosive power at high horizontal velocity to create vertical lift;
• very good rhythm ability (see HILLIARD et al., 2004).

In all the jumping disciplines in track and field, there is a strong relationship between the execution of the approach run and take-off on the one hand and the jumping performance on the other hand. The more consistent and more technically correct the approach run and take-off, the better the jump performance (see TELLEZ & JAMES, 2000).

This leads JACOBY & FRALEY (1995) to regard the approach as the most important concern for all jumping events. They even state that the approach alone dictates the success or failure of the entire jump. All the power, velocity, impulse, and direction are developed during the approach run. Once airborne, other than controlling rotations, the athlete cannot contribute to the effectiveness of the jump. The athlete must be in contact with the ground to have any effect on the performance of a jump.
The Long Jump

One could say, that, from a technical point of view, the long jump is the simplest of the field events. Its approach is from a single direction and the transition from running velocity to an optimum height in the jump and the most effective way of landing in the pit present smaller problems in body mechanics compared with the other three jumps. Against this background, it is not surprising that, until about 1950, long jumpers were usually “sprinters-on-holiday”, doing a second event for fun or team points, with almost no emphasis on special training for the event (see DOHERTY, 1985).

According to HILLIARD (2007), the ability to jump is an innate skill and is easily identified. Therefore, they regard it as unnecessary to embark on an exhaustive series of talent identification tests to determine long jumping capabilities. Coaches should rather look for athletes who possess:

- a sound, rhythmical running action,
- a high degree of speed,
- spatial awareness,
- a natural spring and elastic energy,
- coordination in a range of activities.

It is common practice to break the long jump down into four elements:

1) The approach
2) The last two strides
3) The take-off
4) The action in the air and landing

Long-jump Technique

The approach

If one compares the long jump approach with sprinting, the “techno-motor” differences do not seem to be very significant. At most, variations in three elements could be mentioned (see TIDOW, 1989):

- the knee lift in the forward swinging phase is normally more pronounced;
- the subsequent extension of the knee joint and plant of the foot (support on the ball of the foot) should, according to the Soviet philosophy of long jumping, resemble “slipping into slippers” (see ROSENTHAL, 1988);
- during the last third of the approach run, many long jumpers try to emphasise the stride rate.

The approach should be consistent and allow for gradual acceleration, beginning with the first stride and ending with maximum controlled velocity at the take-off (see TELLEZ & JAMES, 2000).

Although, in general, the approach should be as long as possible, depending on the jumper’s experience, sprinting technique, and conditioning level, its length is usually between 12 and 22 strides. Since the longer the approach, the more difficult it is to develop a consistent stride pattern, inexperienced jumpers should begin by using an approach of 12 strides. A successful approach depends on the consistency of the first two or three strides. It is here that the rhythm of the run is developed. Check marks can help determine the consistency of a jumper’s approach run (see TELLEZ & JAMES, 2000).

JACOBY & FRALEY (1995) state that the sole purpose of the approach is for the athlete to reach the take-off point at the greatest possible velocity. The basic rule is: Set the approach to fit the individual’s acceleration curve; the acceleration curve should not be dictated by approach length.

It is also important to stress that it is not raw speed that is crucial in the long jump, but maximum controllable velocity. This means that the approach should be made at the maximum velocity at which the jumper can complete a successful take-off. However, the acceleration during the approach must be gradual. Accelerating too soon or too quickly can lead to deceleration toward the end of the approach going into the take-off, resulting in a poor performance (see TELLEZ & JAMES, 2000).
As far as body position is concerned, there is a slight inclination of the whole body from the ground at the start of the approach. However, as the jumper accelerates, the body gradually straightens up into an upright position by the end of the fourth or sixth stride (see TELLEZ & JAMES, 2000).

**The last two approach strides**

The main objective in the last two strides of the approach is to prepare for the take-off while conserving as much velocity as possible. During the penultimate stride, i.e., the next to the last stride from the take-off, there is a lowering of the jumper’s centre of mass (CM). The penultimate stride is normally the longer of the last two strides because of the lowering of the CM and the flexion of the knee and ankle of the supporting leg. There is a noticeable “gathering” of the jumper’s body during the penultimate stride. The rear support during the penultimate stride is performed with only an incomplete extension. This conserves energy in the take-off leg and introduces the lowering of the hip and CM. The trunk is also straightened. In addition, the foot is placed flat on the ground, which leads to what is called the “swing leg squat” (see TELLEZ & JAMES, 2000 and TIDOW, 1989).

From the swing leg squat, the jumper, through an incomplete extension of the knee of the swing leg during the support phase, applies a more horizontal impulse leading to a comparatively flat trajectory for the final stride (see TIDOW, 1989).

Because of the raising of the jumper’s CM, the last stride is shorter than the penultimate stride (see, however, JONES, 2008, who shows that the two longest jumps in the history, by Mike Powell (USA) and Bob Beamon (USA), were made with penultimate strides that were shorter than the last stride). As the take-off foot makes contact with the ground, it is placed flat and in front of the jumper’s body. In addition, there is a slight flexion of the joints of the take-off leg during which the muscles are forced into an active stretching phase or eccentric contraction. Immediately following this active stretching, there is a shortening, or concentric contraction, of these muscles. When a concentric contraction is preceded by a phase of active stretching, elastic energy is stored and the muscles are “loaded up,” as it were (see TELLEZ & JAMES, 2000).

Since the last stride is generally shorter than the penultimate stride, jumpers should think of the last two strides as long-short. They must avoid reaching on the last stride, because placing the take-off foot too far out into the front of the body will result in a braking or stopping effect and poor jump performance (see TELLEZ & JAMES, 2000).

The board contact, which is characterised by a pronounced front support, a slight backward inclination of the trunk and a slight twist towards the side of the take-off leg, marks the finish of the take-off preparation phase (see TIDOW, 1989).

The maintenance of velocity through the last two strides is also helped by continuing the arm swing of the running action (see TELLEZ & JAMES, 2000).

**The take-off**

The take-off, which is the most essential part of long jump technique, can only be successful if its preparation is performed correctly, so that the loss of horizontal velocity is minimised. This means that the jumper’s CM should reach its lowest point at the moment the take-off foot hits the board and when the trunk has a slight backward inclination. If this happens, the CM’s forward and upward directed path of acceleration will be as long as possible. This means that the redirection from the horizontal to the vertical begins immediately after the foot plant. Prerequisites for this are a pre-tension of the take-off leg, from the muscles of the sole of the foot up to the hip extensors at the backside, and an actively pawing foot plant (see TIDOW, 1989).

According to TELLEZ & JAMES (2000), coaches should encourage jumpers to think about jumping first and then running up and out off the ground. Focusing only on running...
up and out off the ground tends to cause the jumpers to not load up the take-off leg and thus bypass a vertical impulse.

TELLEZ & JAMES (2000) also emphasise that the take-off foot is placed flat and directly in front of the jumper’s body to allow for maximum vertical lift. If the jumper places the foot heel first, it will cause a braking or stopping effect. On the other hand, if the jumper places the take-off foot high up on the toes, there will be little stability on impact, causing the leg to buckle or collapse.

An optimal position at take-off is characterised by the jumper’s body being upright to the ground. Assuming this posture is easier if the eyes are focused up and out when leaving the ground. Looking down at the sand or the take-off board should be avoided (see TELLEZ & JAMES, 2000).

However, jumpers should not over emphasize jumping up high at take-off. A high angle of take-off usually causes jumpers to slow down considerably to achieve the height, thus losing critical velocity. Long jumpers should jump for distance, not height, which means that the optimum take-off angle is roughly around 20°, implying a vertical velocity about 40% of the horizontal velocity at the end of the take-off (see DAPENA, 2005 and TELLEZ & JAMES, 2000).

**Action in the air**

The objective of the flight phase is to rotate the body into an efficient landing position that maximises jump distance. Once contact with the ground is broken, the jumper can do nothing to alter the flight path of the CM. However, the jumper moves his or her arms and legs about the CM to counteract forward rotation and assume an optimal position for landing (see TELLEZ & JAMES, 2000).

The hitch-kick style, which is described as a continual running action during the flight phase of the jump (see JACOBY & FRALEY, 1995), allows the jumper to counteract the forward rotation developed at the take-off. By cycling the legs and arms through the air, the jumper is able to maintain an upright body position and set up for an efficient landing position. If the jumper did not counteract forward rotation by cycling the arms and legs, the body would continue to rotate forward into a face-down position in the sand (see TELLEZ & JAMES, 2000).

Other techniques for long jumpers in the air are the hang and the sail. Each of these styles accomplishes the same task as the hitch-kick, counteracting forward rotation in the air in order to achieve an efficient landing position. In the hang technique, the jumper extends his or her body in a long, outstretched position and holds that position momentarily so that he or she appears to be hanging. Then, upon descending, the jumper snaps the legs to a forward landing position. The hang is beneficial in that the long position of the athlete as he or she rises in the air retards the tendency to tumble forward and lose extension (see TELLEZ & JAMES, 2000).

A detailed analysis of the hang and hitch-kick, or running-in-the-air, styles of long jumping is presented by TIDOW (1989). He states that after the take-off, both hang and running-in-the-air style jumpers show a release of the take-off posture leading to the so-called “first step”, which is characterised by an opening of the knee joint angle of the swing leg. While, in the case of the hitch-kick, this is done in a thrusting way, the movement is active in the running-in-the-air style and tends to be smoother and more passive in the hang style.

The heel of the take-off leg (which is behind the body) is slightly kicked up at the back in a similar action to the backward swinging phase of sprinting. Although the leg posture is very similar, there are great differences as far as the arm action is concerned. In the running-in-the-air style, the arm on the side of the swing leg begins a forward “windmilling” movement. At the same time, the opposite arm performs a forward and downward movement parallel to the swing leg (which is still in front of the body). Thus both arms rotate in the same direction, but the leading arm is 180° ahead of the following arm.
In comparison, the arm action in the hang style is quite different. Since here the jumper must perform a double-arm swing, the counter-swinging arm movement realised in the take-off posture must first be eliminated. Correspondingly, the opposite arm locked in front and above must be lowered towards the swing leg. At the same time, the arm on the side of the swing leg is moved towards the trunk where it virtually "waits" for the opposite arm.

Then, the long jumper, for a very short time, reaches a "one-leg stand" in the air, the longitudinal axis of the body being vertically aligned. In the running-in-the-air style, the one-leg stand is caused by the active, backward movement of the (almost) extended swing leg, being overtaken by the take-off leg as it is brought forward for compensation. Parallel to this, the arms, which are as extended as possible, continue their forward windmill-like action.

In the hang-style, this "swing-leg stance" is achieved through a passive lowering of the swing leg and not through the use of the hip-extension muscles, as is the case in the running-in-the-air style. Since the flexed take-off leg, which is still backward, performs no active forward movement, the lowering brings about a parallel position of the longitudinal axes of the thighs. The arm on the side of the take-off leg, which is simultaneously lowered or moved backward, now also reaches a position parallel to the "waiting" opposite arm in the one-leg stand. Thus, during the hang style, the one-leg stand is that phase starting from which legs and arms can be used jointly and parallel to one another.

When, in the running-in-the-air style, the leading arm as well as the (opposite) take-off leg, which has been brought forward and is extended, have again reached an almost horizontal position, they are locked for a very short moment in a parallel position. Here, the 180° angle between the arms is reduced to approximately 90°, so that the "following" arm is directed vertically upward. Since the swing leg moved backward is flexed again behind the trunk in order to prepare the subsequent forward movement, the result is very similar to the hurdle seat, which is characteristic of what is known as the "second step".

During the hang style the typical hang phase is created: While the arms perform their backward and upward directed "double-arm circle", the previously extended swing leg is flexed at the knee joint up to an approximately right-angled position. This leads to a "knee stand" in the air. All the following leg and arm actions of the hang style are performed parallel and simultaneously.

The sail technique is the simplest because it involves no complex movement: The athlete immediately lifts his or her legs up into a toe-touching position upon rising up from the take-off. This makes it easy for the novice to get into a landing position early. However, the sail technique is seldom used by successful jumpers because of the difficulty of keeping the body balanced through the entire flight parabola. The jumper is likely to begin a premature rotation, and the weight in front of the hips adds impetus to his already problematic forward rotation. This large amount of total weight moves the CM out in front of the hips, and the jumper's legs quickly drop into the pit before the flight curve is completed (see Jacoby & Fraley, 1995 and Tellez & James, 2000).

Landing preparation

In the descending segment of the flight curve, both the second step of the running-in-the-air style and the hang phase of the hang style inevitably lead to the preparation for landing. In order to achieve this, in the running-in-the-air style, the rear arm catches up to the leading arm waiting in front of the body in a horizontal position. The flexed swing leg, which has been kept behind, also joins the take-off leg locked in front of the body. The results of these synchronous actions are a parallel position of both the arms and legs and a trunk that is pressed slightly forward.

Tidow (1995) emphasises that, to minimise landing loss, the legs should be kept approximately horizontal, which means that the feet
should be a little higher than the flight curve. From the point of view of forward rotation, it is then easier to achieve an optimal “diving into the sand angle” by a slight opening of the hip angle.

In the case of the hang style, the jumper forms a bundle by actively flexing at the hip joint, actively swinging through (or forward circling) both arms and bending the trunk forward. Here, the knee joints remain flexed. The position achieved during the preparation of landing, therefore, is very similar to the flight phase of the sail style (see above).

If one compares the resulting initial positions of both techniques, it becomes clear that, in the case of the running-in-the-air style, only a slight opening of the hip angle is necessary for “gaining space” when landing, whereas, in the case of the hang style, a relatively wider opening of the hip angle and an extension at the knee joints are needed.

The landing

According to TIDOW (1995), the analysis of the landing technique of long jump specialists reveals four variations, which can be differentiated according to the behaviour of the arms:
- the arms are parallel in front of the body when breaking the sand,
- the arms are laterally beside the body,
- the arms are behind the trunk,
- a “counter-arm landing” is performed.

Since, from a biomechanical point of view, the flight curve should be utilised to the greatest possible degree, which would automatically result in a deep sinking of the CM, a landing with the arms held beside the trunk would be optimal. If the arms are held that way, their partial CMs are maximally low. The lateral position of the arms, however, means that – in comparison with the “arms-behind-position” – the horizontal distance to the point of breaking the sand is smaller. From this follows a relative equality of the landing postures with the arms kept beside or behind the trunk.

As the jumper makes contact with the sand, the knees bend and flex to cushion the impact. In addition, the arms are brought forward to assist the jumper’s forward momentum and avoid falling back (see TELLEZ & JAMES, 2000).

Teaching the Long Jump

When teaching the long jump, the main emphasis should be on the approach and the take-off, whereas the flight phase deserves less attention (see FRANZ, 1986).

According to TELLEZ & JAMES (2000), when establishing an approach for beginning jumpers, it is best to do so without jumping. This way, the jumpers can isolate the approach run and develop a consistent acceleration, stride pattern and rhythm of the run through repetition. In addition, even with experienced jumpers, it is beneficial to practice the approach run without jumping to develop the consistency and rhythm of the run.

To work on the technique of the last two strides and the take-off, a short approach run of eight strides should be established. Short-run jumping allows the jumpers to isolate and emphasise the proper technique. In addition, jumpers can take more jumps, since short runs reduce the fatigue during training (see TELLEZ & JAMES, 2000).

As far as flight technique is concerned, one of the most common methods is to establish the basic elements leading to the single-stride technique, universally accepted as the most suitable for young athletes (see JARVER, 1988). This technique provides an excellent base for further technique developments. It is easy to learn and combines all essential elements without distracting the learner with complicated movements (see LOHMANN, 1997 and HILLIARD, 2007).

The long-jump teaching method proposed by WENSOR (2010) consists of the following steps:
- Standing long jump into the pit (aims: to give the athletes confidence in safely landing in the pit, to teach a safe two foot
landing, to teach the athletes how to use the arms to assist the distance of the jump);  
- **Jump into the pit from a short approach – one to two feet** (aim: to introduce the basic long-jump action using a one-foot take-off and two-feet landing);  
- **Long jump for distance from a longer approach** (aim: to allow the athletes to attempt the full long jumping action from a longer approach).

**Training for the Long Jump**

Apart from the development of running speed for the approach, the development of strength, specifically jumping power, is crucial to a long jumper’s success. In developing strength, the emphasis should be on the specific qualities needed in jumping. According to TELLEZ & JAMES (2000), these qualities are:  
- **Power** - the maximum available ability of the leg and back muscles during approach and take-off;  
- **Jumping Endurance** - the muscular ability to withstand multiple bounding and jumping;  
- **Special Strength** - bridging the gap between sheer strength and explosive power, it gives the jumper control over all mechanics of the back and leg muscles used in horizontal jumping.

When preparing young athletes, coaches should focus on the following areas:  
- running mechanics and speed development;  
- postural strength, body weight, strength and power activities;  
- balance, coordination and agility activities;  
- leaping, jumping, hopping related activities and drills;  
- general conditioning.

As long jumping is a single-leg skill, a number of activities and drills must be rehearsed on a regular basis and the muscles and tendons and ligaments surrounding the feet, ankle, knee and hip joints must be sufficiently strengthened and mobilized to withstand the forces involved and constant loadings. The primary focus of all take-off drills is to develop the capacity to run at a rhythmical, optimal speed and experience the unloading during the take-off. This is achieved by modifying the running action by way of lowering the CM into the penultimate stride before converting this into an active, upward and forward take-off. However, it is critical that these actions are not overemphasised as they must be part of the whole movement pattern and should be as natural as possible (see HILLIARD, 2007).

As far as special strength training is concerned, the most productive and prominent strength training method used by elite jumpers today is plyometrics in conjunction with weight training (see TELLEZ & JAMES, 2000).

**Plyometrics**

Plyometric drills and exercises combine endurance, coordination, and pure strength training, through which jumpers can produce better explosive reaction movements. However, the biggest benefit of this type of training is the development of stretch reflex in the muscles involved during take-off and flight.

The goal of jumping drills is to develop the neuromuscular system so that strength gains can be incorporated into speed movements. Two methods of plyometrics are used: long jumping and short jumping. Long jumping takes place during the first six weeks in order to condition the athlete and build speed endurance. These jumps can be subdivided into low-intensity long jumps and high-intensity long jumps. Both types of jumps are done over a distance greater than 30m, but they are done at a lower amplitude or as quickly as possible, respectively. Short jumping is done over a shorter distance (less than 30 meters) very explosively. Plyometrics should be done two times per week, allowing several days rest in between. Mondays and Thursdays or Mondays and Fridays before weight training is preferable.

Plyometric jumping exercises include:  
- **Long-jumping exercises** - at low intensity (e.g., high skips, alternate bounding, single- and double-leg hops, gallops, bound-
Period 3:
Week 9: Short jumping: 3 x 2 x 6 reps or 3 x 2 x 30m
Week 10: Short jumping: 4 x 4 x 6 reps or 4 x 4 x 30m
Week 11: Short jumping: 5 x 4 x 6 reps or 5 x 4 x 30m
Week 12: Short jumping: 2 x 6 reps

Free-weights, medicine-ball exercises, running

The development of a jumper’s explosive strength, or power, can be supported by the following free-weight exercises:

- **Squat movements** - back squat (full, half-jump, static, dynamic), front squat (full, static, dynamic);
- **Pull movements** - cleans (mid-thigh pull, below-knee pull, full pull, clean from mid-thigh, clean from below the knee, full clean), snatches (mid-thigh pull, below-knee pull, full pull, snatch from mid-thigh, snatch from below the knee, full snatch);
- **Press movements** - bench (incline, behind-the-neck-press: seated, push), jerk (split, power).

The jumper’s body can also be effectively developed by medicine-ball exercises:

- **Upper body** - chest pass, overhead pass, underhand pass, seated rotations, kneeling pass, seated roll back-and-up pass, seated cross-body scoop, side-overhead-extension pass, bend over between-legs pass (for details see TELLEZ & JAMES, 2000);
- **Lower body** - thigh bounces, foot passes, heel passes, leg-raise rollover – put back, seated squad lifts, lying hamstring lifts, “fire” balls, ninety-degree “drives” (for details see TELLEZ & JAMES, 2000).

The following types of running workouts should also be a part of the long jumper’s training schedule:

- **Speed Endurance** - 5 x 100m with 5-10 min rest, 3 x 150m with 5-10 min rest, 2 x 200m with 10 min rest, 1 x 400m with 10 min rest;
- **Tempo Endurance** - 6 x 200m with 2 min rest, 4 x 300m with 2 min rest, 50m-100m-
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150m-200m-250m-300m walking the same distance for rest;

- **Strength Endurance** - 6 x 100m hill, 6 x 15-20 sec resistance running, 2 x (4 x 15-20 sec) jump rope;

- **Power Speed** - 6-8 x short hill runs 50-60m, 6-8 x 30m assistance running, 6-8 x 10 sec fast rope jumps;

- **Endurance** - 15-45 min of running at a steady pace.

**Sample training programme**

With all the above listed types of workouts in mind, TELLEZ & JAMES (2000) propose the following training programme for long jumpers:

**Weeks 1-4: Technique, Speed and Strength**

**Monday:** 3 x 300m with 200m of walk or jog recovery, drills: 3-6 x 60m of A-skip the free leg swings up until the thigh is parallel to the ground and the heel of the free leg meets the hips then extends down to meet the ground), and B-skip (same as A-skip, except that the free leg extends straight forward before landing), 3-6 x 60m of high knees, event-specific drills, weights.

**Tuesday:** Temporuns: set 1 – 100m + 100m + 100m, set 2 – 100m + 200m, set 3 – 100m + 100m + 200m, set 4 – 100m + 200m, set 5 – 100m + 100 m+ 100 m (50m jogging between reps, 100 m walking between sets).

**Wednesday:** Power Speed (progresses to power technique): 6 x 20m of A-skip into 20m sprint, 6 x 20m of B-skip into 20m sprint, 3 x 60m of running bounds, 6-10 x 50m, event-specific drills, weights.

**Thursday:** 6-8 x 200m, with 200m of walk or jog, drills: same as Monday.

**Friday:** 8-10 x 150m, with 150m of walk recovery, weights.

**Weeks 5-12: Speed, Strength and Endurance**

**Monday:** 2 x 300m + 1 x 200m with 10 min recovery, technique drills, weights.

**Tuesday:** 8 x 100m at 80-90% speed, light technique drills.

**Wednesday:** Jog and stretch, weights, event technique.

**Thursday:** 3 x 200m, light technique drills.

**Friday:** 5 x 150m with full recovery, weights.

**Weeks 13 and on: Competitive phase**

**Monday:** 2 x 200m fast, with full recovery, light technique drills.

**Tuesday:** Full technique drills, weights, 6 x 60 m at 60-70%, with full recovery.

**Wednesday:** Jog and stretch.

**Thursday:** 3 x 150m fast, technique drills, weights.

**Friday:** Rest.

**Saturday:** Competition.

Although the various drills and workouts presented above can enhance the long jumper’s performance, TELLEZ & JAMES (2000) hold that the majority of training time for the long jump should be devoted to developing a technically correct approach and take-off. This is because of the strong correlation between correct technique or execution of the approach run and take-off and jumping performance.

**The Triple Jump**

The triple jump is the only jumping discipline in track and field that does not require a big explosive effort, but is actually a continuous sequence of movements, with each phase dependent on the preceding one. Although each element can be isolated, it is important to keep the total activity in mind. This means that the three distinct jumping phases – the hop, the step and the jump - must flow into one another.

To be successful, triple jumpers must possess above-average ability in sprinting and jumping, and at the same time possess powerful muscles and good motor skills (see HAYES, 2000).

Each of the three jumping phases includes a take-off, flight and landing. In the hop, the take-off and landing are performed on the same foot, in the step the landing takes place on the opposite foot, and the jump is performed simi-
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lar to the long jump. While the hop and jump are relatively easy to master, the step is a more difficult skill (see HAYES, 2000).

Since the three jumping phases form a unit, understanding the later phases requires going back to the hop phase, and especially to how the landing occurred at the end of the hop – as it almost totally dictates what can and cannot occur in the step and later in the jump. As with other jumping events, the height of the hips into the hop and then into each succeeding phase will create efficiency of distance. The higher the hips, the greater the flight curve. The angle of the hips going into each flight phase must be as low as possible. As the jumper’s velocity diminishes through each phase, the take-off angle will automatically increase through the step and jump phases. Elite triple jumpers will average under 14° for the hop and step and then move up to a little under 22° for the jump phase.

Balance and rotations are always a product of forward rotation at the take-off of each jump phase. Here angular momentum is in a frontal or horizontal direction. Lateral rotations are generally caused by an uneven arm thrust or by landing with inappropriate foot support or placement. Finally, an efficient landing in the jump phase is achieved by keeping the hips on the flight curve as long as possible. Good landings are a product of the take-off from the step phase. The objective is to reduce forward rotation as much as possible (see JACOBY & FRALEY, 1995).

**Triple-jump Technique**

**Approach and take-off**

The triple jump approach should be long enough to allow the jumper to accelerate to nearly full velocity. At the same time, the approach must be relaxed so that the jumper is under control. If the approach is too slow, the jumper will lose momentum in the later phases of the jump. If it is too fast, the jumper will be unable to control the legs and keep them from collapsing. The length of the approach run should be 30-40m with beginning jumpers using the shorter end of the range (see HAYES, 2000).

HUTT (1989) divides the triple-jump approach into two phases. The first, or acceleration phase, consist of 8-16 strides. The second phase, the take-off preparation, begins between 6 and 4 strides out from the take-off board. This phase is characterised by an increase in stride frequency and a straightening of the trunk. During the final strides, the knee lift is higher. Both the increased stride frequency and higher knee lift lead to an approach rhythm that prevents a lowering of the CM.

The triple jumper should not, as in the long jump, prepare for a high-angle take-off from the board, but instead should concentrate on accelerating well past the board. Any loss in velocity at the take-off board should be kept as small as possible since a low velocity at this point has negative effects on the initial velocity of the two subsequent take-offs.

The final approach velocity significantly contributes to performance. However, the statistical correlation between the two is not as great as in the long jump. Jumping power and technique have considerably greater influence on final performance in the triple jump than in the long jump (see HUTT, 1989).

Following the take-off preparation phase, the triple jumper begins the jump by planting the foot of the take-off leg flat on the take-off board. Since for the triple jump, the horizontal speed component ratio is 3:1, a good performance requires a very low take-off angle, well under 16°. According to JACOBY & FRALEY (1995), there is little need for a complicated transition from horizontal velocity to lift. The planting foot is more directly under the hips than in other jumping events. During the take-off, the trunk is kept upright while the arms are moved as in sprinting. A double arm action should be avoided at this point since it would result in a reduction of horizontal velocity (see HUTT, 1989).

**The hop**

The objective in the hop is to go forward and up (not up and forward as in the long jump), i.e., the emphasis should be on forward motion rather than vertical. Vertical forces occurring at
this time would cause a reduction of speed on landing. The parabola for the hop should be low going up and consequently low coming down (see JACOBY & FRALEY, 1995). The aim should be to keep the body upright and rotate the heel of the hop leg high up under the buttocks and then extend it as far forward as possible. The athlete should feel that he or she is running off the board (see HAYES, 2000).

The swing leg is brought forward quickly as a short lever, the knee joint forming an acute angle. At the moment of take-off, the knee of the swing leg should have reached hip height where it is held momentarily. When changing the position of the legs, the swing leg is pulled backward as a long, almost extended lever. Simultaneously, the take-off leg is brought forward as a short pendulum (with an acute knee joint angle) all the way to a high, “reaching out” position (see HUTT, 1989).

To minimise any possible braking effect, the jumper must make ground contact just ahead of the CM (hips). To do this, the jumper must be patient, waiting for the ground to come up to the foot rather than reaching for the ground. The athlete should not rush the extension of the knee and hip (see JACOBY & FRALEY, 1995).

Landing on the toes interrupts speed and flow, whereas landing on the heel can cause heel bruises. Also, a heel landing makes it more difficult to control the forward movement. The landing should therefore be very slightly on the heel, followed by a “rolling” action of the foot (see HAYES, 2000).

The grounding foot must be very active. This foot should move backward as rapidly as possible in a short downward and backward “pawing” motion (see JACOBY & FRALEY, 1995 and HUTT, 1989). Foot contact with the ground should be minimised, i.e., the jumper must get onto and off the ground in the shortest possible time. HUTT (1989) recommends to visualize the ground moving backward underneath the athlete and then to aim at bringing the foot down to the ground moving faster than the ground is moving in order to maintain as much horizontal velocity as possible. He also points out that the foot of the take-off leg is better prepared for the high impact with the ground if the sole of the foot is tensed by drawing the big toe towards the body.

**The step**

The step is the most troublesome and difficult to manoeuvre and the most difficult to integrate into the overall jump. It is a combination of a supported landing and then a jump, with the athlete moving from one foot at take-off to a landing on the opposite foot (see JACOBY & FRALEY, 1995).

Just before the hop is finished, the arms are pulled back again in preparation for the step (see HUTT, 1989). At the take-off into the step, the ground is “kicked backward” with the extended leg while the swing leg (opposite of the hop leg) is being brought forward quickly and powerfully, the knee angle being more obtuse than during the take-off into the hop. At the moment of take-off, the thigh should have reached a horizontal position and formed a right angle with the lower leg. The trunk is kept upright (see HAYES, 2000).

During the flight phase, the thigh of the swing leg should be locked beyond the horizontal and form a right angle with the lower leg. When the arms reach backward in order to perform a double-arm swing, the trunk, because of the law of action and reaction, is inclined slightly forward. This inclination can be avoided by moving the arms in a sprinting action (see HUTT, 1989).

The leg that has been the take-off leg during the hop and step is bent at the knee and moved far backward in a relaxed way. The triple jumper should take care that the foot of the take-off leg is not swung backward and upward beyond hip height as this would cause a forward rotation at the moment of the reversing movement (when the leg is brought forward quickly to function as the swing leg during the jump). A forward rotation at this point would have a negative influence on body posture and the potential jumping distance (see HUTT, 1989).
Following HAYES (2000), there are two methods of executing the step:

1) The body is kept upright and the upper body is basically perpendicular to the ground. The upper leg is parallel to the ground, and the lower leg is positioned so that the toes are just ahead of the knee. This is done so the jumper can “ride” the leg, or hold it up. At the last instant, the jumper extends the leg and reaches out as far as possible. This extension is aided by pulling the arms back to prepare for double-arm action in the jump phase. Again, the foot should hit the ground almost flat-footed. The heel “barely” leads the action.

2) The jumper lets the lower leg extend ahead of the knee during the step. This requires the upper chest and head to be stooped slightly forward in an effort to hold the foot up. As the foot is extended, or held forward, the arms are drawn behind the back to prepare for the jump phase.

As the body begins to descend, the lead leg, which has been held at 90°, begins to extend out in front of the jumper. At the completion of this extension, the leg is actively pulled down and back so there is an active foot plant (see JACOBY & FRALEY, 1995).

The jump

The take-off for the jump is introduced at the end of the flight phase of the step, by placing the foot of the swing leg (which now becomes the take-off leg) on the ground with an active downward and backward pawing motion, the knee and hip joints of the take-off leg being extended. The swing leg forms a right angle at the knee joint and is brought forward quickly and powerfully as a long lever (see HAYES, 2000).

At the moment of take-off, the thigh of the swing leg should have reached the horizontal position. This is only possible if, during the step, the swing leg has not been kicked up too high at the back. Also at this moment, the body is straightened, which is a prerequisite for performing a hang-style jump. Many triple jumpers perform a float-style jump, which is particularly useful if the flight phase is short. The running-in-the-air, or hitch-kick, style is very rare since, in most cases, the horizontal velocity at the take-off for the jump is too low (see HAYES, 2000 and HUTT, 1989).

In the jump, the horizontal speed of the support phase of the step must now be converted into a much more vertical component than was present in either the hop or the step (see JACOBY & FRALEY, 1995). This means that the jumper should try to get as high as possible, with his or her arms (both of which are used in the hang style) reaching up and then extending forward. The feet are extended so that the heels lead the way into the pit (see HUTT, 1989).

By the time of the jump, the majority of the jumper’s horizontal velocity build up in the approach has been lost through the hop and step phases. To counteract this, the jumper’s emphasis must be on vertical velocity. The impulse at take-off is provided by the swinging free leg, with special attention to the motion of the double arms, which are pulled through with a punch (see JACOBY & FRALEY, 1995; HUTT, 1989).

No matter which technique is used during the jump phase, it is important that a “distance-gaining” landing is well prepared for. Shortly before landing, the arms are swung far backward so that the feet can be simultaneously lifted higher. At the moment of breaking the sand both arms are swung powerfully forward to counter the tendency to fall backward. A variation of landing technique is characterised by the movement of only one arm backward and upward. This is to introduce a sideways landing. Here the athlete’s trunk is inclined far forward. After completing the landing the athlete leaves the pit towards the front (see HUTT, 1989).

Hop, step and jump ratios

The breakdown of the triple jump performance into hop, step and jump phase distances has helped to examine how an athlete distributes his/her effort and to identify areas of strength and weakness. The contribution of each phase to the overall performance is determined by ex-
pressing each phase distance as a percentage of the effective distance. The three phase percentages form a phase ratio that describes the athlete’s distribution of effort in any given jump (see GRAHAM-SMITH & LEES, 2000).

The ratio between the hop, step, and jump phases in the triple jump has been dealt with in quite a number of articles (see ECKER, 1987 and HAY, 1994, 1995, 1996, 1997, 1999). This is not surprising because success in the triple jump depends very much on how the athlete distributes his or her effort over the three phases (see HAY, 1997). While normally there is an equal number of triple jumpers using a hop-dominated or a jump-dominated technique, there is also the case for the jump-dominated technique (see HAY, 1999).

It is widely agreed that there is no single optimal distribution of effort that suits all triple jumpers. Research indicates that individual athletes have their own optimal phase ratios dependent on factors such as speed, strength, technique, anthropometric measures and psychological profile. As these factors can also be related to temporal changes, i.e., training age, growth and experience in the event, there may well be a dynamic nature to the optimal distribution of effort. For example, novice athletes may have an optimum phase ratio that is likely to be different from that of an elite athlete jumping in excess of 17m.

GRAHAM-SMITH & LEES (2000) conducted a study to investigate developments in approach speed and phase distances with respect to increases in performance and to examine the existence of “dynamic” optimal phase ratios. The approach speed and phase distances data from all triple-jump performances at major domestic competitions in Britain from June 1991 to August 1996 were examined (343 jumps, 156 by female athletes and 187 by male athletes). The levels of ability ranged from Junior and Senior British National squad members to world-class performers. Among the women, the effective distance ranged from 11.73 to 14.94m, while the men’s performances ranged from 14.44 to 17.43m.

As with other studies examining wide ranges of performance, strong positive relationships were found between speed and phase distances on the one hand and the effective distance on the other. However, noticeable stepwise developments were observed as distance increases. This supports the notion that an “optimal” phase ratio is a dynamic phenomenon and will change with respect to developments in speed, strength, and experience in the event.

**Teaching the Triple Jump**

*Introducing the movement*

According to HAYES (2000), after studying triple-jump films and a brief demonstration of a standing triple jump with the emphasis on the leg movements only, prospective triple jumpers should be instructed to do a few standing triple jumps. Jumps should be done with each leg to decide which is most comfortable. Instead of going for distance, an even distance for each phase and learning the leg movements of each of the three phases should be emphasised. Not trying to extend the reach too far can help in keeping the jump under control. It will also keep learners from leaning too far forward during the jump and give them time to have an active phase leg. The phase leg should be developed next, by having the jumper stand on one leg and jump up, making the standing leg rotate under the buttocks and reach out in front before landing. The athlete should alternate legs for this drill so that coordination is developed in both legs.

As mentioned above, the step phase is the most difficult to master. The hop is relatively easy to perform, but the recovery is difficult. The athlete usually will not have problems learning the basics of the jump phase. The greatest progress in triple jump training will come from improving the step. However, one must remember that each phase is dependent on the others.

*Bounding exercises*

The next stage of development comes through bounding exercises, which, in the beginning, should be done for control rather than for strength. Later, strength (endurance) can
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be included. The main exercises used at this stage (see HAYES, 2000) are:

- **Hopping exercise** - This should be done with both legs (R-R-R-R . . . or L-L-L-L . . .). In the beginning, it is done for about 25m with each leg. As the jumper grows stronger and more confident, the distance is increased. The jumper’s body should be upright throughout the hopping. Beginners should do two sets of 25m of hopping on Monday, Wednesday, and Friday (three days a week).

- **Step exercise** - This is R-L-R-L-R. . . . Again, the upright body and bounce in the legs should be emphasised. The beginner just reaches out as far as he or she can, being careful not to lead with the toes. The landing is flat-footed, with a “pawing” action just before the foot strikes the ground.

- **Hop-to-step exercise** - This exercise helps the jumper in changing from the hop to the step. The drill is R-R-L-L-R-R . . . It is beneficial if two or more jumpers work together, as the competition tends to make the jumpers run faster and stretch farther. The triple jumper works on the jump phase by doing pop-ups, just like the long jumper. The pop-up should be done from a short approach and using the hang style, since the time in the air is too short for a good hitch-kick.

**Running and jumping exercises**

The next step is to incorporate a short run with the jump. Exercises helpful here (see HAYES, 2000) are:

- **Running over low hurdles** - The hurdles should be spaced at high-hurdle distance and “three-stepped.” This is done at least twice a week.

- **Jumping over low hurdles** - The hurdles should be spaced apart to allow an even distribution, or the hop, the step, and the jump. The athlete should use a three- or five-step approach. This gives some speed but not enough to cause a total breakdown of the step phase. The emphasis should be on a “level flight” during each phase, keeping the body upright. If the jumper gets too high in a phase, the landing leg will break down, which curtails momentum for the next phase.

**Arm action**

The next step is deciding what type of arm action should be used. Some jumpers use single-arm action in the hop to maintain speed, and use a double-arm action in the step and jump (see HAYES, 2000).

At this stage, the athlete should be ready to attempt the complete triple jump. To start, a seven-step approach should be used (under control) and the hop phase should be stressed, with an easy step and jump included. The hop should be relatively short so it does not cause the jumper to break down. Also, the jumper should avoid getting too much height, because this causes a jarring effect and can lead to a breakdown, too. The head should be level, with the eyes focused straight ahead. The athlete should attempt to go through the complete triple jump to learn extension in each of the three phases (see HAYES, 2000).

**Lengthening the approach**

The final phase of instruction is to lengthen the approach. A distance of about 35m should be adequate. To begin with, a controlled run should be used. As the athlete is able to use it, the speed should be increased (see HAYES, 2000).

**Timing, rhythm and kinesthetic feel**

TODD (1998) points out that important to the development of any triple jumper is an understanding of the feel or rhythm of the event. The athlete must clearly understand how the event flows from one segment to the next when done correctly. It is crucial that the coach begin instruction with a whole-part-whole teaching philosophy. The novice triple jumper must develop the kinesthetic awareness of the whole movement before instruction progresses to the individual parts. Without knowledge of the whole, the individual parts are meaningless. Hand in hand with developing a “feel” for the event is the need for the athlete to get accurate feedback from the coach and from his/her personal feedback system (i.e., the sensory perceptions of the in-
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Training for the Triple Jump

Triple jump drills

HAYES (2000) recommends the following drills to be used as part of an overall triple-jump training programme:

- **Standing triple jump** - The athlete faces the long jump pit and places a mark about 6-7.5m from the pit. From this mark, the jumper does a standing triple jump and lands in the pit. Next, the hop, step, and jump distances are marked. Concentration should be on knee drive for the hop and step, and arm action (both arms driving) for the jump. The distance should be 2.4-3m for the hop, 3.4-4m for the step, and 3.7-4.6m for the jump. Anything between 9 and 11m is a good distance for male beginners. Women's distance should be proportional.

- **Hurdle hopping** - Four to eight low hurdles are placed 1.5-1.8m apart. The jumper, with the aid of the double-arm upswing, leaps over the hurdles with both legs together and with the knees brought up to the chest in order to clear the hurdle. As strength increases, the height and the number of hurdles can be increased. Hurdle height and the distance between the hurdles should be adjusted for individual jumpers.

- **Split-squat** - This is a squat jump in which the legs are alternated. The arm action should be disregarded because this is not a triple jump action. The front knee should be brought up close to about a 90º angle, with a slight bend in the back leg. Then the legs should be alternated.

- **Double-leg jump** - The jumper should drive off both legs with the use of his or her knees and ankles. As soon as the jumper is off the ground, the left knee is driven up as high as possible, beyond parallel with the ground. Landing takes place on both feet. Then the athlete should settle down and drive right back up this time, lifting the right knee as high as possible. The foot should be kept under the knee while using arms vigorously.

- **Hopping drill** - The jumper should stay on the same leg, with a single-arm action (unless double-arm action is normally used). As the jumper lifts off the jumping leg, he or she brings the thigh to parallel and, as that leg returns to the ground, the opposite knee comes from the behind (split) position and forward as it would in the step phase.

The following drills are the core of the triple-jump training programme. They help the jumper to learn to perform each phase of the triple jump correctly. At the same time, they give the jumper the thrill of competing. The drills emphasise each phase and the movement from one phase to the next.

- **Bench drill #1** - The benches are about 30cm wide, so that good foot placement can be taught, and about 45cm high. The jumper bounces up on to the bench and then drives off. The sequence of this drill is hop-step-hop-step-hop-jump. The starting leg should be alternated so that both legs are developed equally. The sequence is: Right leg (take-off in front of the first bench) – right leg (landing on and take-off from the first bench) – left leg (landing and take-off from between the first and second bench) – left leg (landing on and take-off from the second bench) – right leg (landing and take-off from between the second and third bench) – right leg (landing on and take-off from the third bench) – both legs (landing after the third bench and take-off into the pit).

- **Bench drill #2** - This drill develops the step phase and encourages a bounce action. It has the jumper stepping over the benches with another alternate step between the benches. The step between benches is a real jump step. The legs can be reversed in this drill, too. The sequence is: Left leg (take-off in front of the
first bench) – right leg (landing after the first bench) – left leg (landing and take-off in front of the second bench) – right leg (landing after the second bench) – left leg (take-off in front of the third bench) – both legs (landing after the third bench).

• **Bench drill #3** - This is a pop-up drill. The athlete runs to and then jumps off of the bench into the pit. It requires only a short run and therefore does not fatigue the jumper. In fact, a five-step approach can be used for all the drills. The sequence is: Right leg (take-off in front of the first bench) – right leg (landing on and take-off from the first bench) – landing in the pit.

Each of the drills ends with the jump phase into the landing pit. The heels lead the jumper into the pit.

**Weight training**

Weight training is a major portion of the triple jumper’s training routine. Weights should be lifted regularly – at least three times a week. HAYES (2000) proposes the following programme:

- **Knee extensions:** 3 x 10 reps
- **Leg curls:** 3 x 10 reps
- **Incline sit-ups:** 3 x 15 reps
- **Leg presses:** 4 x 10, 7, 4, 2 reps
- **Toe raises:** 3 x 20 reps (using a 5 x 10cm board under the toes)
- **Half-squats:** 3 x 8 reps (use one-half of body weight)
- **Split-squats:** 2 x 10 reps (use one-fourth of body weight)
- **Knee raises:** 3 x 15 reps
- **Step-ups:** 3 x 10 reps (with heavy weight)

**Developing a training programme**

According to HAYES (2000), a training programme for triple jumpers could look as follows:

### Early season (fall)

- **Monday:** Grass run (5-8km) + 100m-200m-300m-400m 200m-100m/jog same+ Weights
- **Tuesday:** 10 x 200m, with 200 jog interval + Running stadium steps with weightjacket + Easy take-off drills (just to get the arm technique)

### Wednesday

- 8 x 300m, with 300m jog interval + 6 x 75m easy + Weights

### Thursday

- Grass run + Running stadium steps + Take-off drill

### Friday

- Grass run + Weights

### In season

- **Monday:** Bounding: 3 x 25-100m of hopping (the regular hopping leg should be used twice and the other leg once; if an athlete is having trouble making the transition from one phase to the other, he or she should use 3 x 50m of R-R-L-L-R-R, as this incorporates the bounding and adds practice of changing from the hop to the step; also, this drill helps to improve the capabilities of each leg) + Running: 2 x 300m for endurance, 6 x 75m for speed + Weight lifting
- **Tuesday:** “Drill” day: Bench work (6 good drills of each of the 3 exercises) + Running 10 x 3 low hurdles set at high-hurdle spacing (10m between) + Running 6 x 100m or work on the actual approach + Running stadium steps (5 times wearing a weight jacket) + Practicing the actual triple jump take-off (at a reduced speed, correct technique is stressed, especially the correct arm action).
- **Wednesday:** The same basic workout as Monday, but running should be 5 x 25m, 5 x 35m, and 5 x 50m.
- **Thursday:** Same as on Tuesday.
- **Friday:** Same as Monday, except much more relaxed and easy.

**Performance Development**

Since the 1990s, performance development in the horizontal jumping events has stagnated. The current world record in the men’s long jump (8.95m by Mike Powell (USA) in 1991) is over 20 years old and the world record in the women’s long jump (7.52m by Galina Chistyakova (URS) in 1988) was set almost 25 years ago. Although the situation in the triple jump
According to OSOLIN “it is universally known that an acceleration of 10.0 m/sec produces a long jump of 8m, of 9 m/sec a 7m, and of 8 m/sec a 6m result and that a triple jumper’s hop should not be greater by more than one metre, theoretically, than his jump. The prime slot earmarked for improvement is of course the step; by equating its length with that of the jump even a 7m long jumper should be ideally capable of 19m, with increments of 7m + 6m + 6m. It’s within the realm of an athlete’s physical capabilities.”

From the current point of view, OSOLIN’s prognosis seems interesting on a theoretical level but there is nothing in practice to support his calculation. The last triple jump over 18m was achieved in 1996 (18.09m by Kenny Harrison (USA)). So, before thinking of jumping 19m, it would be more realistic to think about how to achieve more 18m+ jumps and to stabilise performances.

According to this calculation, a top male long jumper with a best of 8.35m, would, given the correct training, be capable of 18.50m in the triple jump and thus achieve a PSP factor of 1.80m.

With a PSP factor of 2.60 m, which is an achievable target, 19m thus be reached by an 8.20m long jumper, if he can start the hop at a speed of 10.5 m/sec and limit the fall in acceleration to 9.5 m/sec for the step and 8.5 m/sec for the jump, producing increments of 7.22m + 5.60m + 6.18m (taking as ideal increments of 38% + 29.5% + 32.5%).

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Biomechanical Analysis of the Horizontal Jumping Events at the 2009 IAAF World Championships in Athletics

by Luis Mendoza and Eberhard Nixdorf

Transcribed from the original German by Jürgen Schiffer

ABSTRACT

The 2009 IAAF World Championships in Athletics in Berlin presented German sport scientists with a rare opportunity to study the world’s best athletes in a top-level competition at a venue close to home. A team of 18 researchers from six institutions around the country planned, organised and carried out a major biomechanics research project at the championships with the support of the German athletic federation (DLV) and the IAAF. The project’s objectives included making detailed analysis of the finals of the horizontal jumping events for both men and women. The approach velocity for each attempt was measured using a laser measurement device and 2D video analysis based on video recordings made with a high-speed video camera and was carried out on the best attempt by the top eight placers in each event. This report, prepared specially for NSA, provides analysis and commentary on the data obtained by the project team, with sections on each of the events. The authors conclude with seven points that generally confirm the current technique models.

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Introduction

The 2009 IAAF World Championships in Athletics in Berlin presented German sport scientists with a rare opportunity to study the world’s best athletes in a top-level competition at a venue close to home. A team of 18 researchers from six institutions around the country planned, organised and carried out a major biomechanics research project at the championships with the support of the German athletic federation (DLV) and the IAAF.
The project’s objectives included making detailed analysis of the long jump and triple jump events for both men and women. Data on various parameters characterising the two events were collected using electronic measurement and kinematic techniques and then analysed in order to gain insights on the current state of the technical performance at the highest level of competition. This report presents the results and commentary on the research.

Methodology

Laser measurement of approach velocity

The approach velocity for each attempt in all the four events studied was measured using a laser measurement device (LAVEG Sports) made by Jenoptik. The instrument was placed on the right side of the runway at a distance of about 63m from the take-off board for the long jump competitions and at about 54m for the triple jump competitions. The laser beam was directed at the lumbar region of the athletes’ back.

The distance from the measuring instrument to the target object (the athlete) was determined at a sampling rate of 50 Hz. The measurement signal was recorded using software developed by the research team (LSpeed 2.2) and further processed. The measurement values were smoothed using a Butterworth low-pass filter (cut off frequency 5 Hz).

The approach velocity was calculated as mean velocity for the intervals normally measured in previous studies (1-16m or 6-1m in front of the take-off board) by simple difference formation.

Kinematography

The kinematic characteristics of each attempt were collected using 2D video analysis. The video recordings were made with a high-speed video camera (Basler pilot piA640-210gc) at a frame rate of 150 frames/sec and a resolution of 640x480 pixels. The camera was placed in the stands at a distance of about 63m from the plane of motion and at a height of 31m above the runway. It was panned horizontally for recording the movement during the last five strides through to the landing. The image section in the orthogonal plane of the camera as related to the plane of motion was approximately 3.80m wide and about 2.80m high. The video signal was fed directly into a laptop via a GigE connection and stored.

A detailed analysis was made of the best jump by the top eight placers in the finals of each of the four competitions. Most of the movement characteristic data were collected by sampling 20 points of the athlete’s body (toe, heel, ankle, knee, hip, shoulder, elbow, wrist and hand on the right and left, neck and head) and two markers on the runway (one in front of and another one behind the athlete).

In the long jump evaluation, seven images were digitised: four from the approach (the first ground contact each of the fourth to last to the final approach stride), two from the take-off (the first and last ground contacts) and one from the landing (the first ground contact) (see Figure 1).

In the triple jump evaluation, a total of nine images were digitised: two from the approach (the first ground contact of the penultimate and final approach strides), two from the take-off (the first and last ground contacts), two from the hop-step transition (the first and last ground contacts), and two from the step-jump transition (the first and last grounds) and one from the landing (the first ground contact) (see Figure 2).

By digitising three joint points (ankle, knee and hip) in four to six images of the respective support phases, measurement was made of the minimal knee angle during the take-off for the long jump and for the step and jump in the triple jump.

The scanning of the image coordinates was carried out with the aid of the SIMI Motion 7.5 computer program. The coordinate transformation was made using a specially developed program that calculates the image scale, depending on the distance of the image object to the origin of the coordinate system (orthogonal to the camera in relation to the plane of motion), and corrects the perspective image dis-
Biomechanical Analysis of the Horizontal Jumping Events at the 2009 IAAF World Championships in Athletics

tortions depending on the angle of the camera in relation to the plane of motion. This way the position of each point relative to the scanned markers and thus in relation to the calculated original coordinate can be calculated. Based on the transformed coordinates for each image, the body centre of mass (CM) (according to the center of gravity definition given by DEMPSTER, 1955) and all kinematic features described below were calculated.

Figure 1: Digitised pictures of the long jump

Figure 2: Digitised pictures of the triple jump

**Definition of evaluated features**

To describe and compare the occurrence of the features described below, the group mean values and dispersion parameters such as standard deviation and the variation are used. Furthermore, the theoretical relationships between the different characteristics given in Tables 1a – 1d (which are derived from recognised biomechanical models, e.g. BALLREICH & BRÜGGEMANN, 1986; HAY et al., 1986) are quantified by calculating the correlation coefficients (Pearson Correlation). These correlation coefficients must be understood primarily as a descriptive measure to clarify the relationships between the characteristics within the groups studied and only partly as evidence of a causal relationship.

**Table 1a: Definitions of the studied distance characteristics**

- **Official Distance** – The distance given in the official final results.
- **Effective Distance** – The distance measured from the tip of the foot at take-off to the mark in the sand closest to the take-off board.
- **Take-off Loss** – The distance from the tip of the take-off foot at take-off to the front edge of the take-off board.
- **Landing Loss** – The distance from the point of first ground contact of the heels in the landing pit to the mark in the sand closest to the take-off board if the athlete falls backward during the landing and his/her buttocks make contact with the sand behind the heels.
Table 1b: Definitions of the studied take-off preparation characteristics

- **Stride Length** - The length of the third to last, penultimate and last approach strides (3last, 2last, 1last) in the long jump and the last two approach strides (2last, 1last) as well as the hop and step in the triple jump as measured from the tip of the support foot in one picture to the tip of the support foot in the next picture (Similar to the long jump, the jump length in the triple jump is measured from the tip of the foot at the point of take-off to the mark in the sand closest to the take-off board).

- **Relative Difference / Length** – The percentage length difference between one approach stride and the previous one in the long jump or the percentage lengths of the hop, step and jump as related to the effective distance in the triple jump.

- **Lowering of CM** – The difference between the height of the athlete’s centre of mass at the beginning of the take-off and the median CM height at the beginning of the third to last and penultimate strides.

- **Velocity 3last, 2last, 1last** - The velocity of the athlete’s centre of mass during the last three approach steps measured as average stride velocity from the first ground contact of one stride to the first ground contact of the next stride.

Table 1c: Definitions of the studied take-off characteristics

- **Take-off Velocity** – The horizontal velocity of the athlete’s centre of mass at the moment of the take-off.

- **Velocity Loss at Take-off** – The change in the horizontal velocity of the athlete’s centre of mass at the moment of take-off in the long jump or during the support phase of the hop, step and jump in the triple jump.

- **Vertical Velocity at Take-off** – The velocity in the vertical direction of the athlete’s centre of mass at the moment of take-off in the long jump or in the hop, step and jump of the triple jump.

- **Take-off Duration (of the support phase)** – The time period of the take-off in the long jump or the support of the hop, step and jump in the triple jump.

- **Inclination Angle** – The angle measured from the vertical to the line between the heel of the take-off foot and the athlete’s centre of mass (see figure).

- **Trunk Angle** – The angle measured from the vertical to the axis of the athlete’s trunk at the beginning of the take-off in the long jump (see figure below) or at the beginning and end of ground contact in the hop, step and jump in the triple jump.

- **Trunk Rotation** – The angle of rotation of the axis of the athlete’s trunk from the beginning until the end of the take-off in the long jump (see).

- **Minimum Knee Angle** – The smallest angle of the knee of the jumping leg during the take-off in the long jump or the step and jump in the triple jump.

- **Angle of Projection** – The angle the movement of the athlete’s centre of mass on leaving the ground after the take-off or after the hop, step and jump

- **Thigh/Lead-leg Angle at Take-off** – The angle of the thigh of the swinging leg measured from the horizontal during the take-off in the long jump or the hop, step and jump (see figure).

- **Thigh/Lead-leg Average Velocity** – The mean angular velocity of the thigh of the swinging leg during the take-off in the long jump (see figure) or during the support phase of the hop, step and jump
Angular characteristics in the take-off

Table 1d: Definitions of the studied landing characteristics

- **Landing Distance** – The horizontal distance between the athlete’s centre of mass and the heel at the first ground contact in the sand pit.
- **Trunk Angle at Landing** - The angle of the median axis of the athlete’s trunk measured to the horizontal at the beginning of the landing
- **Knee Angle** - The angle of the knee joint of the landing leg at the beginning of the landing.
- **Hip Angle** – The angle of the hip joint of the landing leg (measured from the thigh to the trunk) at the beginning of the landing.

Landing characteristics
Men’s Long Jump

Results

Dwight Phillips made up for a disappointing Olympic Year in 2008 by winning his third long jump gold medal in this competition with a leap of 8.54m, the sixth best mark of the year (three of the better marks were by Phillips himself). After taking the lead with a first round jump of 8.40m, on which his take-off was more than 20cm behind the board, he responded to the challenge of Olympic silver medallist Godfrey Khotso Mokoena’s 8.47m with the winning jump in the second round. Mokoena’s mark put him second again and Australia’s Mitchell Watt took the bronze medal with 8.37m (see Table 2).

With an average distance of 8.24m and a standard deviation of 0.19m, the performance level in the final was similar to that at the 2007 IAAF World Championships in Athletics in Osaka (8.24m and 0.20m) and significantly better than in the 2008 Olympic Games in Beijing (8.17 and 0.10m).

The effective distance of most of the jumpers was only slightly greater than the official distance, since the average take-off loss was only 0.05m. Thus, the approach accuracy of the jumps evaluated can be regarded as very good. Lapierre was the only jumper whose take-off loss in his best jump was more than 10cm, all the other jumpers show significantly lower losses on their best jumps (see Table 3). There was no athlete who showed a measurable landing loss (see Table 3).

Table 2: Results of the men’s long jump final (m) at the 2009 IAAF World Championships in Athletics (wind readings are shown in parentheses in m/sec)

<table>
<thead>
<tr>
<th>Pos</th>
<th>Athlete (Country)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
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<tr>
<td></td>
<td></td>
<td>Round</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
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<td>22 August – 18:05</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Dwight Phillips(USA)</td>
<td>8.40</td>
<td>(0.1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Godfrey Khotso Mokoena (RSA)</td>
<td>X</td>
<td>8.47</td>
<td>(0.1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Mitchell Watt (AUS)</td>
<td>8.28</td>
<td>(0.2)</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Fabrice Lapierre (AUS)</td>
<td>8.21</td>
<td>(0.1)</td>
<td>7.77</td>
<td>(0.3)</td>
<td>8.19</td>
<td>(0.3)</td>
</tr>
<tr>
<td>5</td>
<td>Greg Rutherford (GBR)</td>
<td>7.83</td>
<td>(0.9)</td>
<td>X</td>
<td></td>
<td>8.05</td>
<td>(0.7)</td>
</tr>
<tr>
<td>6</td>
<td>Salim Sdini (FRA)</td>
<td>7.78</td>
<td>(0.1)</td>
<td>X</td>
<td></td>
<td>8.07</td>
<td>(0.2)</td>
</tr>
<tr>
<td>7</td>
<td>Gable Garenmotse (BOT)</td>
<td>8.06</td>
<td>(0.2)</td>
<td>8.04</td>
<td>(0.2)</td>
<td>7.77</td>
<td>(0.5)</td>
</tr>
<tr>
<td>8</td>
<td>Christopher Tomlinson (GBR)</td>
<td>8.02</td>
<td>(0.2)</td>
<td>7.93</td>
<td>(0.2)</td>
<td>7.66</td>
<td>(0.4)</td>
</tr>
<tr>
<td>9</td>
<td>Brian Johnson (USA)</td>
<td>6.30</td>
<td>(0.3)</td>
<td>X</td>
<td>7.86</td>
<td>(0.1)</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Yahya Bernah (MAR)</td>
<td>5.91</td>
<td>(0.1)</td>
<td>X</td>
<td>7.83</td>
<td>(0.4)</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Louis Tsatouras (GRE)</td>
<td>X</td>
<td></td>
<td></td>
<td>7.59</td>
<td>(0.4)</td>
<td>X</td>
</tr>
<tr>
<td>12</td>
<td>Irving Saladino (PAN)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 3: Distance characteristics of the individual best jumps in the men’s long jump final at the 2009 IAAF World Championships in Athletics

<table>
<thead>
<tr>
<th>Name</th>
<th>Studied Attempt</th>
<th>Official [m]</th>
<th>Effective [m]</th>
<th>Take-off Loss</th>
<th>Landing Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phillips</td>
<td>2</td>
<td>8.54</td>
<td>8.59</td>
<td>0.05</td>
<td>0.00</td>
</tr>
<tr>
<td>Mokoena</td>
<td>2</td>
<td>8.47</td>
<td>8.48</td>
<td>0.01</td>
<td>0.00</td>
</tr>
<tr>
<td>Watt</td>
<td>5</td>
<td>8.37</td>
<td>8.44</td>
<td>0.07</td>
<td>0.00</td>
</tr>
<tr>
<td>Lapiere</td>
<td>5</td>
<td>8.21</td>
<td>8.33</td>
<td>0.12</td>
<td>0.00</td>
</tr>
<tr>
<td>Rutherford</td>
<td>6</td>
<td>8.17</td>
<td>8.23</td>
<td>0.06</td>
<td>0.00</td>
</tr>
<tr>
<td>Sdiri</td>
<td>4</td>
<td>8.07</td>
<td>8.07</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Garenamote</td>
<td>1</td>
<td>8.06</td>
<td>8.14</td>
<td>0.08</td>
<td>0.00</td>
</tr>
<tr>
<td>Tomlinson</td>
<td>5</td>
<td>8.06</td>
<td>8.10</td>
<td>0.04</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td></td>
<td><strong>8.24</strong></td>
<td><strong>8.30</strong></td>
<td><strong>0.05</strong></td>
<td><strong>0.00</strong></td>
</tr>
<tr>
<td><strong>Std. Dev.</strong></td>
<td></td>
<td><strong>0.19</strong></td>
<td><strong>0.19</strong></td>
<td><strong>0.04</strong></td>
<td><strong>0.00</strong></td>
</tr>
</tbody>
</table>

**Take-off preparation**

With the exception of Rutherford, who slightly shortened his penultimate stride, the take-off preparation of the top eight placers was characterised by a short-long-short structure of the last three strides (see NIXDORF & BRÜGGEMANN, 1983, 1990b; HAY et al. 1986; MÜLLER & BRÜGGEMANN, 1997). The penultimate stride (2last) was extended by an average of 0.14m, about 6% in comparison with the third to last stride (3last). The final stride (1last), however, was shortened by an average of 0.24m, about 9% compared to the penultimate stride (2last). The relatively large dispersion within this movement pattern is notable. Thus, in Phillips and Sdiri there was a pronounced extension of the penultimate stride of 14 or 16%, while the remaining jumpers extended this stride by only 2-7%.

There was an average lowering of the CM by about 8cm. But in this group, there is no connection between lowering of the CM and the vertical take-off velocity generated (see Table 4).

In almost all athletes studied here, the approach velocity slightly increased in the penultimate stride (2last) and decreased in the last stride (1last). This behaviour is closely related to the stride length design. The more extended the penultimate stride, and especially the more shortened the last stride, the more significant is the velocity decrease in the last stride. Rutherford accelerated even up to the take-off board by the extension of his last stride.

Overall, there is a relatively high correlation between the approach velocity and the effective distance achieved. Although the correlation coefficient of $r = 0.69$ is not as high as in other studies (HAY et al., 1986; Nixdorf & Brüggemann, 1990a; LEE et al., 1994), it illustrates the importance of this feature and Phillips’ victory can be seen primarily as a result of his outstanding approach velocity.
Table 4: Take-off preparation characteristics of the individual best jumps in the men’s long jump final at the 2009 IAAF World Championships in Athletics

<table>
<thead>
<tr>
<th>Player</th>
<th>3last</th>
<th>2last</th>
<th>1last</th>
<th>Relative difference 2last/3last [%]</th>
<th>Relative difference 1last/2last [%]</th>
<th>Lowering of CM [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Philips</td>
<td>2.30</td>
<td>2.62</td>
<td>2.09</td>
<td>+14%</td>
<td>-23%</td>
<td>0.06</td>
</tr>
<tr>
<td>Mokoena</td>
<td>2.27</td>
<td>2.32</td>
<td>2.19</td>
<td>+2%</td>
<td>-6%</td>
<td>0.08</td>
</tr>
<tr>
<td>Watt</td>
<td>2.45</td>
<td>2.63</td>
<td>2.42</td>
<td>+7%</td>
<td>-8%</td>
<td>0.11</td>
</tr>
<tr>
<td>Lapierre</td>
<td>2.24</td>
<td>2.36</td>
<td>2.28</td>
<td>+5%</td>
<td>-3%</td>
<td>0.08</td>
</tr>
<tr>
<td>Rutherford</td>
<td>2.23</td>
<td>2.19</td>
<td>2.24</td>
<td>-2%</td>
<td>+2%</td>
<td>0.07</td>
</tr>
<tr>
<td>Sdiri</td>
<td>2.24</td>
<td>2.39</td>
<td>2.16</td>
<td>+16%</td>
<td>-17%</td>
<td>0.06</td>
</tr>
<tr>
<td>Garenamotse</td>
<td>2.30</td>
<td>2.38</td>
<td>2.22</td>
<td>+4%</td>
<td>-7%</td>
<td>0.06</td>
</tr>
<tr>
<td>Tomlinson</td>
<td>2.40</td>
<td>2.49</td>
<td>2.14</td>
<td>+4%</td>
<td>-14%</td>
<td>0.15</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>2.31</td>
<td>2.45</td>
<td>2.21</td>
<td>+6%</td>
<td>-9%</td>
<td>0.08</td>
</tr>
<tr>
<td><strong>Std. dev.</strong></td>
<td>0.08</td>
<td>0.16</td>
<td>0.12</td>
<td>6%</td>
<td>8%</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Figure 3: Velocity during take-off preparation in the individual best jumps in the men’s long jump final at the 2009 IAAF World Championships in Athletics
Biomechanical Analysis of the Horizontal Jumping Events at the 2009 IAAF World Championships in Athletics

The take-off

The average loss of velocity at take-off in the best jumps of the top eight placers was 1.61 m/sec (see Table 5). For most of the jumpers, this value scatters between 1.25 and 1.78 m/sec. The exception is Lapierre, who with a loss of 2.30 m/sec shows an extreme above-average value. However, due to his take-off technique he generated an equally above-average vertical velocity of 4.23 m/sec (see Figure 4). In this way he compensated for his rather poor approach velocity and jumped farther than other, faster athletes.

The average vertical velocity at take-off for all the finalists was 3.53 m/sec. Removing Lapierre’s exceptional velocity values gives an average of 3.43 m/sec. The vertical velocity reached at take-off strongly depends on the loss of velocity at take-off \( (r = 0.93) \). This means that in order to produce high vertical velocities, a stronger deceleration at the take-off board must be taken into account.

The extent of the vertical velocity is reflected in the take-off angle or angle of projection. Among the finalists in Berlin, this amounted to an average of 22.2°. However, discounting the Lapierre’s outlier, the average was 21.3° and, like the vertical velocity, was only slightly greater than in previous big events like the 1988 Olympic Games or the 1997 World Cup (see NIXDORF & BRÜGГEMANN, 1990a; MÜLLER & BRÜGГEMANN, 1997). Although the angle of projection correlates closely with the vertical velocity generated \( (r = 0.99) \), there is only a small correlation with the jumping distance achieved.

Looking at the characteristics of the take-off, there was an average take-off duration of 0.119 sec, which is within the range given in the literature (see BALLREICH & BRÜGГEMANN, 1986), but is in no way connected with the jumping distance achieved.

The relatively strongly pronounced average inclination angle of 25° is relatively closely related to the loss of velocity at take-off \( (r = 0.62) \). In this group, the inclination angle was very strongly affected by the trunk angle \( (r = 0.91) \). The athletes with the greatest inclination angle (Tomlinson, Phillips and Lapierre) also showed the strongest backward lean of the trunk at the beginning of the jump.

During the jump, there was an average forward rotation of the trunk of 10°. A slighter rotation of the trunk, as in Watts and Tomlinson, indicates a stronger stretching of the hip in a horizontal direction. However, in this group, this feature was not related to the velocity parameters of the jump or the jump distance.
### Table 5: Take-off characteristics of the individual best jumps in the men's long jump final at the 2009 IAAF World Championships in Athletics

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Phillips</td>
<td>2</td>
<td>155</td>
<td>27</td>
<td>13</td>
<td>137</td>
<td>0.113</td>
<td>3.35</td>
<td>20.0</td>
<td>0.118</td>
<td>3.79</td>
<td>2.36</td>
<td>26.99</td>
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<td>Morcena</td>
<td>2</td>
<td>168</td>
<td>26</td>
<td>99</td>
<td>143</td>
<td>0.114</td>
<td>3.79</td>
<td>23.6</td>
<td>0.107</td>
<td>2.22</td>
<td>2.00</td>
<td>28.97</td>
<td></td>
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<tr>
<td>Watt</td>
<td>5</td>
<td>160</td>
<td>97</td>
<td>6</td>
<td>143</td>
<td>0.107</td>
<td>2.22</td>
<td>97</td>
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<td>2.22</td>
<td>2.00</td>
<td>97.22</td>
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<td>Lapierre</td>
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<td>230</td>
<td>28</td>
<td>11</td>
<td>147</td>
<td>0.120</td>
<td>4.23</td>
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<td>0.120</td>
<td>1.89</td>
<td>2.32</td>
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<tr>
<td>Rutherford</td>
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<td>128</td>
<td>95</td>
<td>9</td>
<td>149</td>
<td>0.120</td>
<td>3.14</td>
<td>18.9</td>
<td>0.120</td>
<td>1.99</td>
<td>2.00</td>
<td>95.98</td>
<td></td>
</tr>
<tr>
<td>Sdiri</td>
<td>4</td>
<td>148</td>
<td>98</td>
<td>9</td>
<td>139</td>
<td>0.120</td>
<td>3.15</td>
<td>19.9</td>
<td>0.120</td>
<td>1.91</td>
<td>2.00</td>
<td>98.98</td>
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<td>Garneramboise</td>
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<td>125</td>
<td>99</td>
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<td>0.134</td>
<td>3.72</td>
<td>23.6</td>
<td>0.134</td>
<td>3.00</td>
<td>2.20</td>
<td>99.99</td>
<td></td>
</tr>
<tr>
<td>Thomlinson C.</td>
<td>5</td>
<td>178</td>
<td>104</td>
<td>3</td>
<td>132</td>
<td>0.134</td>
<td>3.72</td>
<td>23.6</td>
<td>0.134</td>
<td>3.00</td>
<td>2.20</td>
<td>104.99</td>
<td></td>
</tr>
</tbody>
</table>

| Mean            |                 |                        |                          |                |                      | 0.33                              | 0.39                                 | 3.2                   |               |                |              | 3      |

Std. Dev.
The average minimum knee angle of the take-off leg during the jump was 141°, which is roughly identical with the data presented by LEE et al. (1994). However, the dispersion of this feature is relatively large. While Rutherford’s and Lapierre’s knee angles were 149° and 147°, respectively, indicating relatively stiff ankle bones, Tomlinson’s flexion angle of 132° is significantly smaller. This may be due to the high forces that are created by his strong bracing action at the start of his jump.

The Landing

The characteristics of the landing were very different between the studied jumps and thus reflect the different techniques and conditions that are typical of this movement phase. The average landing distance was 0.54m with a large range from 0.36m (Lapierre) to 0.70m (Sdiri), i.e., a difference of about 95%. The relationship between the landing distance and the effective jumping distance is \( r = -0.37 \) and thus relatively low. However, it is interesting that this relationship tends to be negative. This means that the landing distance of the better jumpers is rather small. This can be partly explained by the fact that large landing distances, as seen with Sdiri and Garenamotse, are associated with a fully upright trunk and a highly extended hip. This posture leads to a relatively high position of the CM at the time of landing, which shortens the flight curve of the CM and thus the flight distance.

In contrast, Phillips and Rutherford exhibited a clear forward lean of the trunk and a strong flexion of the hip, which leads to a shorter landing distance on the one hand but results in a lengthening of the flight curve by the low landing position on the other hand. From this point of view, Lapierre’s landing can be regarded as a failure, because due to the extremely long duration of his flight phase the forward lean of his body was too strong and he was forced to extend his hip too early and too much.

Table 6: Landing characteristics of the individual best jumps in the men’s long jump final at the 2009 IAAF World Championships in Athletics

<table>
<thead>
<tr>
<th>Name</th>
<th>Studied Attempt</th>
<th>Landing Distance (m)</th>
<th>Trunk Angle [°]</th>
<th>Knee Angle [°]</th>
<th>Hip Angle [°]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phillips</td>
<td>2</td>
<td>0.44</td>
<td>51</td>
<td>129</td>
<td>55</td>
</tr>
<tr>
<td>Mokoena</td>
<td>2</td>
<td>0.56</td>
<td>74</td>
<td>151</td>
<td>96</td>
</tr>
<tr>
<td>Watt</td>
<td>5</td>
<td>0.59</td>
<td>92</td>
<td>148</td>
<td>115</td>
</tr>
<tr>
<td>Lapierre</td>
<td>5</td>
<td>0.36</td>
<td>61</td>
<td>143</td>
<td>92</td>
</tr>
<tr>
<td>Rutherford</td>
<td>6</td>
<td>0.40</td>
<td>49</td>
<td>143</td>
<td>64</td>
</tr>
<tr>
<td>Sdiri</td>
<td>3</td>
<td>0.70</td>
<td>108</td>
<td>127</td>
<td>106</td>
</tr>
<tr>
<td>Garenamotse</td>
<td>1</td>
<td>0.67</td>
<td>94</td>
<td>153</td>
<td>109</td>
</tr>
<tr>
<td>Tomlinson</td>
<td>5</td>
<td>0.47</td>
<td>76</td>
<td>133</td>
<td>94</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>0.54</td>
<td>79</td>
<td>143</td>
<td>97</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td></td>
<td>0.13</td>
<td>20</td>
<td>10</td>
<td>17</td>
</tr>
</tbody>
</table>
Women's Long Jump

Results

Brittney Reese completed a double of the long jump gold medals for the USA with her world leading 7.10m, the best mark since 1997. She became the third American woman in history to win the title. The defending champion Lebedeva (RUS) led briefly in the second round with her best jump of 6.97m and then had to settle for second place. The bronze medal went to Karin Mey Melis (TUR) who jumped 6.80m (see Table 7).

With an average jumping distance of 6.80m and a standard deviation of 0.16m, the performance level was comparable with that of both the 2007 IAAF World Championships in Athletics (6.83m and 0.14m) and the 2008 Olympic Games in Beijing (6.81m or 0.17m).

The average effective distance 6.85m is only a little greater than the official distance, because the average loss in the long jump was only 0.05cm. Therefore, as with the men, the approach accuracy of the evaluated jumps must be judged as very good. Here, too, one athlete (Maggi) showed a loss at the take-off board that is greater than 0.10m. With 0.09m and 0.08m, Gomes and Reese also demonstrate an above-average loss of distance at the take-off. In the case of Gomes, this led to the loss of the bronze medal. Only one athlete (Balta) showed a landing loss that can be considered as relatively large (0.13m) (see Table 8).

Take-off preparation

In all the studied athletes, the take-off preparation was characterised by a typical short-long-short structure of the last three strides. The penultimate stride (2last) was extended by lengthening of the penultimate step of only 15cm, or about 7%. These values are in the range of the values found in the men.

Similar to the men, the final stride (1last) was reduced by an average of 0.24m, or about 10%, as compared to the penultimate stride (2last). Here, a large dispersion can be an average of 0.20m, or about 10%, compared with the third to last step (3last). However, these values are slightly distorted due to the extreme step lengthening exhibited by Reese (28%). Taking Reese from consideration

Table 7: Results of the women's long jump final (m) at the 2009 IAAF World Championships in Athletics (wind readings are shown in parentheses in m/sec)

<table>
<thead>
<tr>
<th>Pos</th>
<th>Athlete (Country)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>23 August – 16:15</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>1</td>
<td>Brittney Reese (USA)</td>
<td>6.92 (0.8)</td>
<td>6.85 (0.5)</td>
<td>7.10 (1.0)</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>2</td>
<td>Tatyana Lebedeva (RUS)</td>
<td>6.78 (0.3)</td>
<td>6.97 (1.0)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>3</td>
<td>Karin Mey Melis (TUR)</td>
<td>6.76 (0.9)</td>
<td>X</td>
<td>6.80 (0.4)</td>
<td>X</td>
<td>X</td>
<td>6.49 (0.1)</td>
</tr>
<tr>
<td>4</td>
<td>Naide Gomes (POR)</td>
<td>6.77 (0.5)</td>
<td>X</td>
<td>6.52 (1.5)</td>
<td>6.88 (0.6)</td>
<td>6.69 (0.9)</td>
<td>6.65 (-0.4)</td>
</tr>
<tr>
<td>5</td>
<td>Olga Kucherenko (RUS)</td>
<td>X</td>
<td>X</td>
<td>6.77 (1.1)</td>
<td>6.83 (0.4)</td>
<td>X</td>
<td>6.65 (1.3)</td>
</tr>
<tr>
<td>6</td>
<td>Shara Proctor (AIA)</td>
<td>X</td>
<td>6.56 (1.6)</td>
<td>6.71 (1.2)</td>
<td>X</td>
<td>X</td>
<td>6.40 (0.5)</td>
</tr>
<tr>
<td>7</td>
<td>Maureen Higa Maggi (BRA)</td>
<td>6.68 (0.7)</td>
<td>X</td>
<td>X</td>
<td>6.84 (0.0)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>Ksenija Balta (EST)</td>
<td>6.62 (0.3)</td>
<td>6.52 (0.1)</td>
<td>X</td>
<td>6.15 (-0.3)</td>
<td>6.60 (-0.5)</td>
<td>6.57 (0.3)</td>
</tr>
<tr>
<td>9</td>
<td>Brianna Glenn (USA)</td>
<td>X</td>
<td>6.59 (0.1)</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Teresa Dobija (POL)</td>
<td>X</td>
<td>6.58 (0.7)</td>
<td>6.51 (-0.1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Nastassia Mironchyk (BLR)</td>
<td>X</td>
<td>6.24 (0.8)</td>
<td>6.29 (0.0)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Kella Costa (BRA)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 8: Distance characteristics of the individual best jumps in the women’s long jump final at the 2009 IAAF World Championships in Athletics

<table>
<thead>
<tr>
<th>Name</th>
<th>Studied Attempt</th>
<th>Distance [m]</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Official</td>
<td>Effective</td>
<td>Take-Off Loss</td>
<td>Landing Loss</td>
</tr>
<tr>
<td>Reese</td>
<td>3</td>
<td>7.10</td>
<td>7.18</td>
<td>0.08</td>
<td>0.00</td>
</tr>
<tr>
<td>Lebedeva</td>
<td>2</td>
<td>6.97</td>
<td>6.97</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Mey Melis</td>
<td>3</td>
<td>6.80</td>
<td>6.65</td>
<td>0.05</td>
<td>0.00</td>
</tr>
<tr>
<td>Gomes</td>
<td>1</td>
<td>6.77</td>
<td>6.86</td>
<td>0.09</td>
<td>0.00</td>
</tr>
<tr>
<td>Kucharenko</td>
<td>3</td>
<td>6.77</td>
<td>6.77</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Proctor</td>
<td>3</td>
<td>6.71</td>
<td>6.76</td>
<td>0.05</td>
<td>0.00</td>
</tr>
<tr>
<td>Maggi</td>
<td>1</td>
<td>6.68</td>
<td>6.81</td>
<td>0.13</td>
<td>0.00</td>
</tr>
<tr>
<td>Baia</td>
<td>1</td>
<td>6.62</td>
<td>6.64</td>
<td>0.02</td>
<td>0.13</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>6.80</td>
<td>6.85</td>
<td>0.05</td>
<td>0.02</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td></td>
<td>0.16</td>
<td>0.16</td>
<td>0.05</td>
<td>0.05</td>
</tr>
</tbody>
</table>

The average lowering of the CM was about 6cm. Figure 5 shows that there is a relatively high correlation between the lowering of the CM and vertical take-off velocity created ($r = 0.73$). In almost all the studied athletes, there was a slight increase of the approach velocity in the penultimate step (2last) before the take-off and a decrease again during the final stride (1last). However, there is no close correlation of the velocity course with the stride length pattern, as was observed in the men. The relationship between approach velocity and effective jumping distance, however, is similarly close to that of the men (correlation coefficient $r = 0.65$).

Table 9: Take-off preparation characteristics of the individual best jumps in the women’s long jump final at the 2009 IAAF World Championships in Athletics

![Stride length diagram]
Figure 5: Relationship between vertical velocity and lowering of the CM in the take-off of the individual best jumps in the women’s long jump final at the 2009 IAAF World Championships in Athletics

![Graph showing the relationship between vertical velocity and lowering of the CM.](image)

Figure 6: Velocity during take-off preparation in the individual best jumps in the women’s long jump final at the 2009 IAAF World Championships in Athletics

![Graph showing velocity during take-off preparation.](image)

Figure 7: Relationship between the loss of horizontal velocity and the vertical velocity generated in the take-off of the individual best jumps in the women’s long jump final at the 2009 IAAF World Championships in Athletics

![Graph showing the relationship between loss of horizontal velocity and vertical velocity.](image)
That the approach velocity is very important in the women's long jump, too, is supported by the fact that the gold medal was won by the fastest athlete (Reese). However, this is mitigated by the fact that the slowest athlete of the group (Mey Melis) won the bronze medal. This was possible because Mey Melis athlete was able to compensate for her slow approach velocity with above-average vertical velocity in the take-off.

The take-off

The average loss of velocity at take-off was 1.42 m/sec. This is less than in the men, although there is a dispersion of the individual values in a similar range from 1.22 to 1.76 m/sec. In general, the correlation between the achieved vertical velocity and the loss of velocity at take-off is significantly lower than among the men \((r = 0.58)\) (see Figure 6). However, the trend is similar: female athletes, who generated higher vertical velocities at take-off, like Lebedeva or Kucherenko, generally slowed down to a greater extent during the take-off. Maggi, the athlete with the lowest loss of velocity at the take-off board, generated the lowest vertical velocity at take-off. Only Mey Melis managed to achieve a high vertical velocity in spite of a relatively small loss of velocity. This is an indication of a very successful take-off technique. Here, too, the vertical velocity determines the projection angle, which was 21.9° on average and is thus considerably larger than in previous events such as the 1988 Olympic Games or the 1997 IAAF World Championships in Athletics (see NIXDORF & BRÜGGEMANN, 1990a; MÜLLER & BRÜGGEMANN, 1997). This can only be explained by the lower horizontal take-off velocity, since the average vertical velocity was only slightly higher than in the aforementioned competitions. Although the take-off angle correlates closely with the generated vertical velocity \((r = 0.96)\), there is only a slight relationship with the jumping distance achieved.

With regards to the take-off characteristics, the average take-off duration was 0.115 sec, which is slightly shorter than in the men. However, as with the men, there is no correlation between take-off duration and the distance achieved.

The average inclination angle was 26°, which is the same as with the finalists in the 1988 Olympic Games (Nixdorf & Brüggemann, 1990a), and depends to a moderate extent on the vertical velocity created at take-off \((r = 0.59)\). In this group, the inclination angle, in contrast to the men, was negatively related to the trunk angle \((r = -0.81)\). A more pronounced bracing is usually associated with a more upright posture of the trunk at the beginning of the take-off. Thus, the larger inclination angle can only be caused by a lower position of the CM or by placing the take-off foot further in front of the body.

During the take-off, there was an average forward rotation of the trunk of 6°. Although this figure is significantly less than we see in the men’s finalists, the dispersion is considerably greater.

While Balta maintained the backward lean of her trunk almost constantly throughout the take-off, Lebedeva rotated forward by 15° and left the ground with a slight forward lean of her trunk. In the women, there is a moderate correlation between the trunk rotation and the loss of horizontal velocity at take-off \((r = 0.53)\). Greater trunk rotation is associated with a more rigid position of the hip joint and thereby with a slightly harder deceleration.

The minimum knee angle of the take-off leg during the take-off was an average of 137°. Both this value and the dispersion are smaller than observed in the men. The greatest knee flexion was demonstrated by Reese (128°) and the smallest by Maggi (142°). The expected relationship of this feature with the lowering of the CM at the beginning of the take-off \((r = -0.47)\) and with the inclination angle \((r = -0.58)\) is low to moderate, and is only an indication of the tendency that a lower position of the CM and a greater inclination angle at the beginning of the take-off lead to a greater knee flexion in the take-off. The negative correlation of the minimum knee angle with the effective jumping distance is not high \((r = -0.58)\) but tends to suggest that a “softer” take-off behaviour has a negative effect on jumping distance.
Table 10: Take-off characteristics of the individual best jumps in the women’s long jump final at the 2009 IAAF World Championships in Athletics

<table>
<thead>
<tr>
<th>Name</th>
<th>Studied Attempt</th>
<th>Velocity Loss at Take-off [m/sec]</th>
<th>Vertical Velocity at Take-off [m/sec]</th>
<th>Angle of Projection [°]</th>
<th>Duration [sec]</th>
<th>Inclination Angle [°]</th>
<th>Trunk Angle [°]</th>
<th>Trunk Rotation [°]</th>
<th>Minimum Knee Angle [°]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reese</td>
<td>3</td>
<td>1.28</td>
<td>3.14</td>
<td>20.7</td>
<td>0.127</td>
<td>29</td>
<td>97</td>
<td>5</td>
<td>128</td>
</tr>
<tr>
<td>Lebedeva</td>
<td>2</td>
<td>1.71</td>
<td>3.40</td>
<td>24.0</td>
<td>0.107</td>
<td>25</td>
<td>101</td>
<td>15</td>
<td>134</td>
</tr>
<tr>
<td>Mey Melis</td>
<td>3</td>
<td>1.26</td>
<td>3.42</td>
<td>23.5</td>
<td>0.107</td>
<td>27</td>
<td>100</td>
<td>5</td>
<td>136</td>
</tr>
<tr>
<td>Gomes</td>
<td>1</td>
<td>1.33</td>
<td>3.22</td>
<td>21.7</td>
<td>0.120</td>
<td>28</td>
<td>99</td>
<td>2</td>
<td>137</td>
</tr>
<tr>
<td>Kucherenko</td>
<td>3</td>
<td>1.75</td>
<td>3.37</td>
<td>24.5</td>
<td>0.120</td>
<td>27</td>
<td>98</td>
<td>7</td>
<td>141</td>
</tr>
<tr>
<td>Proctor</td>
<td>3</td>
<td>1.43</td>
<td>3.10</td>
<td>22.1</td>
<td>0.127</td>
<td>27</td>
<td>96</td>
<td>2</td>
<td>131</td>
</tr>
<tr>
<td>Maggi</td>
<td>1</td>
<td>1.22</td>
<td>2.64</td>
<td>17.6</td>
<td>0.113</td>
<td>21</td>
<td>102</td>
<td>8</td>
<td>142</td>
</tr>
<tr>
<td>Balta</td>
<td>1</td>
<td>1.35</td>
<td>2.96</td>
<td>20.2</td>
<td>0.113</td>
<td>27</td>
<td>97</td>
<td>1</td>
<td>138</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>1.42</td>
<td>3.16</td>
<td>21.9</td>
<td>0.115</td>
<td>26</td>
<td>99</td>
<td>6</td>
<td>137</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td></td>
<td>0.20</td>
<td>0.26</td>
<td>2.4</td>
<td>0.007</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>
The landing

In the women, the characteristics of the landing present a much more homogeneous picture than with the men. If one considers the mean values of the various parameters, no significant difference from the men can be observed. However, the dispersion is significantly less. The medium landing distance was 0.49m and varies from 0.44m (Proctor) to 0.53m (Mey Melis). Here, too, the correlation between the landing distance and the effective jumping distance is low (r = 0.27). Thus, for the women long jumpers in Berlin as with for the men, this phase was not crucial for success.

The landing position was similar for all jumpers in this group. The average trunk angle was 74° and varied between 60° and 87°, so that there is in all cases a moderate forward lean of the body. The average knee angle was 144°, and only Proctor exhibited a knee angle less than 130°. Thus, nearly all jumpers demonstrate an almost straight position of the legs. The average hip angle was 86°, which is 11° less than in the average for the men. Only Mey Melis and Balta with 106° and 98°, respectively, demonstrate a relatively strong but not overly extended hip position. In summary, in all women the landing position can be considered as good and appropriate.

Men’s Triple Jump

Results

Phillips Idowu (GBR) produced a 17.73m jump, his personal best and the world leading mark for the year, when it counted to take the triple jump gold medal. Defending world and Olympic Champion Nelson Evora (POR), who led the competition after the first round and later improved to 17.55m, had to settle for second. Third place went to Alexis Copello (CUB) at 17.36m (see Table 12).

With an average distance of 17.28m and a standard deviation of 0.29m, the performance level of the finalists was 0.08m lower and thus only slightly weaker than at the 2008 Olympic Games in Beijing (17.36m and 0.28m). However, the average distance of the finalists in Berlin was comparable with that at 2007 IAAF World Championships in Athletics (17.27m and 0.31m).

In Table 13 we see that at 17.40m, the average effective distance was significantly greater than the average official distance, since the average loss of distance at the take-off board was 0.11m. Although with three of the finalists there was a loss of 0.18m and more, the final results would hardly have changed on basis of

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Table 11: Landing characteristics of the individual best jumps in the women’s long jump final at the 2009 IAAF World Championships in Athletics

<table>
<thead>
<tr>
<th>Name</th>
<th>Studied Attempt</th>
<th>Landing Distance [m]</th>
<th>Trunk Angle [°]</th>
<th>Knee Angle [°]</th>
<th>Hip Angle [°]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reese</td>
<td>3</td>
<td>0.52</td>
<td>68</td>
<td>150</td>
<td>83</td>
</tr>
<tr>
<td>Lebedova</td>
<td>2</td>
<td>0.49</td>
<td>70</td>
<td>148</td>
<td>84</td>
</tr>
<tr>
<td>Mey Melis</td>
<td>3</td>
<td>0.53</td>
<td>87</td>
<td>158</td>
<td>106</td>
</tr>
<tr>
<td>Gomes</td>
<td>1</td>
<td>0.49</td>
<td>75</td>
<td>135</td>
<td>85</td>
</tr>
<tr>
<td>Kucherenko</td>
<td>2</td>
<td>0.46</td>
<td>60</td>
<td>158</td>
<td>79</td>
</tr>
<tr>
<td>Proctor</td>
<td>3</td>
<td>0.44</td>
<td>77</td>
<td>128</td>
<td>82</td>
</tr>
<tr>
<td>Maggi</td>
<td>1</td>
<td>0.49</td>
<td>66</td>
<td>137</td>
<td>69</td>
</tr>
<tr>
<td>Balta</td>
<td>1</td>
<td>0.52</td>
<td>81</td>
<td>148</td>
<td>98</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td></td>
<td><strong>0.49</strong></td>
<td><strong>74</strong></td>
<td><strong>144</strong></td>
<td><strong>86</strong></td>
</tr>
<tr>
<td><strong>Std. Dev.</strong></td>
<td></td>
<td><strong>0.03</strong></td>
<td><strong>9</strong></td>
<td><strong>12</strong></td>
<td><strong>12</strong></td>
</tr>
</tbody>
</table>
Table 12: Results of the men’s triple jump final (m) at the 2009 IAAF World Championships in Athletics (wind readings are shown in parentheses in m/sec)

<table>
<thead>
<tr>
<th>Pos</th>
<th>Athlete (Country)</th>
<th>Round</th>
<th>Round</th>
<th>Round</th>
<th>Round</th>
<th>Round</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 August – 18:05</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Phillips Idowu (GBR)</td>
<td>17.51 (0.0)</td>
<td>17.44 (0.1)</td>
<td>17.73 (0.0)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>2</td>
<td>Nelson Évora (POR)</td>
<td>17.54 (-0.3)</td>
<td>X</td>
<td>17.35 (0.1)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>3</td>
<td>Alexis Copello (CUB)</td>
<td>17.06 (-0.2)</td>
<td>17.19 (0.2)</td>
<td>14.82 (0.4)</td>
<td>X</td>
<td>17.04 (-0.4)</td>
</tr>
<tr>
<td>4</td>
<td>Leevan Sands (BAH)</td>
<td>17.20 (0.8)</td>
<td>17.08 (-0.4)</td>
<td>16.96 (-0.1)</td>
<td>17.05 (-0.1)</td>
<td>17.32 (-0.5)</td>
</tr>
<tr>
<td>5</td>
<td>Arnie David Girat (BAH)</td>
<td>17.26 (0.6)</td>
<td>17.18 (0.2)</td>
<td>X</td>
<td>17.19 (0.1)</td>
<td>17.01 (-0.6)</td>
</tr>
<tr>
<td>6</td>
<td>Yanxi Li (CHN)</td>
<td>16.95 (0.6)</td>
<td>16.92 (0.0)</td>
<td>14.23 (0.0)</td>
<td>17.23 (1.1)</td>
<td>X</td>
</tr>
<tr>
<td>7</td>
<td>Igor Spasovkhodskiy (RUS)</td>
<td>16.73 (0.2)</td>
<td>16.91 (-0.3)</td>
<td>14.66 (0.1)</td>
<td>14.75 (0.4)</td>
<td>16.37 (0.1)</td>
</tr>
<tr>
<td>8</td>
<td>Jadel Gregório (BRA)</td>
<td>X</td>
<td>16.89 (-0.1)</td>
<td>16.80 (0.0)</td>
<td>16.70 (0.0)</td>
<td>X</td>
</tr>
<tr>
<td>9</td>
<td>Momchil Karailiev (BUL)</td>
<td>16.82 (0.3)</td>
<td>16.76 (0.3)</td>
<td>16.81 (0.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Nathan Douglas (GBR)</td>
<td>16.78 (-0.1)</td>
<td>15.44 (0.0)</td>
<td>16.79 (-0.1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Teddy Tamgho (FRA)</td>
<td>X</td>
<td>16.79 (-0.6)</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Dmitri Valuievc (RUS)</td>
<td>X</td>
<td>X</td>
<td>16.54 (0.3)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Take-off preparation

With the exception of Li, the take-off preparation of the finalists was characterised by a typical short-long-short design of the last two approach strides. The last stride (1last) was shortened by an average of 17cm, or by about 6%, in comparison with penultimate stride (2last). Although there is a large dispersion within the group (Sands shortened his last stride by 21% while Li actually lengthened his last stride by 7%), in most of the athletes studied here, a shortening of the last stride by 2-5% can be found. Thus, the kinematic structure of the last two strides is only a little changed.

The approach velocity did not change very much either. In most triple jumpers there was a tendency towards a slight acceleration during the last stride. This behaviour differs significantly from the take-off preparation in the long jump, since the take-off board is “run over” as it were. The velocity during the last stride of the athletes studied here reached an average of 10.14 m/sec and there was a variation between 9.88 m/sec (Girat) and 10.53 m/sec (Idowu). This is very much in agreement with the find-

the effective distances. Only Gregorio would have improved (from 8th to 7th) if his take-off had been more accurate.

The average distances of the partial jumps were 6.35m for the hop, 5.29m for the step, and 5.76m for the jump. When using a relative calculation, these partial jumps represent 36.5%, 30.4% and 33.1% of the total jumping distance. Based on the classification of triple jump techniques proposed by HAY (1990) - i.e. hop-dominated, jump-dominated or balanced - these average distances show that there was a clear dominance of the hop, since this was more than 2% longer than the jump. The hop-dominant technique can be observed in six of the eight finalists (see coloured values in Table 9). Only Copello and Girat, i.e. the two Cuban jumpers, demonstrated a balanced distribution of the partial jumps. An analysis of the relationships between the partial distances and the effective jumping distance shows that performance was highly dependent on the distances achieved in the step and the jump (r = 0.74 and 0.68), while the distance achieved in the hop is not correlated with the total distance achieved in this group.
Table 13: Absolute and relative jumping distances as well as loss of distance at the take-off board of the individual best jumps in the men’s triple jump final at the 2009 IAAF World Championships in Athletics (the coloured values indicate the importance of the respective partial jump in comparison with the respective two other jumpers)

<table>
<thead>
<tr>
<th>Name</th>
<th>Studied Attempt</th>
<th>Distance [m]</th>
<th>Stride Length [m]</th>
<th>Relative Distance [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Official</td>
<td>Effective</td>
<td>TO Loss</td>
</tr>
<tr>
<td>Idowu</td>
<td>3</td>
<td>17.73</td>
<td>17.92</td>
<td>0.19</td>
</tr>
<tr>
<td>Evora</td>
<td>6</td>
<td>17.55</td>
<td>17.60</td>
<td>0.05</td>
</tr>
<tr>
<td>Copello</td>
<td>6</td>
<td>17.36</td>
<td>17.54</td>
<td>0.18</td>
</tr>
<tr>
<td>Sands</td>
<td>5</td>
<td>17.32</td>
<td>17.34</td>
<td>0.02</td>
</tr>
<tr>
<td>Girat</td>
<td>1</td>
<td>17.26</td>
<td>17.39</td>
<td>0.00</td>
</tr>
<tr>
<td>Li</td>
<td>4</td>
<td>17.23</td>
<td>17.32</td>
<td>0.09</td>
</tr>
<tr>
<td>Spasovkhodskiy</td>
<td>2</td>
<td>16.91</td>
<td>16.96</td>
<td>0.05</td>
</tr>
<tr>
<td>Gregorio</td>
<td>2</td>
<td>16.89</td>
<td>17.15</td>
<td>0.26</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td></td>
<td><strong>17.28</strong></td>
<td><strong>17.40</strong></td>
<td><strong>0.11</strong></td>
</tr>
<tr>
<td><strong>Std. Dev.</strong></td>
<td></td>
<td>0.29</td>
<td>0.29</td>
<td>0.09</td>
</tr>
</tbody>
</table>
ings from the 1997 IAAF World Championships in Athletics (MÜLLER & BRÜGGMANN, 1997).

There was only a slight correlation between approach velocity and the effective jumping distance \((r = 0.38)\). Although the fastest athlete was the winner, the second-fastest athlete (Gregorio) was only eighth and the third placed (Copello) was only the sixth fastest. This trend shows that within a group of such homogeneous performances a speed deficit can be compensated by technique and strength as we saw in the long jump in Berlin.

**The hop**

The average horizontal velocity during the hop phase was 9.38 m/sec, resulting in an average loss of velocity of 0.76 m/sec at take-off. Both parameters show a relatively low dispersion. Although in Coppello and Sands, a significantly lower deceleration at take-off can be observed (0.51 and 0.61 m/sec respectively), most of the studied athletes lost between 0.73 and 0.95 m/sec.

The average of the vertical velocity generated during the take-off for the hop was 2.48 m/sec and shows a slight dispersion between 2.27 m/sec (Copello) and 2.68 m/sec (Evora). Similar to the long jump, this characteristic is closely associated with the deceleration at the take-off board \((r = 0.70)\). This means that the athletes whose take-off was more upwardly directed usually decelerated more during the take-off.

The average amounts of these parameters are largely consistent with the results from the 1997 IAAF World Championships in Athletics (MÜLLER & BRÜGGMANN, 1997). There is an expectedly moderate correlation between the vertical velocity and the hop distance \((r = 0.51)\).

The average take-off duration for the hop was 0.117 sec and there was only a small variation between 0.107 and 0.127 sec. The duration was strongly influenced by the initial angle \((r = 0.93)\). The greater the backward lean of the body, the longer the duration of the take-off. However, the support time is only moderately correlated with the hop distance \((r = 0.52)\).

The inclination angle was not, as might have been assumed, influenced by the trunk posture at the start of the take-off (trunk angle TD). The average trunk angle was 91° and hardly differs from the trunk angle at take-off (trunk angle TO), which was an average of 90°. Most of the studied jumpers kept their trunk in a stable upright position throughout the entire take-off. Only two deviated from this trend slightly and in dif-

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**Table 14:** Stride length and horizontal velocity during the last two approach strides of the individual best jumps in the men’s triple jump final at the 2009 IAAF World Championships in Athletics

<table>
<thead>
<tr>
<th>Name</th>
<th>Studied Attempt</th>
<th>Stride Length [m]</th>
<th>Difference</th>
<th>Horizontal Velocity [m/sec]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2last</td>
<td>1last</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Idowu</td>
<td>3</td>
<td>2.58</td>
<td>2.49</td>
<td>10.47</td>
</tr>
<tr>
<td>Evora</td>
<td>6</td>
<td>2.68</td>
<td>2.26</td>
<td>10.10</td>
</tr>
<tr>
<td>Copello</td>
<td>6</td>
<td>2.41</td>
<td>2.29</td>
<td>9.99</td>
</tr>
<tr>
<td>Sands</td>
<td>5</td>
<td>2.92</td>
<td>2.30</td>
<td>10.25</td>
</tr>
<tr>
<td>Girat</td>
<td>1</td>
<td>2.49</td>
<td>2.33</td>
<td>9.86</td>
</tr>
<tr>
<td>Li</td>
<td>4</td>
<td>2.30</td>
<td>2.46</td>
<td>9.89</td>
</tr>
<tr>
<td>Spasovkhodskiy</td>
<td>2</td>
<td>2.55</td>
<td>2.49</td>
<td>10.08</td>
</tr>
<tr>
<td>Gregorio</td>
<td>2</td>
<td>2.71</td>
<td>2.62</td>
<td>10.42</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td><strong>2.58</strong></td>
<td><strong>2.41</strong></td>
<td><strong>-6%</strong></td>
<td><strong>10.13</strong></td>
</tr>
<tr>
<td><strong>Std. Dev.</strong></td>
<td><strong>0.19</strong></td>
<td><strong>0.13</strong></td>
<td><strong>0.09</strong></td>
<td><strong>0.23</strong></td>
</tr>
</tbody>
</table>
different directions: while Idowu rotated backward by about 5° from a slight forward lean of the trunk to an upright position, Spasovkhodskiy at first showed a slight backward lean of the trunk and then rotated forward by about 6° during the take-off.

The motion of the swing-leg thigh was characterised by the angle of the thigh at the take-off, which was -14° on average (i.e., below the horizontal line), and by the mean angular velocity of the thigh, which was an average of 725°/sec. It can be assumed that the movement of the swing leg can affect primarily the deceleration at the take-off and the vertical velocity. Among the finalists in Berlin, there was the tendency towards a positive correlation between the angle of the swing leg at take-off with the vertical velocity generated \(r = 0.63\), although this correlation is only moderate. This means that in the case of a too low swing leg, such as in Copello, a lower vertical velocity was reached. Although the relationship between the swing-leg angle at take-off and the velocity loss is small, it is positive \(r = 0.46\). It can therefore be assumed that, in the hop, the take-off angle can be controlled in part by the lead of the swing-leg thigh during the take-off.

**The step**

The average horizontal velocity during the step was 8.29 m/sec. Thus, compared to the hop, there was an average loss of velocity of 1.08 m/sec. Both parameters show a relatively low dispersion. The lowest velocity loss was observed in Evora (0.94 m/sec), while the highest was observed in Idowu (1.24 m/sec).

The average vertical velocity generated during the take-off for the step is 2.06 m/sec and varies between 1.75 m/sec (Gregorio) and 2.32 m/sec (Girat). Thus, the average was considerably lower than in the hop and the dispersion was much greater. However, the vertical velocity is here not dependent on the loss of velocity in the take-off. The correlation between the two characteristics is low and negative \(r = -0.27\), so we can say that a stronger deceleration even led to a vertical velocity that tends to be lower. Compared to the results of the 1997 IAAF World Championships in Athletics, there was a slightly higher vertical velocity with a slightly lower loss of velocity (MÜLLER & BRÜGGEMANN, 1997).

The correlation between the vertical velocity and the length of the step is \(r = 0.42\). This means that the influence of vertical velocity on the length of the step is even lower than with the hop. Moreover, there was no clear correlation between the other velocity characteristics and the step length.

The average support duration of the take-off for the step was 0.153 sec and varied between 0.140 sec (Li) and 0.170 sec (Spasovkhodskiy), a dispersion about 50% greater than in the hop. In the step, too, the take-off duration was closely related to the inclination angle \(r = 0.85\). Since the inclination angle also correlates with the loss of horizontal velocity \(r = 0.71\), we can, as expected, assume that a stronger backward lean of the body or a more pronounced bracing action can lead both to a stronger deceleration as well as to a longer support time. However, as in the hop, this was not determined by the trunk angle at the start of the take-off. This angle was 90° on average at the end of the hop and rotated forward during the take-off for the step by an average of 8°. Here, relatively large differences can be observed between the jumpers: While Copello and Idowu rotated by just 3° or 4°, respectively, and thus maintain a relatively upright trunk posture during take-off, Gregory and Girat demonstrated very strong rotations of 15° or 13°, respectively. This means that the forward lean of their trunk at take-off was very pronounced.

As far as the characteristics of the swing-leg thigh are concerned, the average angle was -20° and the angular velocity was 612°/sec. Both parameters are significantly less and there is considerably more dispersion than in the hop. However, the positive correlation of the vertical velocity generated with the swing-leg angle at take-off \(r = 0.72\) and with the swing-leg velocity \(r = 0.51\) can be observed here, too. Thus, even in this part of the jump the take-off angle was partly controlled by the swing-leg movement. In addition, the moder-
Table 15: Characteristics of the hop in the individual best jumps in the men’s triple jump final at the 2009 IAAF World Championships in Athletics

<table>
<thead>
<tr>
<th>Name</th>
<th>Studied Attempt</th>
<th>Horizontal Velocity</th>
<th>Loss of Horizontal Velocity</th>
<th>Vertical Velocity</th>
<th>Angle of Projection</th>
<th>Take-off Duration</th>
<th>Inclination Angle</th>
<th>Trunk Angle TD</th>
<th>Trunk Angle TO</th>
<th>Lead-leg Angle TO</th>
<th>Lead-leg Velocity TO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idowu</td>
<td>3</td>
<td>9.72</td>
<td>0.81</td>
<td>2.45</td>
<td>14</td>
<td>0.127</td>
<td>24</td>
<td>85</td>
<td>90</td>
<td>-14</td>
<td>732</td>
</tr>
<tr>
<td>Evora</td>
<td>6</td>
<td>9.19</td>
<td>0.94</td>
<td>2.68</td>
<td>16</td>
<td>0.127</td>
<td>23</td>
<td>90</td>
<td>87</td>
<td>-14</td>
<td>703</td>
</tr>
<tr>
<td>Copello</td>
<td>6</td>
<td>9.49</td>
<td>0.51</td>
<td>2.27</td>
<td>13</td>
<td>0.110</td>
<td>18</td>
<td>89</td>
<td>91</td>
<td>-21</td>
<td>738</td>
</tr>
<tr>
<td>Sands</td>
<td>5</td>
<td>9.53</td>
<td>0.61</td>
<td>2.48</td>
<td>15</td>
<td>0.114</td>
<td>18</td>
<td>92</td>
<td>88</td>
<td>-15</td>
<td>715</td>
</tr>
<tr>
<td>Girat</td>
<td>1</td>
<td>9.14</td>
<td>0.73</td>
<td>2.47</td>
<td>15</td>
<td>0.120</td>
<td>22</td>
<td>94</td>
<td>94</td>
<td>-12</td>
<td>666</td>
</tr>
<tr>
<td>Li</td>
<td>4</td>
<td>9.18</td>
<td>0.81</td>
<td>2.64</td>
<td>16</td>
<td>0.107</td>
<td>17</td>
<td>88</td>
<td>89</td>
<td>-10</td>
<td>842</td>
</tr>
<tr>
<td>Spaso-</td>
<td>2</td>
<td>9.35</td>
<td>0.74</td>
<td>2.39</td>
<td>14</td>
<td>0.122</td>
<td>20</td>
<td>96</td>
<td>90</td>
<td>-12</td>
<td>678</td>
</tr>
<tr>
<td>ykhodskiy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gregorio</td>
<td>2</td>
<td>9.42</td>
<td>0.95</td>
<td>2.48</td>
<td>15</td>
<td>0.113</td>
<td>18</td>
<td>93</td>
<td>92</td>
<td>-16</td>
<td>726</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>9.38</td>
<td>0.76</td>
<td>2.48</td>
<td>14.8</td>
<td>0.117</td>
<td>20</td>
<td>91</td>
<td>90</td>
<td>-14</td>
<td>725</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td></td>
<td>0.20</td>
<td>0.15</td>
<td>0.13</td>
<td>0.93</td>
<td>0.008</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>54</td>
</tr>
</tbody>
</table>
ate negative correlation between the swing-leg velocity and the loss of velocity at take-off ($r = -0.54$) indicates that by a faster movement of the swing leg the braking effect at take-off can be reduced to some extent.

**The jump**

The average horizontal velocity during the jump was 6.99 m/sec. Compared to the step, there was an average loss of velocity of 1.31 m/sec. This higher value and the significantly greater dispersion compared to the hop and step, were mainly caused by Evora. Due to an extremely strong deceleration of 1.76 m/sec, he only reached a significantly below-average velocity of 6.50 m/sec. The remaining jumpers reached velocities between 6.93 and 7.26 m/sec, demonstrating a loss of velocity of between 1.09 and 1.48 m/sec. These values correspond to the dispersion range of the hop and the step. However, on average, the loss in velocity in the jump is significantly greater than in the hop and step.

The average vertical velocity generated in the take-off for the jump was 2.63 m/sec and, with the exception of the outlier produced by Evora (3.14 m/sec), varied only between 2.36 and 2.70 m/sec. A close correlation ($r = 0.80$) between the vertical velocity and the velocity at take-off can only be ascertained when Evora’s values are taken into account. However, this illustrates that the higher vertical velocity of Evora was only achieved by a stronger deceleration. Taking Evora into account, both the vertical velocity and the loss of velocity in the take-off were significantly lower than in the 1997 IAAF World Championships in Athletics (MÜLLER & BRÜGGEMANN, 1997), which underlines that the hop-dominant jumping technique was used more frequently in Berlin.

The landing distance was only 0.41 m, which means that it is 0.13 m (i.e., over 25%) less than that in the long jump finalists. The differences within the group of triple jump finalists are also large: Sand’s landing distance was 0.52 m, while Li’s was only 0.27 m. However, as in the long jump, this parameter is of no great importance for the overall distance, as there is no correlation between the landing distance and the effective jumping distance ($r = -0.09$).

Here, although the swing leg is moved at a slightly higher position than in the step, the movement velocity of the swing leg is considerably slower due to the much longer support duration. The positive relationship between the swing-leg angle at take-off and the vertical velocity generated can also be observed here ($r = 0.67$), provided the extreme value of Evora is not considered.

The average take-off duration of the take-off for the jump was 0.174 sec and the values and varied between 0.140 sec (Li) and 0.193 sec (Gregorio). Again, the large dispersion is only caused by Li’s value, because the duration values of the remaining jumpers were much closer to each other (0.167 to 0.193 sec) and thus within the normal dispersion range of the hop and the step. Similar to the hop and step, the take-off duration for the jump correlates closely with the inclination angle ($r = 0.83$). Thus, a stronger bracing led to a longer support time and sometimes even to a stronger deceleration in the take-off ($r = 0.60$).

However, there is no correlation between the inclination angle and the body posture at the start of the take-off (trunk angle TD). Here, the trunk angle is 89° on average and rotates forward during the take-off by an average of 12°. The differences between the jumpers are relatively clear. While Idowu, Sands and Gregorio pass from a light backward lean of the trunk at the end of the step to a forward lean of the trunk in the take-off for the jump, in Evora, Girat and Spasovkhodskiy a significant forward lean of the trunk can already be observed at the beginning of the ground contact.

**The Landing**

The average landing distance was only 0.41 m, which means that it is 0.13 m (i.e., over 25%) less than that in the long jump finalists. The differences within the group of triple jump finalists are also large: Sand’s landing distance was 0.52 m, while Li’s was only 0.27 m. However, as in the long jump, this parameter is of no great importance for the overall distance, as there is no correlation between the landing distance and the effective jumping distance ($r = -0.09$).
Table 16: Characteristics of the step in the individual best jumps in the men’s triple jump final at the 2009 IAAF World Championships in Athletics

<table>
<thead>
<tr>
<th>Name</th>
<th>Studied Attempt</th>
<th>Horizontal Velocity</th>
<th>Loss of Horizontal Velocity</th>
<th>Vertical Velocity</th>
<th>Angle of Projection</th>
<th>Take-off Duration</th>
<th>Inclination Angle</th>
<th>Trunk Angle TD</th>
<th>Trunk Angle TO</th>
<th>Lead-leg Angle TO</th>
<th>Lead-leg Velocity TO</th>
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### Table 17: Characteristics of the jump in the individual best jumps in the men’s triple jump final at the 2009 IAAF World Championships in Athletics

<table>
<thead>
<tr>
<th>Name</th>
<th>Angle of Take-off</th>
<th>Inclination Angle</th>
<th>Lead-leg Angle</th>
<th>Trunk Angle TO</th>
<th>Trunk Angle TD</th>
<th>Lead-leg Veli.</th>
<th>Vertical Veli.</th>
<th>Projection Veli.</th>
<th>Duration</th>
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<td>503</td>
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<td>83</td>
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<td>1.34</td>
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<td>0.170</td>
<td>89</td>
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<td>84</td>
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<td>531</td>
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<td>1.17</td>
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<td>550</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7</td>
</tr>
</tbody>
</table>

**New Studies in Athletics • no. 3/4, 2011**
Biomechanical Analysis of the Horizontal Jumping Events at the 2009 IAAF World Championships in Athletics

The landing position was characterised by a forward lean of the trunk, which was 74° on average. The average knee angle was 122° and thus significantly smaller than in the long jump and the dispersion (between 75° and 147°) was greater.

The average hip angle was only 75°, which was significantly less than in the long jump. However, the variation range of this feature was between 36° (Li) and 113° (Evora and Sands), i.e., from an extremely bent to a relatively extended hip position.

Women’s Triple Jump

Results

Defending champion and favorite Yargelis Savigne (CUB) became the second woman to win two consecutive world titles in the triple jump with a 14.95m. Her teammate Mabel Gay led briefly after the second round and eventually jumped 14.61m to take the silver medal. Third place went to Anna Pyatykh (RUS), whose best on the day was 14.58m (see Table 19).

The performance level in this discipline was far below that achieved in the major events of the previous two years. The average distance of the finalists was 14.51m, 0.57m shorter than what was achieved by the finalists at the 2008 Olympic Games in Beijing (15.08m) and 0.34m shorter than the finalists at the 2007 IAAF World Championships in Osaka (14.85m). Savigne’s winning mark was 0.33m shorter than in Osaka and the first in a decade below 15m to take a world championship gold medal (six athletes in Beijing jumped over 15m).

The average effective distance was 14.61m, only a little larger than the average official distance since the average loss of distance at the take-off was only 0.10m. Although two jumpers, Gay and Pyatykh, showed a relatively large loss of distance at the take-off of 0.17m and 0.19m, respectively, final placement on the basis of the effective distance would remain unchanged.

The average distances of the partial jumps were 5.38m for the hop, 4.20m for the step, and 5.03m for the jump. The ratio of these par-
## Biomechanical Analysis of the Horizontal Jumping Events at the 2009 IAAF World Championships in Athletics

### Table 19: Results of the women’s triple jump final (m) at the 2009 IAAF World Championships in Athletics (wind readings are shown in parentheses in m/sec)

<table>
<thead>
<tr>
<th>Pos</th>
<th>Athlete (Country)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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<tr>
<td></td>
<td></td>
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<td>(-0.2)</td>
<td>(-0.1)</td>
<td>(0.0)</td>
<td>(1.3)</td>
<td>(0.0)</td>
</tr>
<tr>
<td>2</td>
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<td>14.50</td>
<td>X</td>
<td>14.61</td>
<td>14.48</td>
<td>14.04</td>
</tr>
<tr>
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<td>(-0.1)</td>
<td></td>
<td>(0.5)</td>
<td>(0.5)</td>
<td>(0.1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-0.3)</td>
<td>(-0.1)</td>
<td>(0.0)</td>
<td>(-0.4)</td>
<td>(-0.2)</td>
<td>(0.0)</td>
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<tr>
<td></td>
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<td>(0.0)</td>
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<td>(0.1)</td>
<td>(0.8)</td>
<td>(0.1)</td>
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<tr>
<td>5</td>
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<td>X</td>
<td>X</td>
<td>14.41</td>
<td>14.48</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.4)</td>
<td></td>
<td></td>
<td>(0.1)</td>
<td>(0.2)</td>
<td></td>
</tr>
<tr>
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<td></td>
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<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.1)</td>
<td>(0.0)</td>
</tr>
<tr>
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<td>14.26</td>
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<td>14.03</td>
<td>14.20</td>
<td>14.16</td>
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<tr>
<td></td>
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<td>(-0.2)</td>
<td>(0.0)</td>
<td>(-0.2)</td>
<td>(0.1)</td>
<td>(0.1)</td>
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<td></td>
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<td>(0.3)</td>
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<td>(0.0)</td>
<td></td>
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<td>13.79</td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td>(-0.2)</td>
<td>(0.0)</td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td>(-0.2)</td>
<td></td>
<td></td>
<td></td>
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</table>

The most striking difference with the men’s finalists in Berlin was the significantly shorter step phase. Compared to the 1997 IAAF World Championships in Athletics, it can be concluded that the distance of the hop is comparably large and that the largest differences (both in absolute and percentage terms) are the slightly longer step and the significantly shorter jump (MÜLLER & BRÜGGE-MANN, 1997).

The analysis of the correlations between the partial distances and the effective jumping distance leads to less significant values than in the men. There is a moderate relationship between the total distance and the hop and jump distance ($r = 0.54$ bzw. 0.51), whereas the correlation with the distance of the step is only slight ($r = 0.24$).

### Take-off preparation

The average length of the final stride ($1_{\text{last}}$) was 0.08m, approximately 3%, less than the penultimate stride ($2_{\text{last}}$) (see Table 21). Similar to the differences within the group, this reduction was half as large as with the men. This can be attributed to the inconsistent structure of the last two structure in the take-off preparation: only five jumpers showed the usual long-short rhythm, while in three, including the winner, had a slight lengthening of the last stride. The dispersion reaches from -11% (Gay) to +5% (Savigne). This means that it is considerably smaller than in the men.

In most triple jumpers, the velocity of the final stride remains constant or increases slightly compared with the penultimate stride. In Berlin, there was hardly a change in the last
Table 20: Absolute and relative jumping distances as well as loss of distance at the take-off board of the individual best jumps in the women's triple jump final at the 2009 IAAF World Championships in Athletics (the coloured values indicate the importance of the respective partial jump in comparison with the respective two other jumpers)

<table>
<thead>
<tr>
<th>Name</th>
<th>Studied Attempt</th>
<th>Distance [m]</th>
<th>Stride Length [m]</th>
<th>Relative Distance [%]</th>
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<tbody>
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<td></td>
<td></td>
<td>Official</td>
<td>Effective</td>
<td>To Loss</td>
</tr>
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<td>Savigne</td>
<td>5</td>
<td>14.95</td>
<td>15.04</td>
<td>0.09</td>
</tr>
<tr>
<td>Gay</td>
<td>4</td>
<td>14.61</td>
<td>14.78</td>
<td>0.17</td>
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<td>Pyatykh</td>
<td>6</td>
<td>14.53</td>
<td>14.72</td>
<td>0.19</td>
</tr>
<tr>
<td>Topic</td>
<td>4</td>
<td>14.52</td>
<td>14.63</td>
<td>0.11</td>
</tr>
<tr>
<td>Smith</td>
<td>5</td>
<td>14.48</td>
<td>14.48</td>
<td>0.00</td>
</tr>
<tr>
<td>Lebedeva</td>
<td>2</td>
<td>14.48</td>
<td>14.57</td>
<td>0.09</td>
</tr>
<tr>
<td>Bujin</td>
<td>2</td>
<td>14.26</td>
<td>14.37</td>
<td>0.11</td>
</tr>
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<td>Veldakova</td>
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<td>14.25</td>
<td>14.26</td>
<td>0.01</td>
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<td>Std. Dev.</td>
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<td>0.22</td>
<td>0.25</td>
<td>0.07</td>
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</table>
Table 21: Stride length and horizontal velocity during the last two approach strides of the individual best jumps in the women’s triple jump final at the 2009 IAAF World Championships in Athletics

<table>
<thead>
<tr>
<th>Name</th>
<th>Studied Attempt</th>
<th>Stride Length [m]</th>
<th>Difference</th>
<th>Horizontal Velocity [m/sec]</th>
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<tr>
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<td>1last</td>
<td></td>
<td>2last</td>
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<td>2.18</td>
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<td>2.15</td>
<td>-11%</td>
</tr>
<tr>
<td>Pyatykh</td>
<td>6</td>
<td>2.30</td>
<td>2.18</td>
<td>-5%</td>
</tr>
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<td>2.41</td>
<td>+1%</td>
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<tr>
<td>Smith</td>
<td>5</td>
<td>2.42</td>
<td>2.36</td>
<td>-2%</td>
</tr>
<tr>
<td>Lebedeva</td>
<td>2</td>
<td>2.06</td>
<td>2.09</td>
<td>+1%</td>
</tr>
<tr>
<td>Bujin</td>
<td>2</td>
<td>2.31</td>
<td>2.20</td>
<td>-5%</td>
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<tr>
<td>Veldakova</td>
<td>1</td>
<td>2.46</td>
<td>2.21</td>
<td>-10%</td>
</tr>
<tr>
<td>Mean</td>
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<td>2.30</td>
<td>2.22</td>
<td>-3%</td>
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<tr>
<td>Std. Dev</td>
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<td>0.11</td>
<td>0.06</td>
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</table>

two strides and there was only one finalist, Bujin, who slowed down slightly in the final stride. This finding agrees well with the findings at the 1997 IAAF World Championships in Athletics (Müller & Brüggemann, 1997).

The average approach velocity in the last stride was 9.08 m/sec. The values varied from 8.84 m/sec (Bujin) to 9.39 m/sec (Savigne). The correlation between this feature and the total jumping distance is as low as with the men’s finalists (r = 0.38). However, here, too, the fastest athlete was the winner. Conversely, the second fastest athlete (Veldakova) reached only place eight. Thus, the women confirm the trend already observed in the men that in the triple jump, an approach velocity deficit can be better compensated through technique and strength than in the long jump.

The hop

The average horizontal velocity during the hop was 8.35 m/sec, with an average loss of velocity of 0.73 m/sec during the take-off. Although the horizontal velocity shows a similar dispersion in the women’s finalists as for the men, it was slightly greater from a relative point of view. However, in seven of the women’s finalists, the deceleration during the take-off was within a relatively narrow range from 0.68 m/sec. to 0.83 m/sec, while only Lebedeva demonstrates a significantly lower loss of velocity of 0.53 m/sec.

The average vertical velocity generated during the take-off for the hop was 2.37 m/sec. With values ranging between 2.24 m/sec and 2.49 m/sec, the dispersion was significantly lower than for the men. The results of these parameters are very similar to the values measured at the 1997 IAAF World Championships in Athletics (MÜLLER & BRÜGGEMANN, 1997).

The vertical velocity depended very much on the deceleration at the take-off board (r = 0.83). Thus, athletes who took off “higher” slowed down more during the take-off. The correlation of vertical velocity with the hop distance (r = 0.46) is moderate, but slightly less than in the men’s finalists.

The average take-off duration during the take-off for the hop was 0.122 sec and scattered only from 0.107 sec to 0.140 sec. Thus, the duration and the dispersion are a little greater than in the men. The take-off duration is associated with the inclination angle (r = 0.78), although not as closely as with the men. The correlation with the hop distance is smaller, as well (r = 0.42).
Table 22: Characteristics of the hop in the individual best jumps in the women's triple jump final at the 2009 IAAF World Championships in Athletics

<table>
<thead>
<tr>
<th>Name</th>
<th>Studied Attempt</th>
<th>Horizontal Velocity [m/sec]</th>
<th>Loss of Horizontal Velocity [m/sec]</th>
<th>Vertical Velocity [m/sec]</th>
<th>Angle of Projection [°]</th>
<th>Take-off Duration [sec]</th>
<th>Inclination Angle [°]</th>
<th>Trunk Angle TD [°]</th>
<th>Trunk Angle TO [°]</th>
<th>Lead-Leg Angle TO [°]</th>
<th>Lead-Leg Velocity TO [°/sec]</th>
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</thead>
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<td>Savigne</td>
<td>5</td>
<td>8.63</td>
<td>0.76</td>
<td>2.49</td>
<td>16</td>
<td>0.107</td>
<td>16</td>
<td>90</td>
<td>87</td>
<td>-17</td>
<td>814</td>
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<tr>
<td>Gay</td>
<td>4</td>
<td>8.12</td>
<td>0.75</td>
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<td>87</td>
<td>-14</td>
<td>651</td>
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<td>Pyatyk</td>
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<td>8.21</td>
<td>0.80</td>
<td>2.46</td>
<td>17</td>
<td>0.127</td>
<td>22</td>
<td>90</td>
<td>86</td>
<td>-16</td>
<td>702</td>
</tr>
<tr>
<td>Topic</td>
<td>4</td>
<td>8.45</td>
<td>0.69</td>
<td>2.30</td>
<td>15</td>
<td>0.127</td>
<td>21</td>
<td>89</td>
<td>89</td>
<td>-11</td>
<td>712</td>
</tr>
<tr>
<td>Smith</td>
<td>5</td>
<td>8.34</td>
<td>0.76</td>
<td>2.39</td>
<td>16</td>
<td>0.140</td>
<td>23</td>
<td>89</td>
<td>87</td>
<td>-11</td>
<td>660</td>
</tr>
<tr>
<td>Lebedeva</td>
<td>2</td>
<td>8.59</td>
<td>0.53</td>
<td>2.24</td>
<td>15</td>
<td>0.113</td>
<td>18</td>
<td>87</td>
<td>85</td>
<td>-18</td>
<td>663</td>
</tr>
<tr>
<td>Bujin</td>
<td>2</td>
<td>8.00</td>
<td>0.83</td>
<td>2.49</td>
<td>17</td>
<td>0.113</td>
<td>19</td>
<td>88</td>
<td>88</td>
<td>-13</td>
<td>778</td>
</tr>
<tr>
<td>Veldakova</td>
<td>1</td>
<td>8.48</td>
<td>0.68</td>
<td>2.24</td>
<td>15</td>
<td>0.113</td>
<td>17</td>
<td>91</td>
<td>89</td>
<td>-6</td>
<td>823</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>8.35</td>
<td>0.73</td>
<td>2.37</td>
<td>15.8</td>
<td>0.122</td>
<td>19</td>
<td>89</td>
<td>87</td>
<td>-13</td>
<td>725</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td></td>
<td>0.23</td>
<td>0.09</td>
<td>0.10</td>
<td>0.91</td>
<td>0.012</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>7.0</td>
</tr>
</tbody>
</table>
Among the women’s finalists the inclination angle was not affected by the trunk posture at the beginning of the take-off (Trunk Angle TD). The average angle was 89° and differs little from the trunk angle during the take-off (Trunk Angle TO), which reached an average of 87°. In nearly all athletes the trunk remained stable during the entire take-off or there was just a slight forward rotation. Only Pyatykh exhibited a somewhat clearer movement of the trunk, about 4°. In comparison to the men’s finalists, there was a tendency toward a more marked forward lean of the trunk during the take-off.

During the take-off, the thigh of the swing leg reached an average angle of -13° (i.e., below the horizontal) and values scatter between -6° and -17°. The average angular velocity of the thigh was 725°/sec. These values are broadly consistent with the values measured in the men. The assumed correlation of the swing-leg parameters with the loss of velocity and with the vertical velocity produced during take-off cannot be confirmed for the women, because the largest correlation between the swing-leg angle and the vertical velocity was $r = -0.38$, which is a too low of a value.

**The step**

The average horizontal velocity during the step was 7.65 m/sec. Compared to the hop, there was an average loss of velocity of 0.70 m/sec. These were considerably lower than for the men’s finalists, but both parameters show a greater dispersion. During the take-off for the step Savigne loses only 0.41 m/sec, which is significantly less than the loss of all the other jumpers, male or female. Smith exhibited the greatest loss of velocity, 0.96 m/sec.

With an average of 1.63 m/sec within a range of 1.19 m/sec for Veldakova and 1.93 m/sec for Pyatykh, the vertical velocity values produced during the take-off for the step by women’s finalists were significantly lower than in the men. Compared to the results of 1997 IAAF World Championships in Athletics, there is a slightly higher vertical velocity with a smaller loss of velocity to be observed (MÜLLER & BRÜGGEMANN, 1997).

The relationship between the vertical velocity generated and the loss of velocity during the take-off was $r = 0.79$, which is almost as high as in the hop. The correlation with the step distance is relatively close, too ($r = 0.81$). In the women, a higher vertical velocity led to a greater distance of the step. Although this could be expected, this could not be observed so clearly either in the men or in the hop. This data suggests that women prefer a different technique during the step, which is characterised by a flatter flight curve and a lower braking effect during the take-off.

The average take-off duration for the step was 0.145 sec and varied with between 0.113 sec (Savigne) and 0.160 sec (Gay and Smith). In the step, too, the take-off duration was relatively closely associated with the inclination angle ($r = 0.77$) and the loss of horizontal velocity ($r = 0.70$). A more marked bracing action usually leads to a stronger deceleration and thus also to a longer support time. In this group, as with the men, a larger inclination angle was not caused by the trunk posture at the touchdown for the take-off (Trunk Angle TD). At the beginning of the take-off, the average trunk angle was 89° and during the take-off the jumpers rotated forward by average of 10°. But the differences among the jumpers are clear: while Savigne rotates forward by only 1° and thus remains almost upright, Topic demonstrates a very strong rotation of 16°, which took her from a backward lean of the body to a significant forward lean.

The average thigh angle of the swing leg during the flight reached was -23° and the average angular velocity was 590°/sec. Both values are, as in the men, significantly lower than in the hop. There is no correlation between the swing-leg movement and the vertical velocity generated during the step. There is only a moderate correlation ($r = 0.60$) between the swing-leg angle and the loss of horizontal velocity. Thus we can interpret that a greater movement of the swing-leg thigh leads to a stronger deceleration in the jump.
Table 23: Characteristics of the step in the individual best jumps in the women’s triple jump final at the 2009 IAAF World Championships in Athletics

<table>
<thead>
<tr>
<th>Name</th>
<th>Studied Attempt</th>
<th>Horizontal Velocity [m/sec]</th>
<th>Loss of Horizontal Velocity [m/sec]</th>
<th>Vertical Velocity [m/sec]</th>
<th>Angle of Projection [°]</th>
<th>Take-off Duration [sec]</th>
<th>Inclination Angle [°]</th>
<th>Trunk Angle TD [°]</th>
<th>Trunk Angle TO [°]</th>
<th>Lead-leg Angle TO [°]</th>
<th>Lead-leg Velocity TO [°/sec]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Savigne</td>
<td>5</td>
<td>8.22</td>
<td>0.41</td>
<td>1.24</td>
<td>8.6</td>
<td>0.113</td>
<td>11</td>
<td>89</td>
<td>88</td>
<td>-33</td>
<td>586</td>
</tr>
<tr>
<td>Gay</td>
<td>4</td>
<td>7.30</td>
<td>0.82</td>
<td>1.70</td>
<td>13.1</td>
<td>0.160</td>
<td>17</td>
<td>89</td>
<td>82</td>
<td>-25</td>
<td>548</td>
</tr>
<tr>
<td>Pyatykh</td>
<td>6</td>
<td>7.46</td>
<td>0.74</td>
<td>1.93</td>
<td>14.5</td>
<td>0.140</td>
<td>15</td>
<td>89</td>
<td>79</td>
<td>-28</td>
<td>592</td>
</tr>
<tr>
<td>Topic</td>
<td>4</td>
<td>7.80</td>
<td>0.65</td>
<td>1.72</td>
<td>12.5</td>
<td>0.147</td>
<td>18</td>
<td>94</td>
<td>78</td>
<td>-20</td>
<td>639</td>
</tr>
<tr>
<td>Smith</td>
<td>5</td>
<td>7.38</td>
<td>0.96</td>
<td>1.84</td>
<td>14.0</td>
<td>0.160</td>
<td>17</td>
<td>88</td>
<td>75</td>
<td>-11</td>
<td>569</td>
</tr>
<tr>
<td>Lebedeva</td>
<td>2</td>
<td>7.80</td>
<td>0.79</td>
<td>1.84</td>
<td>13.3</td>
<td>0.147</td>
<td>19</td>
<td>86</td>
<td>73</td>
<td>-29</td>
<td>639</td>
</tr>
<tr>
<td>Bujin</td>
<td>2</td>
<td>7.37</td>
<td>0.63</td>
<td>1.57</td>
<td>12.0</td>
<td>0.147</td>
<td>14</td>
<td>85</td>
<td>75</td>
<td>-19</td>
<td>642</td>
</tr>
<tr>
<td>Veldakova</td>
<td>1</td>
<td>7.90</td>
<td>0.58</td>
<td>1.19</td>
<td>8.6</td>
<td>0.147</td>
<td>16</td>
<td>91</td>
<td>85</td>
<td>-25</td>
<td>507</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>7.65</td>
<td>0.70</td>
<td>1.63</td>
<td>12.1</td>
<td>0.145</td>
<td>16</td>
<td>89</td>
<td>79</td>
<td>-24</td>
<td>590</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td></td>
<td>0.33</td>
<td>0.17</td>
<td>0.28</td>
<td>2.29</td>
<td>0.015</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>7</td>
<td>49</td>
</tr>
</tbody>
</table>
Table 24: Characteristics of the jump in the individual best jumps in the women's triple jump final at the 2009 IAAF World Championships in Athletics

<table>
<thead>
<tr>
<th>Name</th>
<th>Studied Attempt</th>
<th>Horizontal Velocity</th>
<th>Loss of Horizontal Velocity</th>
<th>Vertical Velocity</th>
<th>Angle of Projection</th>
<th>Take-off Duration</th>
<th>Inclination Angle</th>
<th>Trunk Angle TD</th>
<th>Trunk Angle TO</th>
<th>Lead-leg Angle TO</th>
<th>Lead-leg Velocity TO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Savigne</td>
<td>5</td>
<td>6.87</td>
<td>1.35</td>
<td>2.67</td>
<td>21.2</td>
<td>0.147</td>
<td>21</td>
<td>92</td>
<td>87</td>
<td>-18</td>
<td>578</td>
</tr>
<tr>
<td>Gay</td>
<td>4</td>
<td>6.07</td>
<td>1.23</td>
<td>2.57</td>
<td>22.9</td>
<td>0.173</td>
<td>19</td>
<td>90</td>
<td>81</td>
<td>-21</td>
<td>476</td>
</tr>
<tr>
<td>Pyatykh</td>
<td>6</td>
<td>6.32</td>
<td>1.14</td>
<td>2.48</td>
<td>21.4</td>
<td>0.167</td>
<td>21</td>
<td>86</td>
<td>85</td>
<td>-18</td>
<td>578</td>
</tr>
<tr>
<td>Topic</td>
<td>4</td>
<td>6.89</td>
<td>0.91</td>
<td>2.14</td>
<td>17.2</td>
<td>0.153</td>
<td>18</td>
<td>86</td>
<td>75</td>
<td>-16</td>
<td>609</td>
</tr>
<tr>
<td>Smith</td>
<td>5</td>
<td>6.00</td>
<td>1.38</td>
<td>1.78</td>
<td>16.5</td>
<td>0.167</td>
<td>22</td>
<td>86</td>
<td>74</td>
<td>-13</td>
<td>542</td>
</tr>
<tr>
<td>Lebedeva</td>
<td>2</td>
<td>6.30</td>
<td>1.50</td>
<td>2.32</td>
<td>20.2</td>
<td>0.173</td>
<td>26</td>
<td>80</td>
<td>70</td>
<td>-22</td>
<td>613</td>
</tr>
<tr>
<td>Bujin</td>
<td>2</td>
<td>6.11</td>
<td>1.26</td>
<td>2.80</td>
<td>24.6</td>
<td>0.147</td>
<td>18</td>
<td>86</td>
<td>76</td>
<td>-22</td>
<td>555</td>
</tr>
<tr>
<td>Veldakova</td>
<td>1</td>
<td>6.70</td>
<td>1.20</td>
<td>2.24</td>
<td>18.5</td>
<td>0.160</td>
<td>21</td>
<td>85</td>
<td>81</td>
<td>-16</td>
<td>584</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>6.41</td>
<td>1.25</td>
<td>2.38</td>
<td>20.3</td>
<td>0.163</td>
<td>21</td>
<td>86</td>
<td>79</td>
<td>-18</td>
<td>567</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td></td>
<td>0.36</td>
<td>0.18</td>
<td>0.33</td>
<td>2.80</td>
<td>0.014</td>
<td>3</td>
<td>4</td>
<td>6</td>
<td>3</td>
<td>44</td>
</tr>
</tbody>
</table>
**The jump**

The average horizontal velocity during the jump was 6.41 m/sec. This means an average loss of velocity of 1.25 m/sec compared to the step. Similar to the men, this value was significantly higher than in the hop and step. Also, the dispersion was quite large and ranged from 0.91 m/sec (Topic) to 1.50 m/sec (Lebedeva). In this way, Topic achieved the highest horizontal velocity (6.89 m/sec), while Gay was the slowest (6.07 m/sec).

The average vertical velocity generated at the take-off for the jump is 2.38 m/sec and, even without the extremely low value of Smith (1.78 m/sec), there was a relatively wide variation between 2.14 m/sec and 2.80 m/sec. Compared to the 1997 IAAF World Championships in Athletics (MÜLLER & BRÜGGEMANN, 1997), the average vertical velocity in Berlin was significantly lower. This is connected with the lower loss of horizontal velocity and can be used to explain the shorter average jump distance.

Although the influence of the vertical velocity on the jump distance was not great \( r = 0.64 \), it was significantly higher than with the men’s finalists.

The average take-off duration during the take-off for the jump was 0.163 sec and varied from 0.147 sec (Savigne and Bujin) to 0.187 sec (Smith). This dispersion is lower than in the step and also lower than for the men. In the jump, the take-off duration does not depend so closely on the inclination angle \( r = 0.51 \) as in the hop and step. However, a larger inclination angle, together with a more marked bracing action, usually led to a stronger deceleration during the take-off \( r = 0.74 \).

The trunk angle was 86° on average and rotated forward during the take-off by an average of 7°. This value is significantly smaller than in the men and can be attributed to the fact that most of the women’s finalists demonstrated a relatively clear forward lean of the trunk already at the beginning of the take-off. Only Savigne shows a slight backward lean when landing after the step and she rotates forward only a few degrees during the take-off so that her trunk remains largely upright.

As far as the characteristics of the swing leg are concerned, there was an average thigh angle during the take-off of -18° and an average angular velocity of the thigh of 567°/sec. These results are within the range of the values mea-

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**Table 25: Characteristics of the landing in the individual best jumps in the women’s triple jump final at the 2009 IAAF World Championships in Athletics**

<table>
<thead>
<tr>
<th>Name</th>
<th>Studied Attempt</th>
<th>Distance</th>
<th>Landing Loss</th>
<th>Knee Angle</th>
<th>Hip Angle</th>
<th>Trunk Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Savigne</td>
<td>5</td>
<td>0.53</td>
<td>0.00</td>
<td>143</td>
<td>109</td>
<td>91</td>
</tr>
<tr>
<td>Gay</td>
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<td>0.48</td>
<td>0.00</td>
<td>141</td>
<td>80</td>
<td>62</td>
</tr>
<tr>
<td>Pyatykh</td>
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<td>0.00</td>
<td>126</td>
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<td>70</td>
</tr>
<tr>
<td>Topic</td>
<td>4</td>
<td>0.38</td>
<td>0.00</td>
<td>131</td>
<td>55</td>
<td>45</td>
</tr>
<tr>
<td>Smith</td>
<td>5</td>
<td>0.48</td>
<td>0.00</td>
<td>122</td>
<td>56</td>
<td>57</td>
</tr>
<tr>
<td>Lebedeva</td>
<td>2</td>
<td>0.49</td>
<td>0.06</td>
<td>125</td>
<td>74</td>
<td>75</td>
</tr>
<tr>
<td>Bujin</td>
<td>2</td>
<td>0.59</td>
<td>0.04</td>
<td>144</td>
<td>96</td>
<td>84</td>
</tr>
<tr>
<td>Veldakova</td>
<td>1</td>
<td>0.56</td>
<td>0.00</td>
<td>128</td>
<td>86</td>
<td>82</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>0.49</td>
<td>0.01</td>
<td>133</td>
<td>79</td>
<td>71</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td></td>
<td>0.07</td>
<td>0.02</td>
<td>9</td>
<td>18</td>
<td>15</td>
</tr>
</tbody>
</table>
sured in the men’s finalist. Although the swing leg is brought forward slightly higher during the jump than during the step, the movement velocity is lower due to the longer take-off duration. The correlation between the swing-leg angle at take-off and the vertical velocity generated is relatively small, but negative ($r = -0.78$). Thus a higher lead of the swing leg is associated with a lower vertical velocity during the jump, which contradicts both the expected effect and the correlation found in the men.

**The landing**

The average landing distance was 0.49m. This value is similar to that found in the female long jumpers in Berlin and larger than the value found in the male triple jump finalist. The differences within the group were great: Bujin achieved a very good landing distance of 0.59m, while Topic achieves only a moderate value of 0.38m. However, as with the men, this parameter had no relevance for the performance because the correlation between the landing distance and the effective jumping distance is not only small and negative ($r = -0.34$).

The landing position of most athletes was characterised by a marked forward lean of the trunk (71° on average). Here, however, a relativelarge dispersion between 45° (Topic) and 91° (Savigne) was observed. There were correspondingly large differences regarding the hip angle, between 55° (Topic) and 109° (Savigne). With an average angle of 79°, the hip was bent significantly more than in the female long jumpers. The average knee angle was 133° and thus only slightly smaller than in the long jump. However, the variation was smaller (122°-142°).

**Summary**

It can be concluded that the horizontal jumps at the 2009 IAAF World Championships in Athletics were characterised by a very good performance level. With the exception of the women’s triple jump, the performances at the previous two major events, the 2008 Olympic in Beijing and the 2007 IAAF World Champi-

onships in Athletics in Osaka, were matched. However, the performances of the female triple jumpers were almost 4% lower than in Beijing.

In both the long jump and the triple jump, very good approach and take-off accuracy was observed in the attempts analysed. In the landings, only small distance losses were observed. Therefore, the differences between the official and effective jump distances were mostly only small and had no effect on the final placing.

From a biomechanical point of view, the data collected confirmed the current technique models in most cases:

1. In the long jump, the approach velocity proved to be a determining performance factor. In the triple jump, too, the fastest athletes were the winners, but here velocity deficits during the approach could more often be compensated for by technical skill or other physical abilities.

2. The classic organisation of the take-off preparation with an extension of the penultimate stride and a significant lowering of the CM in the long jump or with an acceleration up to the last stride in the triple jump was observed in almost all the finalists in Berlin.

3. The influence of the vertical velocity generated during the take-off and its relation to the loss of velocity at the take-off board or with the force of the bracing phase was clear. The long jumpers all strove to achieve a high vertical velocity. This was mostly achieved by a stronger bracing action (through a greater inclination angle), which leads to a more marked deceleration at the take-off board. The triple jumpers, on the other hand, tried to take off from the board as fast as possible through a less marked bracing action, which was associated with a correspondingly lower vertical velocity in the hop.
In the female long jumpers as well as all the triple jumpers, the bracing action was not controlled by a more marked backward lean of the trunk but by a forward movement of the take-off foot. This seems to be especially important in the triple jump, where a largely upright body posture and body rotations as small as possible (for better balance maintenance) are striven for in the individual jumps.

In the triple jump, ten of the studied finalists demonstrated a hop-dominated technique, while the remaining six demonstrated a balanced technique. No jumper demonstrated an emphasis on the jump. However, the correlations between the total distance and the distance of the step (in the men) and the distance of the jump (in men and women) were closer than the correlation between the total distance and the hop distance, which emphasises the importance of the hop and step.

In the men’s triple jump, there was in some cases a significant relationship between the translation of the velocity in the partial jumps and the swing-leg movement: in most cases a higher lead of the swing leg causes a greater vertical velocity at take-off, but also a greater loss of horizontal velocity. Thus, the angle of projection can be controlled relatively well by the swing-leg lead.

In all disciplines, the landing distance proved to be of little significance for the overall performance. However, this can lead to an underestimation of the importance of the landing phase, particularly as the influence of the landing height on the jumping distance was not examined.

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REFERENCES


ABSTRACT

The purpose of the study was to examine the consistency and variability of kinematic parameters in the technique used in the triple jump, one of the most complex athletics disciplines. An examination was made of two attempts of an elite female jumper performed in laboratory conditions during her preparation for the 2008 Olympic Games, where she placed 6th in the final. The Opto-track system and 3-D kinematical technology were used in to study the parameters of model technique. The analysis revealed that optimal results can be achieved with different programme motor strategies and that the motor pattern is generated by both consistent and variable parameters. The most consistent parameters of motor pattern in the subject were: partial distances of the individual phases, duration of the support phases in the take-off actions, the angles of take-off and the vertical amplitude of the body centre of mass. Variability of the motor pattern was revealed mostly in the following kinematical parameters: the velocity in the last 5m of the approach, the length and proportion of the last two approach strides, the horizontal velocity of the body centre of mass in the take-off actions.

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Introduction

From the biomechanical point of view, the triple jump is one of the most complex track and field disciplines, comprising an approach phase and three consecutive phases (known as the hop, the step and the jump) which themselves include a take-off, flight and landing. Each of the structural units represents a specific motor task with certain characteristics and requirements that the jumper must fulfil in order to execute a successful jump.
Performance in the triple jump, i.e. the overall distance achieved, largely depends on the approach velocity and the optimisation of the distances of the three flight phases in relation to each other (HAY & MILLER, 1985; HAY, 1992; GRAHMAN-SMITH & LEES, 1994; MILADINOV & BONOVI, 2004). According to some previous studies (CONRAD & RITZDORF, 1990; GRAHMAN-SMITH & LEES, 1994; HAY, 1999; JURGENS, 1998, PANOUTSAKOPOULOS & KOLLIAS, 2008), preservation of horizontal velocity throughout the flight phases is a crucial factor for achieving maximal distance and the critical moment for this is the transition from the hop phase into the step phase.

If we look at motor pattern structure, the triple jump can be regarded as a connection of cyclic and acyclic movements. Efficient transformation of approach velocity into the take-off for the hop phase is correlated with correct rhythm and with visual and kinaesthetic control (YU & HAY, 1996; HAY, 1999; KYROLAINE et al., 2007). The hop is generally the longest of the three flight phases and represents 36–39% of the overall distance (GRAHMAN-SMITH & LEES, 1994; KYROLAINE et al., 2007; PANOUTSAKOPOULOS & KOLLIAS, 2008). Efficient execution of the hop is a key element for the next two phases (step and jump) and thus the entire triple jump.

However, the exact proportion of the three phase distances depends on motor strategies adopted by jumpers. Three techniques of triple jump have been identified: “Hop Dominated”, “Hop-Jump” and “Balanced”. In the first, there is an emphasis on the distance of the first phase (hop), in the second, the emphasis is on the distance of the last phase while in the third, the jumper seeks a balance between the distances of all three phases. Distances and proportions of the different phases are defined with the execution of the support and flight phases. The transition of horizontal velocity is correlated mostly with efficient take-off action. The optimal proportion between horizontal and vertical component of the body’s centre of mass (BCM) velocity in the support phase is very important.

It seems clear that overall distance in the triple jump is a product of various types of technique, other factors and their correlations. The Bernstein Theory (LATASH, 1994) defines sports technique as a managed process with compensational and self-regulative characteristics. Although the motor pattern is standardised and automated, an athlete cannot control all the motor process phases (Schmidt & Lee, 1999). In order for the motor pattern to be correct and rational, its individual elements have to be coordinated in such way that some follow the principle of parallel execution and others the principle of consequent execution. Optimal coordination of the motor pattern is possible only if it is programmed, and a movement within a sports technique cannot be executed correctly without the existence of a suitable programme. An athlete possesses programmes and sub-programmes in a primary motor centre of the central neural system; they are either permanent or acquired according to the external and internal circumstances (ENOKA, 1998).

Normally, technique in elite sports performers is never final or absolute. Every athlete constantly seeks to perfect his/her technique and adapt it to numerous external and internal factors. Although the basic elements of technique are relatively stable, some subtle aspects do change. The complete stabilisation of technique is not possible due to various endogenous factors (mental status, degree of fitness, pressure, competitive stress) and exogenous factors (micro-climatic conditions: wind, outside temperature, altitude above sea level; and sports infrastructure: different structure and elasticity of the surface).

According to the Bernstein’s theory (LATASH, 1994) there are two programme strategies for the motor pattern where a high degree of movement stabilisation is required. According to the first, it is possible to realise the motor pattern by keeping the technical parameters constant. The second strategy is based on the consistency of some and variability of other technical parameters. Hypothetically, it could be expected for a result in the triple jump to be achieved with different programme strategies and with combination of various kinematic parameters in the individual technical phases.
The aim of the present study was to examine consistency and variability of technique parameters in a world-class female triple jumper. We wanted to see if such an elite athlete uses different programme strategies when executing the triple jump. Our approach was to establish which kinematical parameters vary and which are consistent from one jump to another.

Methods

The subject of the study was Slovenian jumper Marija Šestak (age: 28, height: 172cm, weight: 66.5kg), who was the bronze medallist in the 2008 World Indoor Championships, the 6th placer in the 2008 Olympic Games and the silver medallist in the 2009 European Indoor Championships. She has a personal best of 15.03m (see Figure 1).

Under laboratory conditions, measurements of her jumps were carried out during the preparation phase prior to the 2008 Olympic Games in Beijing. Six attempts were recorded and analysis was made of the two longest (attempt A, attempt B). The official distance of attempt A was 13.68m with the effective distance of 13.85 (toe-to-board distance = 0.17m). The official distance of the second attempt was 13.63m and the effective distance was 13.66m (toe-to-board distance = 0.03m). The difference in the effective distance between the two attempts was 0.19m.

OPTO-TRACK technology from the Italian manufacturer Microgate was used to measure the distances of different phases as well as the support and flight times of the strides in the approach, and in the three jump phases (hop, step and jump). The basic components of the measuring system are interlinked rods (100cm x 4cm x 3cm) with built-in optical sensors and the computer program for data recording and analysis (see Figure 2). Each of the rods contains 32 sensors – photo cells, which are positioned every 4cm and placed 0.2cm above the ground surface. The total length of the interlinked rods was 20m. The rods of the measuring system were placed on both sides of the runway (width = 1.22m). A system of infrared photocells (BROWER – Timing System) was used to measure the approach velocity (11-6m, 6-1m).
### Table 1: Consistency and variability of kinematical parameters in triple jump technique

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>PHASE</th>
<th>Attempt A</th>
<th>Attempt B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Result (m)</td>
<td></td>
<td>13.68</td>
<td>13.63</td>
</tr>
<tr>
<td>Effective distance (m)</td>
<td></td>
<td>13.68</td>
<td>13.66</td>
</tr>
<tr>
<td>Approach velocity (ms⁻¹)</td>
<td>11 – 6 m</td>
<td>6.94</td>
<td>6.94</td>
</tr>
<tr>
<td></td>
<td>6 – 1 m</td>
<td>8.20</td>
<td>8.77</td>
</tr>
<tr>
<td>Approach stride length (m)</td>
<td>2L</td>
<td>2.20</td>
<td>2.17</td>
</tr>
<tr>
<td></td>
<td>1L</td>
<td>2.30</td>
<td>2.18</td>
</tr>
<tr>
<td>Approach velocity (ms⁻¹)</td>
<td>2 L</td>
<td>8.25</td>
<td>8.40</td>
</tr>
<tr>
<td></td>
<td>1L</td>
<td>8.35</td>
<td>8.41</td>
</tr>
<tr>
<td>Stride length (m)</td>
<td>Hop</td>
<td>4.73</td>
<td>4.73</td>
</tr>
<tr>
<td></td>
<td>Step</td>
<td>4.01</td>
<td>3.92</td>
</tr>
<tr>
<td></td>
<td>Jump</td>
<td>4.94</td>
<td>4.98</td>
</tr>
<tr>
<td>Relative distance (%)</td>
<td>Hop</td>
<td>34.6</td>
<td>34.7</td>
</tr>
<tr>
<td></td>
<td>Step</td>
<td>29.3</td>
<td>28.8</td>
</tr>
<tr>
<td></td>
<td>Jump</td>
<td>36.1</td>
<td>36.5</td>
</tr>
<tr>
<td>Horizontal velocity (ms⁻¹)</td>
<td>Hop</td>
<td>7.88</td>
<td>7.93</td>
</tr>
<tr>
<td></td>
<td>Step</td>
<td>7.35</td>
<td>7.06</td>
</tr>
<tr>
<td></td>
<td>Jump</td>
<td>5.89</td>
<td>6.00</td>
</tr>
<tr>
<td>Loss of horizontal velocity (ms⁻¹)</td>
<td>Hop</td>
<td>-0.47</td>
<td>-0.48</td>
</tr>
<tr>
<td></td>
<td>Step</td>
<td>-0.53</td>
<td>-0.87</td>
</tr>
<tr>
<td></td>
<td>Jump</td>
<td>-1.46</td>
<td>-1.06</td>
</tr>
<tr>
<td>Vertical velocity (ms⁻¹)</td>
<td>Hop</td>
<td>2.54</td>
<td>2.33</td>
</tr>
<tr>
<td></td>
<td>Step</td>
<td>1.86</td>
<td>1.88</td>
</tr>
<tr>
<td></td>
<td>Jump</td>
<td>2.64</td>
<td>2.70</td>
</tr>
<tr>
<td>3 – D velocity – xyz (ms⁻¹)</td>
<td>Hop</td>
<td>8.28</td>
<td>8.27</td>
</tr>
<tr>
<td></td>
<td>Step</td>
<td>7.58</td>
<td>7.31</td>
</tr>
<tr>
<td></td>
<td>Jump</td>
<td>6.46</td>
<td>6.58</td>
</tr>
<tr>
<td>Duration of the support phase (s)</td>
<td>Hop</td>
<td>0.11</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>Step</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td>Jump</td>
<td>0.16</td>
<td>0.17</td>
</tr>
<tr>
<td>Duration of the flight phase (s)</td>
<td>Hop</td>
<td>0.48</td>
<td>0.48</td>
</tr>
<tr>
<td></td>
<td>Step</td>
<td>0.39</td>
<td>0.39</td>
</tr>
<tr>
<td></td>
<td>Jump</td>
<td>0.65</td>
<td>0.66</td>
</tr>
<tr>
<td>Angle off take-off (°)</td>
<td>Hop</td>
<td>19.2</td>
<td>17.4</td>
</tr>
<tr>
<td></td>
<td>Step</td>
<td>14.9</td>
<td>15.7</td>
</tr>
<tr>
<td></td>
<td>Jump</td>
<td>27.5</td>
<td>27.7</td>
</tr>
<tr>
<td>Maximal height of the C.G. (m)</td>
<td>Hop</td>
<td>1.06</td>
<td>1.07</td>
</tr>
<tr>
<td></td>
<td>Step</td>
<td>1.06</td>
<td>1.08</td>
</tr>
<tr>
<td></td>
<td>Jump</td>
<td>1.15</td>
<td>1.15</td>
</tr>
<tr>
<td>Minimal height of the C.G. (m)</td>
<td>Hop</td>
<td>0.90</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>Step</td>
<td>0.90</td>
<td>0.91</td>
</tr>
<tr>
<td></td>
<td>Jump</td>
<td>0.91</td>
<td>0.90</td>
</tr>
</tbody>
</table>
Recordings were obtained from four synchronised video cameras (SONY DVCAM DSR-300 PK) operating at a frequency of 50 Hz and definition of 720 x 576 pixels, which were placed on a 90° angle to the optical axis. The first two cameras covered the area of last two strides of the approach and hop phase while the other two cameras recorded step and jump phases. To achieve better precision and for the purpose of biomechanical analysis of the take-off action in the hop and step phases, two high-speed digital cameras (Mikrotron Motion Blitz Cube ECO-1 and Digital Motion Analysis Recorder) were used. The cameras could record six seconds of movement with the frequency of 1000 frames per second and definition of 640 x 512 pixels; however, a frequency of 500 frames per second was chosen for the present study. The analysed area of the last two approach strides and the three jump phases were calibrated with a referential measuring frame (1m x 1m x 2m), whilst considering eight referential corners. The length of analysed movement has been defined with the x-axis, height with the y-axis and depth with the z-axis (see Figure 3).

For calculation of the kinematic parameters of technique, 3-D software equipment APAS (Ariel Dynamics Inc., San Diego, Ca) was used. Digitalisation of 15-segment model of the jumper’s body was made; the model was defined with 18 referential points (see Figure 4).

Results and Discussion

Optimal velocity, good visual control and an optimal structure of the last three strides of the approach are basic requirements for a good triple jump result. In Table 1, it can be seen that our subject jumper developed identical velocity (6.94 ms⁻¹) in the 11 – 6m zone prior to the take-off board in both of the analysed attempts. However, the velocity differentiated significantly in the 6 – 1m zone. Namely, in attempt B the measured velocity was greater than in attempt A by 0.57 ms⁻¹.

The structure of the last two strides (1L and 2L) also differed significantly, both in terms of stride length and frequency. In both attempts,
the penultimate stride was slightly longer than the last stride. In contrast, a tendency of a longer last stride has been noticed in some other elite female triple jumpers: Savinge (CUB), Smith (JAM), Lebedeva (RUS), Rahouli (ALG), Topic (YUG). The length of the last stride is correlated with the efficient transformation of horizontal into vertical velocity, which ensures the required height of the BCM trajectory in the first jump phase (the hop).

According to the total and relative distances of the individual phases, our subject is a typical representative of the “Hop-Jump” technique, with particular emphasis on the last phase (the jump). The proportion of the partial distances of the individual jump phases did not differentiate significantly between the attempts. In attempt A the distance of the hop was 4.73m (34.6%), the step 4.01m (29.3%) and the jump 4.94m (36.1%). Apparently, the motor strategy of our subject in this phase is very stable. KYROLAINEN et al. (2009) found that on average the proportion between the different partial phases of the women’s finalists at the 2005 World Championships in Athletics amounted to 36.2%:29.4%:34.5%.

The “Hop Dominated” technique is the one most often seen in both male and female triple jumpers. The characteristic of representatives of the “Hop Dominated” technique is high horizontal velocity, which is developed in the approach and the first take-off action. The characteristic of our subject is to have larger potential in elastic strength than in velocity, the former being utilised mostly in the second and third jump phases. Partial distances of the phases and their proportions are influenced by

Figure 4: Kinematics of technique in the hop-step-jump phases (Marija Šestak: 13.68m)
the morphological characteristics, bio-motor abilities, coordination, visual perception and the ability to control a movement in the athlete (WINTER, 1990; LATASH, 1994; MCGINNIS, 1999; SCHMIDTH & LEE, 1999). Therefore, optimal proportions between partial phase distances extremely depend on individuals (HAY, 1992).

In our subject, the jump phase distances were in strong correlation with the duration of the corresponding support and flight phases. In attempt A, the duration of the support in the hop phase was 0.11 sec, in the step phase it was 0.15 sec and in the jump phase it was 0.16 sec. Support times increased with the reduction of the horizontal velocity of the BCM. Our subject slightly deviates from the model of support times of other elite female triple jumpers (KYROLAINEN et al., 2009) in the last take-off and flight phases (the jump). In its kinematical structure, the jump phase is similar to the long jump. The partial contribution of the jump phase to the final result amounted to a relatively high 36.1%. In this phase, a high value for the angle of take-off (27.7°) was seen.

The kinematic parameters of attempt B were almost identical in the duration of support and flight phases as well as in angles of take-off angles and the take-off actions for the three jump phases. The value of the angle of take-off in the jump phase differed significantly from some of the previous studies (PANOUTSAKOPOULOS & KOLLIAS, 2008; KYROLAINEN et al., 2009; MENDOZA et al., 2010). The large angle of take-off resulted in a high flight trajectory of the BCM and was manifest in the duration of the flight of the jump (0.65 – 0.66 sec).

Undoubtedly, the horizontal velocity in the individual take-off phases is a crucial generator of success in the triple jump. The smaller the decrease of horizontal velocity, the better the final result. Our subject achieved the highest horizontal velocity in her last stride (L1) in both the attempt A (8.35ms⁻¹) and the attempt B (8.41ms⁻¹). The decrease of horizontal velocity at the end of the take-off action for the hope amounted to -0.47ms⁻¹ (or 5.6%) in attempt A and – 0.48ms⁻¹ (or 5.7%) in attempt B. In the take-off action of the step phase, the horizontal velocity decreased by 7.3% in attempt A, whereas in attempt B it decreased by 10.9%. In the jump phase, the decrease of horizontal velocity in comparison to the previous take-off action amounted to 19.8% in attempt A and 15.0% in attempt B (Figure 5a, 5b). The difference in horizontal velocity of the BCM was noticeable only in the take-off action of step phase, which was manifested in slightly shorter partial distance of this phase in attempt B.
The magnitude of vertical velocity is correlated with the angle of take-off, which was also the highest in the first and third jump phases. The study by KYROLAINEN et al. (2009) showed the following average values of angles of take-off for the finalists at the 2005 IAAF World Championships in Athletics: hop = 15.5°, step = 11.4° and jump = 21.4°. In comparison, significantly higher values for these angles were noticed for our subject in the present study. The motor pattern of our subject to large extent emphasised the height of the individual a phases, which was related to her relatively lower horizontal velocity. Lower flight trajectories are usually characteristic of both male and female triple jumpers with higher basic speed (HAY, 1992; KREYER, 1993; PANOUTSAKOPOULOS & KOLLIAS, 2008).

From the biomechanical point of view, the motor pattern of the individual take-off actions differed significantly in the duration of support, horizontal velocity, angle of take-off and vertical amplitude of the BCM movement. However, beside kinematical parameters, neuromuscular mechanisms of development of the reaction force of surface are even more important for the efficiency of take-off actions. A small oscillation of the BCM in the vertical axis can be noticed in our subject, pointing to the small amplitude of angle in the knee with the maximal amortisation in the take-off action. Variation of the BCM height in the first two jump phases is 16cm, whereas the difference between the highest and the lowest point of the BCM in the jump take-off is 24cm in the vertical axis.

**Conclusion**

The triple jump is a complex track and field discipline in which the result depends on a combination of speed, strength, technique and visual and kinaesthetic movement control. Optimal integration of cyclic and acyclic movements ensures maximal efficiency of the motor pattern. However, the motor pattern is not always consistent. Some technical elements of the model are consistent, whereas the others vary. The purpose of the study was to find out if a female athlete at the highest international level uses different programme strategies when executing the triple jump, which of the kinematical parameters vary, and which are consistent. With the use of 3-D biomechanical analysis of two attempts, the following conclusions can be made:

- the approach velocity in the last five metres (6 – 1 m) varied significantly;
- the distance and proportion of the last two approach strides varied and the visual control of the subject was not optimal;
- the kinematical structure of the approach revealed the subject had a tendency towards a longer last stride and shorter penultimate stride;
- the velocity of the last two strides (L2 + L1) was different;
- the subject achieved the highest approach velocity in the last stride;
- partial distances of the jump phases (hop-step-jump) were relatively stable with the distance of step varying the most;
- in both attempts the subject used a strat-
egy of preserving the horizontal velocity with emphasis on the distance of the last phase;  
• the subject is a typical representative of the “Jump Dominated” technique;  
• good connection of individual phases was a result of optimal kinaesthetic control and dynamic balance;  
• the model of duration of support and flight phases in the hop, step and jump indicates a tendency towards high stability;  
• horizontal velocity varied in the individual take-off actions with the largest difference noticed in the step phase;  
• a particular reduction of horizontal velocity in the take-off action of the jump phase was a result of an emphasised increase in vertical velocity, which ensured optimal height of the flight trajectory in this phase.

Although the present study has been carried out on a single athlete, the importance of the study for practice, sports science and sports biomechanics is significant. The results are particularly valuable as they were acquired with the use of the latest measuring technologies. Only a high standard of measuring procedures can ensure precise results, which can help coaches and athletes in the process of planning and control of training.

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REFERENCES


The Importance of Horizontal and Vertical Take-off Velocity for Elite Female Long Jumpers

by Stefan Letzelter

ABSTRACT

Although biomechanical research on elite long jumpers has increased knowledge about the event, the analyses conducted to date suffer from certain limitations, including small sample sizes and few studies on women. Among issues that are still open are the statistical reliability of findings about the horizontal and vertical components of take-off velocity and whether findings are equally valid for men and women. This study based on the published findings from six major events to give a larger data set, analysed both take-off velocity components with three different statistical criteria for a total of 42 women who jumped between 6.14 and 7.40m. This allowed comparisons of the impact of both components on the results and the possibility to test five hypotheses. Among the findings are a) better jumpers have more than coincidental advantages over others in both the horizontal and vertical components of take-off velocity, with the vertical being much more distinct, b) the ratio of horizontal to vertical take-off velocity differs in the studied athletes from 2.1 to 3.6 and c) excellent jumps can be achieved with very different combinations of the two components, but overall the ratio of more successful athletes is significantly lower.

AUTHOR

Stefan Letzelter, PhD, teaches at Johannes-Gutenberg-University in Mainz, coaches at a top German athletics club and was the strength and conditioning coach for the German national basketball team. He was a national Champion at 400 metres and represented his country at the European Championships and the IAAF World Cup in Athletics.

Introduction

Problem

For many years, groups of researchers have conducted biomechanical analyses of the athletics events at Olympic Games and IAAF World Championships in Athletics. From this work our knowledge has been greatly increased. In the long jump, for example, the study of world-class performers has helped to determine the vertical and horizontal components of take-off velocity, the factors that produce the biggest differences in the distance achieved. However, studies on elite women long jumpers are rare, which opens the question as to whether the principles apply equally to both sexes. Moreover, a critical analysis of the existing research leads to the conclusion that the single analyses conducted to date by the different groups have led to contradictory results. For example, almost all research
on world-class long jumpers is based on very small samples, because normally only 12 athletes participate in the finals at the major events and only eight have the possibility to jump in all six rounds. Therefore, the requirements for the significance of differences or connections are very high. This leads to mistakes maintaining the null hypothesis “there is no connection” or “there is no difference”.

In an effort to overcome this problem we have adopted a strategy of combining the published data from different studies. Thus, the statistical results are put on a much wider basis. In addition, a comparison of the results for the different finals is possible. For this study we have collected the data on women long jumpers competing in two Olympic Games, three IAAF World Championships in Athletics and one European Cup 1st League Group B. To our knowledge, the use of all this data has not been looked at to draw inferences until now.

In our review of the existing data we found that almost all analysis so far has been limited to the calculation of linear correlations. This is a one-sided choice and there are good arguments for non-linear correlations. In addition, other existing methods can be used to measure the influence of two cause variables, which is clearly important in the long jump. This can lead to divergent as well as more concrete results. Thus, by taking a different strategy in this area, it could become possible to see how the jump distance changes by a comparable altering of the two components and their relative emphasis in a linear combination could become clear.

Starting point

At the beginning of the flight, the trajectory of the centre of mass (CM) is determined by the horizontal \(v_{0x}\) and vertical \(v_{0z}\) take-off velocity. However, this is not necessarily the sole determinate for the distance achieved in jumping events, as flight distance is just a part of the equation. The segmentation of the long jump shown in Figure 1 originates from HAY (1978) and was expended by BALLREICH & BRÜGGEMANN (1986).

Neglecting aerodynamic parameters, the flight distance \(W_2 + W_3\) as a function of the three kinematic parameters horizontal \(v_{0x}\) and vertical \(v_{0z}\) take-off velocity as well as difference in position of the CM from take-off \(h_0\) to beginning of touchdown \(h_1\) can be calculated as an oblique throw. The horizontal component depends on the velocity during the last stride of the approach \(v_{An}\) and its reduction by the transformation during take-off \(D_{vx}\). The vertical component depends on the vertical impulse \(G_{Z}\) and the mass of the athlete \(m\).

Current state of research

BALLREICH (1979) compared three groups of male long jumpers with significant differences in jump distance and found that both the vertical and horizontal velocity components contribute to the differences in performance. The deficits of the weaker groups are almost identical for both of the cause variables, which means the relative influence of the vertical component is much higher. This leads to disadvantageous relations for both variables and a much lower flight trajectory for the jumpers of the weaker group.

In a group comparison made by ČOH et al. (1997), the advantage of the better jumpers also results from a significant plus in both of the velocity components. In this case, the horizontal component at \(\Delta v_{0x} = 0.63\) m/sec is nearly double the value of the vertical of \(\Delta v_{0z} = 0.34\) m/sec. A standardisation into differences of means leads to almost identical results of 0.90 sd and 0.85 sd.

Correlative statistics for samples with big variations only exist for male long jumpers. In a research by BRÜGGEMANN et al. (1982), flight distance only shows a common variance of 4% with the horizontal, but of 79% with the vertical component. ČOH et al. (1997) show a lower dominance of the vertical component of 35 vs. 19%. NIGG et al. (1973) even found out that particularly long jumps depend only on a high horizontal take-off velocity. The value of this result is questionable though, since the sample only consists of 18 jumps by five athletes.
What studies do exist on elite women long jumpers show no evident dominance. Even for \( \alpha = 0.10 \), all coefficients remain under the random maximum. HAY & MILLER (1994) found relations of \( r = 0.3 \) and \( r = 0.4 \) between the two velocity components and effective jump distance for the participants of the 1984 Olympic final (\( n = 12 \)). NIx DORF & BRÜGGEMANN (1988) had \( r = 0.55 \) and \( r = 0.47 \) for the top eight of the 1987 IAAF World Championships in Athletics. From these findings it looks like there are great compensational possibilities. In a special analysis, NIx DORF & BRÜGGEMANN (1990) found a wide ratio of both components between 2 to 1 and 3 to 1.

KOLLATH (1982) and BALLREICH (1979) have estimated the value of both cause variables with a regression analysis. By variation of parameters with identical absolute values, Kollath has found a higher relevance of vertical take-off velocity in the relation of 1 to 1.4 while Ballreich has altered both independent variables by one standard deviation and found a contradictory relation of 4 to 1. However, his results suffer from the fact that the difference of both standard deviations of \( \pm 0.30 \) vs. \( \pm 0.04 \) m/sec is much bigger than in all other studies.

What studies do exist on elite women long jumpers show no evident dominance. Even for \( \alpha = 0.10 \), all coefficients remain under the random maximum. HAY & MILLER (1994) found relations of \( r = 0.3 \) and \( r = 0.4 \) between the two velocity components and effective jump distance for the participants of the 1984 Olympic final (\( n = 12 \)). NIx DORF & BRÜGGEMANN (1988) had \( r = 0.55 \) and \( r = 0.47 \) for the top eight of the 1987 IAAF World Championships in Athletics. From these findings it looks like there are great compensational possibilities. In a special analysis, NIx DORF & BRÜGGEMANN (1990) found a wide ratio of both components between 2 to 1 and 3 to 1.
Above average results in both components are very rare or impossible. The more the approach velocity is decelerated at take-off, the more it can be transformed into vertical velocity, which obviously affects the resultant horizontal. In other words, the higher the horizontal take-off velocity, the lower the vertical take-off velocity. TIUPA et al. (1982) present a correlation of \( r = -0.66^{**} \).

For elite women long jumpers, many questions remain open. In this article following hypotheses will be statistically reviewed:

**HI:** Horizontal and vertical take-off velocity both are statistically relevant for results.

**H II:** The vertical component is more important than the horizontal.

**H III:** Both components have a negative effect on each other.

**H IV:** The ratio of horizontal and vertical take-off velocity is relevant for results as an optimal trend.

**H V:** There are enormous compensational possibilities. Weaker values in one component can be nullified by higher values in the other.

**Methods**

**Data collection**

This documental analysis is based on the data of the long jump finals at the 1984 Olympic Games (HAY & MILLER, 1994), the 1987 IAAF World Championships in Athletics (NIXDORF & BRÜGGEMANN, 1988), the 1988 Olympic Games (NIXDORF & BRÜGGEMANN 1990), the 1997 IAAF World Championships in Athletics (MÜLLER & BRÜGGEMANN, 1998; ARAMPATZIS et al., 1999) and the 2009 IAAF World Championships in Athletics, (MENDOZA et al., 2010), supplemented by the 2006 European Cup 1st League Group B (PANOUT-SAKOPOULOS & KOLLIAS, 2007).

By combining these competitions, the size of the whole sample is multiplied by six. For athletes who participated in more than one of these events, only the best jump is used for the whole sample group (n = 42). A mark of 6.00m has been set as the lower limit for consideration. For the variance analysis, the whole group is split up into four performance sub-groups.

**Statistics**

Because of their functional relation, horizontal and vertical take-off velocities are logically relevant for jump distance. The statistical relevance, indicating that better athletes have significantly higher values, were tested with the following three criteria:

**Variance Analysis** - A simple variance analysis with subsequent paired comparisons was used. The differences in means were weighed with concrete values and in units of standard deviation. Deviations from the normal distribution were tested with the David method, the homogeneity of variances was tested by the Levene (\( F_L \)) method and for dependent samples with the Fergusson t-test. A trend analysis showed if the connection was quadratic, which would be leading to an optimal trend.

**Correlation** - The connection of both cause variables with the jump distance was first analysed with correlations. These also inform about a higher or lower common variance (\( r^2 \)). In addition, the linearity of the connection was tested. Since correlation coefficients can’t be used to show relations, they are transformed into Fisher’s z-values. These were used to test the significance of differences in independent coefficients. The analysis of differences in dependent correlations was done with a special t-test. This was necessary to find out if the connection between horizontal and vertical take-off velocity is significantly different from jumping distance.

**Regression Analysis** - The regression analysis showed how the jumps change if \( v_{0x} \) and \( v_{0z} \) are altered by a comparable amount. Usually the standard deviation is comparable. A multiple regression with \( \beta \)-coefficients also produces a weighing of both components. \( r^2 \) also informs which ratio of the criteria variance is linked by both cause variables.
Many female long jumpers have also been successful sprinters, for example Heike Drechsler (GER). In these cases we would expect that their horizontal take-off velocity could be very much higher than that of their rivals and that the extreme values would have an enormous influence on small samples. Therefore, every suspected outlier was tested with the Dixon method for \( n \leq 25 \) and with the Pearson & Hartley method for \( n > 25 \). Since extreme values are typical for athletics, calculations were made with and without the outliers.

The standards for the significance of statistical measures are very high. A common standard is \( \alpha = 0.05 \). Since this often leads to unjustified rejections of the null hypothesis, LETZELTER (1986) has suggested that for performance analysis \( \alpha = 0.10 \) can be used. The statistics textbook by BORTZ (2000) accepts \( \alpha = 0.10 \). In their analysis HAY & MILLER (1994) have already proceeded along this line. In this report, slightly significant (\( p < 0.10 \)) will be marked with *, significant (\( p < 0.05 \)) with ** and highly significant (\( p < 0.01 \)) with ***.

Results

Comparison of performance groups

The longest jump in the data set was the Olympic record of 7.40m by Jackie Joyner-Kersee (USA) in the 1988 Olympic Games. The best average for the all the finalists was achieved in the 1987 IAAF World Championships in Athletics. The 10 differences in means differ from \( \Delta = 0.04 \) to \( \Delta w = 0.22 \)m, but all remain under the highest coincidental value (\( F = 1.10 \)). In contrast, the decline in performance was significantly different (\( F_L = 4.02^{***} \)), with the highest value in the 1988 Olympic Games. The jumps of the 2006 European Cup 1st League Group B, as expected, were significantly shorter than the results in the Olympic Games and IAAF World Championships in Athletics, namely between 0.43 and 0.65m (\( t \geq 4.06^{***} \)).

The horizontal take-off velocity scatters significantly more than the vertical (\( 1.79^* \leq t \leq 4.36^{***} \)). Therefore, the differences in means, indicated in m/sec, are not comparable. The relative dispersion of \( V = \pm 7.0 \) to \( V = \pm 9.6\% \) for the vertical component is much higher than for the horizontal component of \( V = \pm 3.5 \) to \( V = \pm 5.4\% \). The \( v_{ox} \) of 1987 is enormously enlarged by one outlier (Drechsler). However, the six group variances are not significantly heterogeneous (\( F_L = 0.93 \)) and the data does not significantly differ from a normal distribution. The vertical take-off velocities deviate even less (\( F_L = 0.43 \)), with the European Cup Group being much more balanced than all other competitions (\( F \geq 4.00^{***} \)).

Table 1: Official results of selected groups of elite women long jumpers in major international events

<table>
<thead>
<tr>
<th>Group</th>
<th>min</th>
<th>max</th>
<th>( \bar{d} )</th>
<th>( \pm \text{sd} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>OG 1984 (n=8)</td>
<td>6.44</td>
<td>6.96</td>
<td>6.70</td>
<td>0.18</td>
</tr>
<tr>
<td>WC 1987 (n=8)</td>
<td>6.41</td>
<td>7.14</td>
<td>6.92</td>
<td>0.24</td>
</tr>
<tr>
<td>OG 1988 (n=8)</td>
<td>6.47</td>
<td>7.40</td>
<td>6.88</td>
<td>0.36</td>
</tr>
<tr>
<td>WC 1997 (n=8)</td>
<td>6.64</td>
<td>7.05</td>
<td>6.82</td>
<td>0.14</td>
</tr>
<tr>
<td>WC 2009 (n=8)</td>
<td>6.62</td>
<td>7.10</td>
<td>6.80</td>
<td>0.16</td>
</tr>
<tr>
<td>ECB 2006 (n=8)</td>
<td>5.81</td>
<td>6.71</td>
<td>6.27</td>
<td>0.24</td>
</tr>
<tr>
<td>all (&gt;6m; n=42)</td>
<td>6.14</td>
<td>7.40</td>
<td>6.72</td>
<td>0.28</td>
</tr>
</tbody>
</table>

The Importance of Horizontal and Vertical Take-off Velocity for Elite Female Long Jumpers

Table 2: Horizontal and vertical velocity at take-off of selected groups of elite women long jumpers in major international events

<table>
<thead>
<tr>
<th>Group</th>
<th>Horizontal Velocity $v_{0x}$ (m/s)</th>
<th>Vertical Velocity $v_{0z}$ (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>min</td>
<td>max</td>
</tr>
<tr>
<td>OG 1984 (n = 8)</td>
<td>7.8</td>
<td>8.6</td>
</tr>
<tr>
<td>WC 1987 (n = 8)</td>
<td>7.6</td>
<td>9.1</td>
</tr>
<tr>
<td>OG 1988 (n = 8)</td>
<td>7.4</td>
<td>8.5</td>
</tr>
<tr>
<td>WC 1997 (n = 8)</td>
<td>7.6</td>
<td>8.4</td>
</tr>
<tr>
<td>WC 2009 (n = 8)</td>
<td>7.6</td>
<td>8.3</td>
</tr>
<tr>
<td>ECB 2006 (n = 8)</td>
<td>7.2</td>
<td>7.9</td>
</tr>
<tr>
<td>All (&gt;6m, n = 42)</td>
<td>7.3</td>
<td>8.5</td>
</tr>
</tbody>
</table>


The five means of the horizontal take-off velocity at the Olympic Games and IAAF World Championships in Athletics differ by at most 0.35 m/sec, but because of the big diversion this could be coincidental ($F = 1.31$). The highest value is from the 1984 Olympics, the lowest is from the 1988 Olympics.

In the vertical component, the means differ by up to 0.4 m/sec. This is not coincidental ($F = 2.19^* $). When comparing pairs, only the deficit of 1984 Olympics in contrast to all other groups, except the 1987 world championships is significant. As in the official results, both the means from the 2006 European Cup 1st League are significantly lower than for the five Olympic Games and IAAF World Championships in Athletics ($t \geq 3.7^{***}$).

The means of the results at the Olympic Games and IAAF World Championships in Athletics do not follow the trend “the longer the jump, the higher the take-off velocity”. In fact, the group with the shortest jumps produces the highest average horizontal velocity. For the vertical component, in three cases the ranks are identical, while twice the differences are serious. The rank correlation is illustrated in Figure 3.

Figure 3: Ranks in official distance ($r_d$) compared with horizontal ($r_{v0x}$) and vertical take-off velocity ($r_{v0z}$) for selected groups of world-class women long jumpers in major international events (1984 Olympic Games, 1987 IAAF World Championships in Athletics, 1988 Olympic Games, 1997 IAAF World Championships in Athletics, 2009 IAAF World Championships in Athletics)
The differences in means for the five finals are relatively small; the results overlap. Between the four performance groups they are much larger. The groups are generated as follows:

\[ \text{G1: } W < 6.40\text{m}; \text{ G2: } 6.40\text{m} \leq W \leq 6.69\text{m}; \text{ G3: } 6.70\text{m} \leq W \leq 6.99\text{m}; \text{ G4: } W \geq 7\text{m}. \]

These four groups differ with high significance in vertical take-off velocity \((F = 9.97^{***})\). G1 is more than coincidentally lower than the other three groups. The same is true for G2 being lower than G4. The other two differences are insignificant.

The coherence with jump distance follows a parabolic trend \((F_{\text{quad}} = 3.80)\), quantified by \(\eta = 0.67^{**}\). The optimum is calculated at 3.17 m/ sec. A higher value must be achieved with too much braking, leading to a disproportionate loss of horizontal velocity. Figure 4 shows the trend curve, which almost perfectly adapts to the four empiric means, as well as the standard deviations. These don’t differ significantly \((F_L = 0.72)\).

The differences of the four means in horizontal take-off velocity might be coincidental \((F = 2.01)\). The paired comparison after the Duncan method shows the deficit of the weakest group to be significant, the more conservative Scheffé method doesn’t. The relation with the group at \(\eta = 0.38\) is much lower than for the vertical component and also non-linear. There are no heterogeneous variances \((F_L = 0.84)\). Because of the missing significance of the differences, the shown parabola is only valid for the sample."
Relation of horizontal and vertical take-off velocity and jump distance

Only one of the coefficients for the five Olympic Games and IAAF World Championships in Athletics finals listed in Table 3 is slightly significant. The horizontal component of the 1988 Olympics and the 2009 world championships, as well as the vertical components 1987 and 1997 world championships have no coherence with the jump distance at all if the outlier is included. Without the outlier, the correlation changes considerably. At the 2006 European Cup 1st League, both coefficients exceed the highest coincidental value. We can conclude that the more successful long jumpers take off faster horizontally and vertically.

The results for the complete sample correct the conclusion taken from solitary finals. Forty-seven percent of the differences in jump distance can be explained by those in \( v_{0z} \), but only 10% by those in \( v_{0x} \). The priority of the vertical component is statistically proven, the difference between the two coefficients is not coincidental (\( t = 7.0^{***} \)). Transformed into Fisher’s z’-values this results in impact proportions of 0.83 to 0.32, equalling 2.6 to 1.

If the horizontal take-off velocity increases by 1.0 m/sec, the jump distance is 0.26m longer. For the vertical component, 1.0m/sec faster means 0.57m longer. The equations for the regression straight lines are: \( W = 4.64 + 0.26v_{0x} \) (m) and \( W = 5.04 + 0.57v_{0z} \) (m). This also indicates a clear advantage of the vertical component. In contrast to the trend analysis, the connection with the jump distance is linear. The squared approach only leads to a slightly better explanation. A linear combination of both components explains almost two thirds of the criteria variance (\( R_{corr}^2 = 0.65^{***} \)) with the horizontal and the vertical component contributing \( \beta = 0.44 \) and \( \beta = 0.77 \) respectively, making up a relation of 1 to 1.8. In conclusion, all criteria indicate a dominance of the vertical take-off velocity.

As stated above, it is impossible to reach outstanding results in both components. The more of the approach velocity is decelerated, the more can be transformed. The vertical component benefits, the horizontal component suffers. This is statistically confirmed by significant relations. The lowest correlation was found for the 1984 Olympics, but still at \( r = -0.60^{*} \), the highest for the 1997 world championships at \( r = -0.76^{**} \). For the whole sample, it was \( r = -0.63^{**} \). Long jumpers with 1.0 m/sec more horizontal take-off velocity usually leave the board with a vertical take-off velocity that is 0.5 m/sec lower.

Table 3: Coherence of horizontal and vertical velocity at take-off with official distance for six selected groups of elite women long jumpers in major international events

<table>
<thead>
<tr>
<th>Group</th>
<th>Horizontal Velocity ( v_{0x/d} )</th>
<th>Vertical Velocity ( v_{0z/d} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>OG 1984</td>
<td>0.28</td>
<td>0.50</td>
</tr>
<tr>
<td>WC 1987</td>
<td>0.49/0.50</td>
<td>-0.01/0.50</td>
</tr>
<tr>
<td>OG 1988</td>
<td>0.07</td>
<td>0.62*</td>
</tr>
<tr>
<td>WC 1997</td>
<td>0.51</td>
<td>0.06</td>
</tr>
<tr>
<td>WC 2009</td>
<td>0.09</td>
<td>0.43</td>
</tr>
<tr>
<td>ECB 2006</td>
<td>0.67*</td>
<td>0.73**</td>
</tr>
</tbody>
</table>

Regression equations usually produce statistical norms, the residua inform about strengths and weaknesses. In Figure 5, a number of concrete values differ a lot from the straight lines; even some of the best athletes are not compliant. In the 1988 Olympic Games, Joyner-Kersee jumped an Olympic record despite a $v_{0x}$ of 7.6 m/sec. Drechsler placed third in the 1987 IAAF World Championships in Athletics with $v_{0z}$ of 2.50 m/sec. By all means, the standard estimation of error $Se = \pm 0.27$ respectively $\pm 0.24$ (m) has to be taken into account.

Relevance of the horizontal and vertical take-off velocity ratio for performance

For the five Olympic Games and IAAF World Championships in Athletics finals, the means of the ratios differ from $Q; \ ^\circ = 2.50$ (2009 world championships) to $Q; \ ^\circ = 2.97$ (1984 Olympics). The shortest jump distance goes along with the highest ratio. This is supported by the 2006 European Cup 1st League Group B ratio of $Q; \ ^\circ = 3.05$. 

Figure 5: Coherence of horizontal and vertical velocity at take-off with official distance for selected groups of world-class women long jumpers in major international events (1984 Olympic Games, 1987 IAAF World Championships in Athletics, 1988 Olympic Games, 1997 IAAF World Championships in Athletics, 2009 IAAF World Championships in Athletics, 2006 European Cup 1st League Group B)

Figure 6: Coherence of ratio and official distance for selected groups of elite women long jumpers in major international events (1984 Olympic Games, 1987 IAAF World Championships in Athletics, 1988 Olympic Games, 1997 IAAF World Championships in Athletics, 2009 IAAF World Championships in Athletics, 2006 European Cup 1st League Group B)
Better female long jumpers outperform inferior ones mainly because of a higher vertical take-off velocity; not in every single case, but generally speaking. They also have a higher horizontal take-off velocity, but less definite.

In conclusion, H I has a higher degree of establishment. The lack of significance in single competitions is a β-mistake, resulting from samples that are too small. A novelty is that the conclusions, unlike in those other studies, are not only based on a single criterion. The importance of the vertical component is affirmed by all three criteria, for the horizontal by all but the variance analysis. Another novelty is that according to the trend analysis, both components follow an optimal trend.

The result confirms ČOH et al. (1997), who found a difference in both components for two groups of male long jumpers as well as significant coherences and a slight primacy of vertical take-off velocity, although it was not statistically tested.

It also matches the findings of NIXDORF & BRÜGGE (1982) concerning the meaning of the vertical component, but not the horizontal, since the latter is estimated as unimportant by the authors.

Like in the group of male athletes analysed by KOLLATH (1980), in world-class women the variation of the vertical component is more greatly rewarded in performance increase than the horizontal. It does not matter if the variation is shown in absolute values or in standard deviations, since both spreads are almost identical. Thus, H II also has a higher degree of establishment.

The advantage of better athletes in the vertical component is significantly larger than in the horizontal.

The findings for the single finals mostly coincided with the overall results, but only in being insignificant. For the 1987 IAAF World Championships in Athletics NIXDORF & BRÜGGE-
Summary

To date, analyses of the horizontal and vertical take-off velocities for female elite long jumpers suffered from very small samples. This problem is solved by combining the data from five Olympic Games/IAAF World Championships in Athletics and one European Cup 1st League Group B. Both components were analysed with three different statistical criteria for a total of 42 athletes who jumped between 6.14 and 7.40m. This also allows comparisons of the impact of both components on the jumps.

Better jumpers have more than coincidental advantages over others in both influencing variables, with the vertical being much more distinct. The ratio of horizontal and vertical take-off velocity differs from 2.1 to 3.6. Excellent jumps can be achieved with very different combinations of both components, but overall the ratio of more successful athletes is significantly lower. It is characterized by an optimal trend.

It is impossible to reach outstanding values in both components since they have a negative influence on each other.

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MANN (1988) determined \( r = 0.55 \) and \( r = 0.47 \). The coefficient for the horizontal component is lower and matches the one published by HAY & MILLER (1986); the coefficient for the vertical is much higher.

H III also passed the confrontation with reality. In the finals, as well as in the whole sample, both components have a negative influence on each other. MENDOZA & NIXDORF (2006) point out the impossibility for men to biomechanically transform such big forces. The coefficients all reside in a very small range and are similar to those found by TIUPA (1982) in a much more heterogeneous group of male athletes.

Outstanding results in both components are impossible. In all analyzed groups the connections are disproportionally negative.

Mostly, better female long jumpers rather have lower ratios. Compared to the horizontal take-off velocity, the vertical is significantly higher. For the resulting quotient, both components produce an optimal trend. In conclusion, H IV also has the status of an approved hypothesis. The interval of \( 2.0 \leq Q \leq 3.0 \) mentioned by NIXDORF & BRÜGGERMANN (1990) is not valid for female elite jumpers. It has to be adjusted since even a ratio of 3.5 occurs although in the peak it is an exception.

The extreme individual differences in the ratio of horizontal and vertical take-off velocity as well as the residuals of the values from the regression straight confirm H V. Medals can be won with a very high as well as a very low ratio. Athletes with identical values in one or the other component reach different jump distances and vice versa.
The Importance of Horizontal and Vertical Take-off Velocity for Elite Female Long Jumpers

REFERENCES


Applied Research

contents

Intra-Race Position for Medal Winners in the Track Endurance Events at the 2008 Olympic Games
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Intra-Race Position for Medal Winners in the Track Endurance Events at the 2008 Olympic Games

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ABSTRACT

The aim of this study was to determine how intra-race positioning and finishing sprint ability were related to the final rank order finishes of competitors in the track endurance events at the 2008 Olympic Games. Split times for each 100m were obtained for all men's and women's 800m to 10,000m finalists and mean race position over each fifth of the race was calculated, with the exception of the 800m for which fourths were calculated. It was found that position or racing strategy is different between events and sexes. Medallists in the shorter events (i.e., 800m and 1500m) typically move into medal position earlier than those in the longer events. Medallists in the longer men's events tend to rely on finishing sprint ability to achieve their final position while women medallists generally move into medal position earlier in the race.

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Introduction

In elite competitive distance running an athlete attempts to achieve two main performance outcomes. The first is to record the fastest time possible, e.g. personal or world record, and the second is to win the race and or defeat as many competitors as possible. However, obtaining both of these outcomes in the same event rarely occurs. This is most likely due to the differing strategies undertaken as a function of what the most desired outcome is for that competition (i.e., best time or best place). The desired performance outcome typically depends on the time of sea-
Strategies differ when competitive outcomes are primarily determined by performance time. The optimal pacing strategy resulting in the fastest possible competitive performance has received minimal observation \([1, 2]\). An even pace throughout the entire race has been suggested to be the best strategy for the fastest possible time in longer duration events (i.e., 5000 and 10,000m) \([1]\). In contrast, a positive pacing strategy in which the athlete achieves peak speed early in the race and then progressively slows until the finish of the race was suggested to result in faster performances in shorter events (up to 800m) \([1]\).

However, in world-level championship events (i.e., the IAAF World Championships in Athletics or the Olympic Games) the primary performance goal is to win the race, qualify for the next round, or win a medal in the final. A completely different pacing strategy may be required than that taken by the athlete attempting to achieve the fastest time. Winning or medalling at this level often requires execution of a tactical or racing strategy. Further, the winning athlete is often the one who most effectively executes his/her racing strategy. Obviously talent, training, and natural ability play a role in success, but athletes at the highest level often are relatively equal in these characteristics. Therefore, racing strategy may ultimately determine competitive outcomes.

Beginning in the early 1970’s women began to enter competitive sports, specifically track and field. During this period the world records differed between men and women by approximately 20% for events ranging from the 1500m to the 10,000m \([3]\). At present the difference between men’s and women’s world records are approximately 10–13% \([3]\). From the perspective of athletic performance, females are considered to be quite different physiologically, from males \([4]\). Differences include metabolic capacity (e.g., \(V_{\text{O}2\text{max}}\)), pulmonary structure and function, body composition, hormonal profiles and skeletal traits \([4]\). These physiological differences collectively could account for the differences in athletic performance (e.g., world record times). However, while considerable research attention has been given to sex differences on a variety of physiological parameters, no investigations have focused on potential pacing strategy differences between males and females.

Furthermore, to our knowledge there have been no studies that have examined the racing strategy of endurance athletes, regardless of sex, at major international competitions such as the Olympic Games. While previous research has analysed pacing in world record performances, a similar analysis has not been performed on competitions where finishing place may be as important as the actual timed performance \([5]\). The general perception appears to be that many Olympic finals in the longer races are won by athletes who remain back in the pack early in the race and then utilise a fast finishing kick. In contrast, the winners in the shorter races appear to run at the front throughout the race. This perception has not been examined rigorously. Therefore, the purpose of this investigation was to determine how intra-race positioning and finishing sprint ability were related to the final rank order finishes of runners in the track events at the 2008 Olympic Games. This analysis was made in an attempt to determine whether or not a clear pattern of racing strategy emerged within the medallists. A secondary purpose was to investigate a potential difference in pacing strategy between sexes. We hypothesised that medallists in the longer events (e.g., 5000m and 10,000m) would demonstrate positioning further back in the pack during the early portions of the race, compared to athletes in the shorter events (e.g., 800m and 1,500m). Similarly, we hypothesised that men and women would utilise different pacing strategies given the obvious differences in important physiological characteristics dictating running performance.

**Method**

Data from the 2008 Olympic Games in Beijing was obtained from information publicly available on the IAAF website \([5]\). Data was provided to the IAAF by ST Sportservice
GmbH (Swiss Timing, Corgemont, Switzerland). Briefly, each athlete in all distance events had a wireless transponder placed in their bib number, which was pinned to their chest. Transponder antennae were placed at each of four 100m points on the track, equidistant from the finish line. Split times for each athlete were wirelessly recorded for each 100m segment, with times recorded to the 0.1 second.

Split times were analysed for all competitors in the final round of the 800m, 1500m, 5000m, and 10,000m events for both sexes. The 3000m steeplechase event was not analysed, due to the asymmetrical distance of each split obtained. For analysis of the effect of intra-race positioning on overall placing, the 1500m, 5000m, and 10,000m events were divided into quintiles (fifths), while the 800m was divided into quartiles (fourths). Athlete rank order position at each quartile or quintile was determined, based on the 100m race splits. For further analysis, athletes were divided into three groups based on finishing place: medallists (1st through 3rd), 4th through 6th, and 7th through 9th places. To determine the influence of finishing kick ability on overall placing, the final 200m split for each athlete was determined and placed in rank order.

Data was compared using several mixed method analysis of variance (ANOVA) procedures. ANOVAs used were both two- and three-way in design. This was done to analyse differences between events, time points, and sexes. If the omnibus tests resulted in a significant effect, Tukey’s HSD post hoc test was used to elucidate the means that were significantly different. All statistics were computed using the Predictive Analytic SoftWare (PASW; formerly SPSS) version 17.0 (IBM, Chicago, IL).

The present study was undertaken as a qualitative study to observe how athletes at the top level of distance running obtain an Olympic medal. Therefore, statistics were undertaken as an aid to describe how these athletes raced and also demonstrate how and if medallists between events were different.

Results

Figure 1 displays the mean rank (i.e. position in the race) for the medallists across each quintile (1500m – 10,000m) or quartile (800m) for both men (1A) and women (1B). For the men there was a significant difference between the 800m and 10,000m, as well as between the 5000m and 10,000m. Athletes in the 10,000m had a higher rank in the early portions of the race, compared to men’s medallists in the 800m and 5000m. For the women a similar analysis resulted in a significant difference between the mean ranks at each segment of the 800m and 5000m, as well as, a significant difference between the 1500m and 5000m. As with the men, medallists in the 5000m had a higher rank in the early portions of the race, compared to the shorter events. Statistical analysis of the events showed there to be no significant difference between sexes (p = 0.744).

The percentage of the race spent in medal position for each group (e.g., medallists, finishers 4th – 6th, and finishers 7th – 9th) and each event was calculated (Figure 2). Planned comparisons were performed between all events (e.g., men’s 800m vs. men’s 1500m, men’s 800m vs. men’s 5000m, etc.). Analysis revealed there to be significantly more time (as a percentage of the race) spent in medal position by the medallists for the men’s 800m compared to the men’s

Table 1: Rank of the final segments for the 2008 Olympic Champion in the men’s (M) and women’s (W) middle- and long-distance events

<table>
<thead>
<tr>
<th></th>
<th>Last 400m</th>
<th>Last 200m</th>
<th>Last 100m</th>
<th>Last 400m</th>
<th>Last 200m</th>
<th>Last 100m</th>
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</thead>
<tbody>
<tr>
<td>M 800m</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>W 800m</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>M 1500m</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>W 1500m</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>M 5000m</td>
<td>2</td>
<td>5</td>
<td>9</td>
<td>W 5000m</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>M 10,000m</td>
<td>1</td>
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<td>W 10,000m</td>
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For women, there was a significant effect for group (p < 0.0001), a significant trend for event (p = 0.054), but no significant interaction (p = 0.624).

However, no difference existed between sexes (p = 0.744). Additionally, the rank of the final 200m split was determined for the Olympic champion in each of the eight events studied, with the results displayed in Table 1. Note that in only three of the eight races did the winner have the fastest final 200m split.

The rank of the final 200m for each group (e.g., medallists, finishers 4th – 6th, and finishers 7th – 9th) and each event for both sexes were calculated. The results are displayed in Figure 3. For the men, significant main effect for event and group (p = 0.008 and p < 0.0001, respectively) were present. However, there was no significant interaction effect (p = 0.539).

For women, there was a significant effect for group (p < 0.0001), a significant trend for event (p = 0.054), but no significant interaction (p = 0.624).

However, no difference existed between sexes (p = 0.744).
Discussion

The principle purpose of this investigation was to determine how intra-race positioning and finishing sprint ability were related to the final rank order finishes of track athletes in the distance events at the 2008 Olympic Games in Beijing. A secondary purpose was to compare race strategies between men and women runners. The results of this study suggest that there are different racing strategies between the shorter and longer distance events. These findings were consistent between sexes.

Based primarily on anecdotal evidence, we hypothesised there would be a difference in racing strategy (i.e., intra-race positioning) between the shorter and longer events (e.g., 800m compared to 10,000m). It was thought that athletes that medalled in the shorter events (middle-distances) would place themselves early in medal position (top 3) and attempt to stay in that position throughout the entire race. Whereas, in the longer events the medallists were out of the top 3 for the majority of the race and relied entirely on finishing sprint ability (usually over the final fifth of the race) to obtain a medal. The present results support this hypothesis.

There are two main performance objectives that athletes in track and field attempt to achieve that may or may not be mutually exclusive. These are running the fastest time possible and winning the race. Again, in many championship races (e.g., the Olympic Games, IAAF World Championships in Athletics) the primary objective appears to be obtaining a medal. Therefore, the athletes must construct a racing strategy that will give them the best chance of finishing in one of the top three places. CHAPMAN [6] suggests that there are four general racing strategies that athletes employ in the distance events. These strategies are Leader, Kicker, Pacer, and Breaker. First, using a “Leader” strategy requires that a runner take the lead immediately from the start or at some point early in the race. This is done as a means to control the pace of the event and either “run away” from the other competitors or “burn up” the finishing ability of the other runners. The next strategy, the “Kicker,” entails expending as little energy as possible not leading the race, and then using strong finishing speed to ultimately win. The “Pacer” will attempt to estimate a priori the time required to win the race and either “run away” from the other competitors or “burn up” the finishing ability of the other runners. The next strategy, the “Kicker,” entails expending as little energy as possible not leading the race, and then using strong finishing speed to ultimately win. The “Pacer” will attempt to estimate a priori the time required to win the race and then execute even splits for as long as possible to achieve that estimated winning time. Finally, the “Breaker” is a strategy whereby the athlete will attempt to “break open” the race by using an increased pace in the middle of the race. This is done in an attempt to catch others off guard and based on the response from the other competitors, invoke the appropriate pacing to win the race from that point on [8].
Based on the results of the present analysis (see Figure 4) and Chapman’s pacing paradigm \(^6\), it appears that athletes in the shorter distance events utilise a strategy that closely resembles that of the “Leader” described above. For example, the medallists in the men’s and women’s 800m had a mean rank of approximately 4 during the first quarter of the race (200m) and maintained or improved this rank throughout the event (see Figure 1A). A similar pattern is observed in both the men’s and women’s 1500m. The strategy the medallists seem to utilise is a combination of the “Leader” and the “Kicker”. The women held a constant mean rank throughout the duration of the event while the men had a little bit higher (worse) rank (about 4 and 5 respectively). In contrast, the medallists in the longer distance events appear to primarily utilise the “Kicker” or “Breaker” strategies described above. These athletes tend to stay relatively far away from medal positions through the early and middle portions of the race and then “kick” to place (see Figure 1A). However, sometimes the winner and/or medallists will utilise a “Breaker” strategy. This can be seen in the men’s 10,000m where the gold medallist led a large portion of the final few kilometres and outsprinted the others for the win.

Medallists in the longer events have a significantly higher mean rank over the duration of the race than those in the shorter events. It is generally accepted that following is less energetically costly than leading, and therefore it makes logical sense those athletes that medalled in the longer events would stay out of the lead for the majority of the race (i.e., “Kicker”). McCOLE et al. \(^7\) studied the energy expenditure during bicycling. The authors found there to be no difference in VO\(_2\) when cyclists were being led by 1, 2, or 4 other cyclists. However, there was a significant reduction in VO\(_2\) when cyclists rode in a pack. When riding at 40 km/h VO\(_2\) was reduced by 39 ± 6% when riding in a pack compared to riding behind 1, 2, or 4 riders. Although this study was done in cyclists it is relevant to the present investigation as it demonstrates a lower metabolic cost to follow when compared to leading. Similarly, DAVIES \(^8\) measured the VO\(_2\) of runners with varied wind resistances (1.5 – 18.5 m/sec). The author showed that VO\(_2\) increased linearly over the lower wind velocities and increased curvilinearly over the faster wind velocities. Similarly, MORGAN & CLAIB \(^9\) suggest that running while following one and two metres behind another runner can save 6% and 3% of energy respectively. These studies support the supposition that leading is more energetically costly than following (i.e., drafting). Therefore, it makes strategic sense for runners in the longer distances to stay further away from medal position during early stages of the race.

There are admittedly several weaknesses inherent in this analysis. One limitation of this study is the small sample size. In all events a sample size of less than ten runners (and of course only three medallists) was present. This greatly reduces the statistical power that can be obtained and thus makes it difficult to ob-

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<th>Event</th>
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<td>800m</td>
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<td>1500m</td>
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<td>Kicker/Breaker</td>
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*Figure 4: Preferred racing strategy for each middle- and long-distance event at the 2008 Olympic Games based on the racing strategy paradigm proposed by Chapman* \(^6\)
serve statistical differences when making comparisons. However, the purpose of this investigation was not to show statistical differences per se, but to describe what the top middle- and long-distance athletes were doing to earn a medal at the Olympic Games in Beijing.

A second limitation is represented by attempting to compare events with a different numbers of competitors. For example, in the 800m final there were only eight athletes whereas there were 35 finishers in the 10,000m. Specifically, in Figure 3 the mean rank of the final 200m was examined. No statistics were reported on this data because the worst (slowest) final 200 in the 800m would earn a rank of 8 whilst in the 10,000m it would earn a 35. Immediately there is a large numerical difference between the two, but practically both hypothetical athletes had the slowest final 200m in their respective events.

How important is the finishing kick to overall competitive success, compared to positioning prior to the kick? Data on the final 200m splits highlight some interesting results. For example, in the men's races, only the winner of the 10,000m had the fastest final 200m kick. Surprisingly, in two of the men's races, the 800m and the 5000m, the winner's final 200m split wasn't even among the top three fastest. This data would suggest that positioning at or near the lead prior to the start of the kick would be more important to winning than the speed of the kick itself. However, this data may be influenced by fact of the winner, with victory in hand, easing off to celebrate in the final metres. In the men's 5000m, the three medallists were well clear of the pack at the beginning of the final 200m, and thus had only the 5th, 7th, and 6th best final 200m splits, respectively. Clearly in this specific event, overall fitness and racing strategy execution over the first 4800m of the race determined the medallists more than finishing sprint ability. However, note for example that in the women's races, only the 5000m and 10,000m winners had the best final 200m splits. Interestingly, the winner of each of the women's 800m, 1500m, 5000m, and 10,000m events had the fastest split over the final 400m. This would suggest that, along with medallists in the women's races tending to get into medal position earlier in the race compared to men, women winners tend to also have the best finishing kicks among competitors in their event. Nevertheless, choosing the best overall pacing strategy, executing that strategy, and final sprinting ability all contribute significant portions to success in championship type races.

Conclusion

This analysis observed a differing strategy between those athletes who are successful in the shorter and longer distance track races at championship type races. Generally, medalists in the shorter races (800m and 1500m) get themselves into medal position earlier in the race, compared to medallists in the longer races (5000m and 10,000m). Runners in the longer races who medal do not get themselves into medal position until the final 20-40% of the race. There were no differences between the men and women, which provides further support to the observations. This suggests that strategy is dictated by the event and that sex does not appear to have an effect on pacing strategy selection. Strategy is influenced by the physiological demands of the event such that, those in the longer events are concerned with energy conservation and those in the shorter events are more concerned with being in an optimal position throughout the event. Finally, CHAPMAN [6] provides a framework to classify events based on the strategy those individuals most often utilise when place is the primary desired outcome.

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REFERENCES


Coaching

contents

- The 21st North America, Central America and Caribbean Track and Field Coaches Association Congress
  Mérida, México

- The 1st European Decathlon Conference
  Tallinn, Estonia

- International Festival of Athletics Coaching
  Glasgow, Scotland
Sixty-five coaches from countries throughout the region convened in the historic Mexican city of Mérida for the 21st Congress of the North America, Central America, and Caribbean Track & Field Coaches’ Association (NACACTFCA), entitled the Art and Science of Athletics Training, from 6 to 8 October 2011.

The NACACTFCA president and chairman of the IAAF Coaches Commission Victor Lopez (PUR), was the keynote speaker and the line-up of lecturers included Carlos Cavalheiro (BRA), Alain Jean Pierre (HAI), Raul Barreda (MEX), David Johnston (USA), Peter Pratt (BAH), Dennis Österberg (SWE), and Richie Mercado (USA).

Following are highlights from the main presentations.

The Current Situation of the Coaching Profession
Victor Lopez (PUR)

Lopez outlined the development of educational opportunities in athletics since the 1950s and the impact on the coaching profession, noting the recent success of athletes and coaches educated through the Central America and Caribbean (CAC) and IAAF systems and the great cooperation between programmes in the USA, Canada, and the CAC. He explained the role that NACACTFCA has played in bringing world-class coaches and educators into the region, promoting programmes for women in coaching, increasing accreditation opportu-
Practical Applications of Speed

**David Johnston (USA)**

Johnston, currently serving as the national pole vault coach in Saudi Arabia, spoke about the development of speed in the jumps, especially the correlation of stride length to approach velocity. For approaches in the horizontal jumps and pole vault, speed is important, but consistency in the approach is paramount. Johnston explained how he developed theories and specific distance tables in the 1970s that are now supported by the latest biomechanical research. He repeated his mantra “push, push, push!” for both acceleration and maximum velocity running - emphasising the vital relationship between force production, stride length and velocity. In sprinting there should be neither reaching nor pulling, only pushing - down and back in acceleration progressing to vertical force at maximum velocity. He offered the adage “form follows function”, as well as analysis of great sprint races from Lewis to Gay to Bolt to confirm his points. His key numbers for acceleration: seven strides for 10m, twelve for 20m, and sixteen for 30m. His training for acceleration patterns and push mechanics utilises marking on tracks, cones, marked bungees to stretch for progressive ladder marks, etc. Johnston has also developed patterns for long jump and pole vault. These have been used for years by coaches to help their athletes train, establish consistent patterned approaches, and set mid marks that help avoid over-reaching. Former world-class triple jumper and current coach Brian Wellman joined Johnston to demonstrate proper technique for acceleration development using the pattern on the track. Johnston said over-reaching is the number one culprit destroying both natural acceleration in the sprints and in jump approaches! More information on Johnston’s approach and his stride charts for sprints, hurdles, and jumps may be found at http://www.oneapproachrun.com/

The Art and Science of Endurance Training

**Carlos Cavalheiro (BRA)**

Cavalheiro, whose Brazilian athletes have amassed three Olympic and 12 world championships medals over two decades, is currently the senior endurance coach at the Aspire Academy in Qatar. He explained his approach to training distance runners by starting with his personal background as a sprinter and coach of sprinters like two-time Olympic bronze medallist Robson Da Silva. Cavalheiro said that speed is a necessity for top-level success in the middle- and...
long-distance events and that even endurance training must take into account this requirement. He uses the concept of speed capacity, putting emphasis on dynamic foot strike, neuromuscular coordination and power. Cross country, fartlek, and aerobic running are coupled with intensive interval training and training means that stress special endurance. In addition, he makes use of circuits and obstacle runs to strengthen runners in general and specific ways. His training means include breath holding during circuits, running drills and pool running circuits. Weight training is also used to develop strength in the hips and overall power (squats, snatch, clean, etc). Cavalheiro presented the general approach used with junior athletes at the Aspire Academy in Qatar and senior distance runners he trains. Examples of periodised training plans were outlined. He also explained specific race drills, for example for the 1500m: 1-3 x 300m / 100m / 300m). He also showed a visual tour of the Aspire facilities in Doha, competition site of the 2010 IAAF World Indoor Championships and a current candidate for the 2019 IAAF World Championships in Athletics.

Triple Jump: The Game

Peter Pratt (BAH)

Currently a national team coach and a former triple jumper himself, Pratt said that development of a triple jumper is a long-term affair, with at least four years required to achieve real technical and aesthetic success. He takes a simple but well-founded approach that begins with posture and foot strike, sound mechanics of bounding, hopping and jumping, and enhancing the emotional fortitude or daring spirit of the athlete. In the first year, the emphasis is on the approach run mechanics, rhythm, and moving through the phases; the second year focus is on posture and refining technique – hopping, step phase, transitioning; and in the third year the focus is on spatial awareness, attacking the board, maintaining body position, exaggerating arms, and holding on to phases. Preparation work includes three components - physical training (jump work); anticipating, compensating or making adjustment to environmental situations that may arise in competition; and mental strategy preparation – working on situational issues in competition. Pratt said he utilises sand, grass and hill running for general development and progresses to jumping into pole vault and high jump mats for the development of stabilisation and specific technical strength and strength endurance. He demonstrated several examples of running posture and strength exercises on the mat as well as special strength exercises he uses. Pratt said he teaches competitors to be observant in setting marks, knowing what is going on with other competitors, officials, etc, and remembering the first attempt to build on throughout the competition. He wants the athlete to function well without the coach, since the coach is often far away from the field or completely absent in major competitions.

The 400 Meter Sprint

Raul Barreda (CUB)

Barreda has worked for many years in Mexico, where his best known athlete is former world 400m champion Ana Guevara. He discussed the training of long sprinters, noting that the 400m is often referred to as “la carrera de la muerte,” (the run of death)! One of the major reasons is that the demands of the event are so much more anaerobic than the shorter sprints or middle-distance races. Vital to a 400m runner is development of speed, speed endurance, special endurance, and strength endurance. High intensity training must increase the glycolitic capacity and ability to maintain high levels of oxygen debt. Anaerobic special endurance is trained using distances of 300m, 500m, and 600m, with distances of 320-400m yielding the most return in terms of increased percentage of lactate training and acidosis tolerance. Barreda discussed the percentages of 200m segments for men’s and women’s finalists in the 1999 IAAF World Championships in Athletics to make the point of the need for both speed in some (Freeman – 23.79 / 25.88 = 49.67 [diff=2.09], and Parrela – 21.13 / 23.16 = 44.29 [diff=2.03]) and special endurance in others (Johnson – 21.22 / 21.96 = 43.18 [diff=0.74], and Rücker – 24.03 / 25.71 = 49.74 [diff=1.68]). Indeed, Johnson was the model for both speed and special endurance, with a 200m differential of only 0.74 and a very fast first 200m! There was a direct correlation among men to placing and ability to main-
coaches are available, as well as programmes for exchanges of administrators between regions. Also represented in the plan and funding programmes are sport medicine research, sport and the environment, culture and education, heritage and the Olympic Academies, improving the role of women in sport, and the “Sport and All” programme.

The Evolution of the Javelin
Dennis Österberg (SWE)

Österberg, who works at Nordic Sport in Sweden, discussed the history and evolution of javelin design and production and the new direction that his company is taking to develop “stiffness” ratings for javelins much like those on vaulting poles. The current distance ratings of javelins do not take into account the vibrations and flexing that take place in flight and affect the length of a throw, but Nordic has developed a carbon technology that will allow for stiffer or less stiff (softer) javelins to meet the specific throwing style, strength and shoulder girdle stability of the thrower. As a result of experimentation in production and with special mechanical devices to measure stiffness and
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normal or high-speed video. Its practical applications include accurate and quick measurement of maximum velocities, angular velocities, stride length, stride frequency, angles, hurdle unit times, flight times, ground contact times, and distance. With a limited number of athletes, some important variables can be measured between runs or attempts, allowing for accurate evaluation of each aspect of a training session. Kinovea allows the coach to measure and track aspects of training and technical development that can frame future training goals, and test athletes accurately. All this for the best price yet – totally free! There is also a great online forum with answers to questions, ideas from a variety of coaches and sports, and solutions to the common and unusual problems that may arise - go to www.kinovea.org for information and to download the program.

Conclusion

The 22nd NACACTFCA Congress will be held in Nassau, Bahamas from 4-7 October 2012. The theme will be “New Frontiers in Athletics Training.” More information including presentations from past congresses is available at www.nacactfca.org.

Reported by Richie Mercado

Richie Mercado is the Secretary of the NACACTFCA.

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The 1st European Decathlon Conference

Tallinn, Estonia

Introduction

More than 75 athletes and coaches from six countries attended the first European Decathlon Conference, which took place in Tallinn, Estonia, from 5-6 October 2011. The conference, which was hosted by the Estonian Athletic Association, kicked off the the 2011 European Athletics Coaching Summit Series.

The programme focused on the long jump and high jump in the context of the decathlon and included a wide range of theoretical and practical presentations from top specialist Yevgeniy Zagorulko (RUS), as well as career analyses of former elite performers Erki Nool (EST) and Tõnu Lepik (EST).

This report gives summaries of the main presentations.

Thoughts on the Difference in Training and Competition Results

Erki Nool (EST)

Nool, the 2000 Olympic champion in the decathlon and 5th in world all-time list with 8815 points, is the unofficial world record holder for the long jump within a decathlon (8.22m). However, he feels he did not reach his full potential in this discipline. He said around 70% of decathletes are not pleased with their long jump results and about 2/3 of them make their lifetime bests in training. He cited lack of technique training with a full approach as a problem area and said that because of their relatively higher bodyweight compared to specialised long jumpers, decathletes must try even harder to their speed abilities. Typically training approximately 80% of the time with a half approach allows them to include technique work more frequently in the programme, perform more repetitions and easily control the technique. However, such jumps do not fully prepare them for the higher velocities and forces experienced from a full approach in competition. He mentioned that his average training jump from an eight-step approach was 7.30-7.40m but in competition he would normally expect to jump 7.70-7.80m from a full approach.

Nool also gave an overview of his training programme for the 1995 summer season. In the preparation phase, he focused on sprint drills (every training session included at least 15 x 60m and up to 700m in short acceleration runs). Depending on the day, he did sprint runs with different intensities and loads, but no longer than 150m. The result was an 8.10m long jump in his first competition that year and both a 21.03 sec 200m and 46.98 sec 400m dur-
Epro, a PhD student at the German Sport University Cologne, explained the possibilities of the 3-dimensional video analysis to evaluate the high jump technique of athletes and provide them with key points for improvement. After giving an overview of the performance parameters for the event, he presented analyses of four top-level decathletes competing at the 2011 IAAF World Championships in Athletics - Ashton Eaton (USA), Aleksey Drozdov (RUS), Thomas Van Der Plaetsen (BEL) and Roman Šebrle (CZE). He also showed a graphical view of a 3D biomechanical video analysis of different level decathletes and high jumpers in Estonia that he had made in winter competitions in early 2011.

Espo's main message was that running is the key to jumping higher. His analyses clearly showed the importance of optimal horizontal velocity at the end of the approach for producing vertical velocity in the take-off, and therefore maximal height of the CM (centre of mass) in the bar clearance phase. The goal of the take-off is to transform as much horizontal velocity as possible to vertical velocity but too little horizontal velocity does not produce enough forward motion while too much horizontal velocity leads to an inappropriate take-off position and probably a failed attempt. This process calls for both muscular strength and optimal body positions. The technique of most decathletes is characterised by a slow approach and over-reliance on muscular strength in the take-off. He concluded with key objectives for improvement:

- aim for higher, but optimal, horizontal velocity in the end of the approach (transform more horizontal velocity with no decrease in the muscle contraction mechanisms in the take-off) to produce higher vertical velocity;
- penultimate stride (fast over + push);
- lengthen the path of vertical acceleration of the CM without losing velocity (reasonable lateral and backward lean for the start of the take-off);
• generate the appropriate amount of rotations in the take-off phase to clear the bar.

Modern Training of the Elite High Jumpers
Yevgeniy Zagorulko (RUS)

The conference keynote speaker, Zagorulko, has been the head coach for the high jump in the USSR and Russian Federation almost for three decades. He is one of the most well-known high jump coaches in the world and has probably coached more major event medallists than anyone else.

The first of his two presentations was a theoretical lecture dealing mostly with the physical and mental requirements of elite high jumpers and the key technical aspect of performance in the event. To become an elite high jumper, an athlete has to be tall, light and possess great physical abilities, especially strong legs.

He or she must show certain levels in speed and strength parameters and work day to day to improve technique. However a well trained body is no guarantee for getting to the top. A champion has to be like a gladiator and do everything that it takes to beat the opponent. Strong willpower, a trusting relationship with the coach, self-discipline, patience, toughness and endless perseverance describe the true champion.

Zagorulko stressed the importance of correct running. In his words: “Athletics is running! This is were you have to suffer and this is where you build the character.” He sets a high value on speed – “a high jumper has to be fast!” - his best female athlete, Anna Chichereva, has a personal best 12.0 sec in the 100m and 25.4 sec in the 200m. But he also uses the well-known 12 min Cooper-test on his jumpers in the preparation phase and looks for them to show results around 3000m. When talking about his training philosophy and methodolo-
Conclusion

The conference can qualify as a success both for the organisers (Estonian Athletics Association and European Athletics) and participants. A post-event survey showed the gratification of the participated coaches and athletes from Estonia or other European countries. Some expressed the hope that the conference becomes a tradition and a helpful knowledge and experience sharing point for wide range of combined event coaches and athletes.

Thoughts from the participants:

“In my opinion the conference was a success and the keypoints, mentioned by different speakers, are important and known truth, which have to be reminded time-to-time to the experienced coaches and newcomers. A little has changed, but the basics stay.” - Martin Kutman (Estonian coach with over 60 year experience; best athletes: Anna Iljuštšenko, 1.96m NR)

“The practical session of Mr. Zagorulko was interesting and showed us that we are moving in the right direction.” - Karl Lumi (Estonian high jumper; PB: 2.21m)

“I think it was a interesting and necessary conference. It showed us the basic physical criteria that an athlete should have and some specific nuances. We will see the value from the next season’s results.” - Huko Linnas (Estonian coach for decathletes)

Reported by Gaspar Epro

Gaspar Epro is a PhD student in the German Sport University Cologne and the website administrator for JumpsCoach.eu. He can be contacted at gaspar@jumpscoach.eu.
Introduction

The 2011 edition of the International Festival of Athletics Coaching (IFAC) lived up to its name and was a true international affair. With Glasgow set to host the 2014 Commonwealth Games in 2014 – not to mention London’s preparations for the 2012 Olympic Games and, later, the 2017 IAAF World Championships in Athletics - there is an unprecedented focus on sport in the city and it warmly welcomed 318 participants from no less than 26 nations from the 28th to 30th of October.

The festival, which serves as the annual conference of the European Athletics Coaching Association (EACA), was hosted by scottish athletics with support from European Athletics. Joining the athletics-oriented participants were a number of representatives from other sports including football, netball, triathlon, water-skiing and skeet.

The theme for this year’s festival was practical application. In addition to the formal presentations and seminars at Glasgow’s Marriott Hotel, a number of workshops were staged at two of the city’s top sporting venues – Scotstoun Stadium and Kelvin Hall. Seventy-five local athletes participated in these as a part of development days organised in conjunction with the festival.

There was also promotion of health and recreational running through an all-day seminar presented by jogscotland and a new feature, the Coaches Mall, designed to encourage exchange of experience, networking and long-term cooperation among the participating coaches.

All in all, the IFAC 2011 was a busy and successful event and both the organisers and participants seemed to be satisfied with the results. This report provides an overview of the main activities of the festival.

Keynote Presentations

The keynote presentations were delivered by a range of top international speakers throughout the three days of the festival.

Vern Gambetta (USA), the founding father of functional sport training gave a talk, entitled “From Chalkboard to iPad – The Evolution of the Art and Science of Coaching Athletics,” in which he looked at how the advancements in technology and in society are shaping the way in which we coach.

Wolfgang Ritzdorf (GER), the Director of the IAAF World High Jump Centre in Cologne, addressed the “Challenges in Coaching the Jumping Events.” He highlighted the discrepancy between today’s performances and those of the 1980s and 1990s and provided a few thought provoking suggestions on how we can advance as a sport from where we are not.

Penny Werthner (CAN), a former Olympian and now a leading sports psychologist who has worked with Canada's top athletes at the last ten summer and winter Olympic Games, spoke about “Managing Anxiety on a Competitive Stage.” Werthner's message was clear: in order to succeed at international level, physical preparations need to be complimented with psychological preparations.
Jimmy Beauttah (KEN), the Chief Coach at the IAAF High Performance Centre in Kenya, shared his experiences in helping athletes to “Deliver on the Day” – in particular the coaching philosophy used with Asbel Kiprop, winner of the 1500m at both the 2008 Olympic Games and the 2011 IAAF World Championships in Athletics.

Elio Locatelli (ITA), the Director of the Member Services Department, spoke about “Getting the Best Performance – The Critical Factors.” The internationally renowned speed and long jump expert gave a well-informed synopsis of how coaches can help athletes attain their best performance.

Don Babbitt (USA), the veteran throws coach at the University of Georgia spoke about the “Development to Elite: Across the Throws Disciplines”. He focussed on the importance of developing the technical aspects of each of the throwing events.

**Practical Workshops**

The IFAC organiser’s new emphasis on practical workshops, which were held at the Scotstoun Stadium and Kelvin Hall, proved to be popular with participants. These sessions encouraged a hands-on approach oriented to different stages of the performance continuum - form development to elite.

In their workshops, the coaching team behind European Junior double sprint champion Jodie Williams – Stan Madiri (ZIM) and Mike McFarlane (GBR) – presented drills for speed development.

Kelvin Giles (GBR) gave one workshop on assessing physical competencies as well as movement skills. In a second session aimed at school sport teachers, he focused on building a strong movement vocabulary for young athletes, in order for activities seen in the sport curriculum to better serve as a foundation for the development of athletes.

Don Babbitt and former international thrower Shaun Pickering (GBR) led workshops covering the shot put, hammer and discus as well as one focusing on power training.

The javelin was covered by Terseus Liebenberg (RSA), who is the coach of 2011 IAAF World Championships in Athletics bronze medallist, Sunette Viljoen. Working with a group of developing Scottish javelin athletes, Liebenberg broke down the technical model of the event so the key aspects could be better understood.

Wolfgang Ritzdorf gave two workshops in which he took the participants through the development of reactive strength as well as general jumps drills in two of his practical workshops. He then teamed up with the former European high jump medallist Dalton Grant (GBR) to deliver an innovative Master Class to some of Scotland’s top high jumpers – including video analysis and discussion with the athlete on the “Anatomy of Competition: The Tough Decisions.”

Vern Gambetta delivered three well-attended practical sessions that focused on developing foundational strength and the importance of core strength development as well as remedial exercises for injury prevention.

Vincenzo Canali (ITA) delivered an excellent workshop on athlete conditioning for all events and then he teamed up with renowned pole vault expert, Steve Rippon (AUS), to deliver a
pole vault specific conditioning session and a vaulting clinic with local athletes.

Ian Mirfin (GBR) led the UK’s first RaceRunning workshop with coaches and some of the top young athletes in this new event. The session, which was an introduction to the event, also allowed coaches the opportunity to discuss the successful interventions in coaching athletes with a disability.

Seminars

Complementing the keynote presentations and practical workshops, a wide range of seminars designed to promote questions and discussions from the participants were delivered by the feature speakers, workshop leaders and others.

Dave Sunderland (GBR) and his Scottish athlete Lynsey Sharp (European U23 800m bronze medallist) discussed their journey in developing as a young endurance athlete.

Penny Werthner followed on from her keynote to discuss techniques for managing anxiety as well as the role that coaches can play in an athlete’s psychological preparations.

Elio Locatelli led two fascinating seminars on his specialist events, sprints and jumps, using the latest biomechanical research to enhance discussion.

Toni Minichiello (GBR), coach to Jessica Ennis (2010 European Heptathlon Champion and 2011 World Heptathlon silver medallist), based his series of interactive seminars on his experience developing Ennis from an eleven year-old. Included were discussions with coaches on the transition of athletes from promising juniors to senior international performers.

Jimmy Beauttah drew on his coaching experiences to discuss building the complete endurance athlete and preparing for major championships.

Laura Forrest (GBR), sport physiologist from sportscotland Institute of Sport, gave an insightful seminar on understanding and harnessing physiology in the context of training and performance.

Emma Gardner (GBR), sports scientists at Lucozade Sport, discussed nutrition in her seminar entitle “Mouth to Muscle: Fuelling Performance.”

Frank Dick (GBR), the EACA President, used his seminar to look at the coaching profession, how coaches can utilise coaching associations and the development a meaningful coaches' licence.

Coaches’ Mall

The Coaches’ Mall was a new addition to the 2011 IFAC programme was an opportunity for coaches to further develop their knowledge and to energise their personal coaching networks. This innovative format saw coaches mixed into groups by sport, event and nationality for open discussions, ensuring a variety of different perspectives were shared.

Each group was given a series four questions related to coaching and training problems and participants were encouraged to share their personal experiences and knowledge. At the end of the session each group shared their three key points from each question, which were all collated and then distributed to all participants at the end of the festival.
Closing Address

The festival was closed with the EACA President’s address in which Frank Dick highlighted the current levels of European performances and success on the global stage.

IFAC 2012

Looking ahead to IFAC 2012, delegates can expect an equal focus on practical sessions with longer workshops as well as a break down to different athlete development stages. After a busy year in international athletics, we will also take the time to analyse the performances at the 2012 European Athletics Championships in Helsinki and the 2012 Olympic Games.

Registration information and announcements about the format and speaker line-up are available at www.ifacscotland.co.uk.

Reported by Jamie Bowie

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Development

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Development Spotlight – Ukraine, A Model of Success

by Helmut Digel

ABSTRACT

The Ukraine can look back on a long and glorious tradition in athletics. As a part of the Soviet Union it supplied many of that country’s famous victories, most notably those by Olympic champions Valeriy Borzov and Sergey Bubka, both of whom are presently in leading positions in Ukrainian sport organisations. Since independence in 1991, Ukrainian athletes have won 15 medals at the Olympic Games and recently the country has consistently been among the most successful at both the world and European levels. This success has helped to make athletics among the most popular sports with the public and ensure continued government support. The sport’s achievements can be largely attributed to the country’s support model. In this case study, the author outlines the key elements of the model and provides interesting insights. The points covered include the federation, athletics infrastructure, coaches, technical officials, talent identification system, performance development structure and reward system.

AUTHOR

Helmut Digel is a Professor for Sport Science and Sport Sociology. He is an IAAF Council member, Chairman of the IAAF Marketing and Promotion Commission, a member of the IAAF Development Commission and a Consultant Editor for New Studies in Athletics. He also holds various leadership positions in both sport and sport science in Germany.

Introduction

The Ukraine can look back on a long and glorious tradition in athletics. A republic of the Soviet Union for nearly 70 years, its athletes played a central role in the development of that country’s high-performance sport and were responsible for some of its greatest victories. Surely, the best known from that time are Valeriy Borzov, who won the men’s 100m and 200m gold medals in the 1972 Olympic Games in Munich, and Sergey Bubka, whose multi-gold medal and world record career in the pole vault puts him in anybody’s top rank of champions.

In today’s independent Ukraine, both men are in leading positions in sport administration. As the president of the national federation, Borzov applies his expertise and experience to the development of athletics in the country while Bubka, as the national Olympic
committee president, IAAF Vice-President and International Olympic Committee member, is similarly influential in international sport, particularly athletics. Under these two, there has been a flowering of athletics and recently Ukrainian athletes have been attracting attention through their consistently strong performances in international competitions.

Since independence Ukrainian athletes have won 15 medals at the Olympic Games, three of which are gold and are to be specially noted. At both the 2004 and 2008 Games, Ukraine was ranked ninth in the athletics medal table. At the European level, it was ranked third on the medal table at the 2010 European Athletics Championships and in 2011 the national team placed third in European Team Championships behind Russia and Great Britain, beating the likes of France, Italy and Germany, and there were many successes at the European U23 Championships in Ostrava.

In this article I will outline the elements of the model behind Ukraine’s athletics success in the hope that it provides insight and ideas for federations and others with an interest in the development of sport.

**The Country**

In terms of landmass, the Ukraine is the second largest country in Europe after Russia. Since the collapse of the Soviet Union in 1991, it has been a semi-presidential republic comprising 24 oblasts (regions). The capital is Kyiv and other important cities are Donetsk, Charkiw, Dnipropetrowsk and Odessa. Of the 47.1 million inhabitants (down from 51 million in the 1980s) 77.8% are Ukrainians, 17.3% are Russians and there are more than 100 other nationalities.

The Ukraine maintains 966 universities and colleges. The most important university cities are Kyiv, Charkiw, Odessa and Lemberg. In terms of faith, it has traditionally been a mixed country with the orthodox churches dominating.

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**Ukraine Facts**

<table>
<thead>
<tr>
<th>Area:</th>
<th>603,700 km²</th>
</tr>
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<tbody>
<tr>
<td>Population:</td>
<td>47.1 million</td>
</tr>
<tr>
<td>Capital:</td>
<td>Kyiv – pop. 2.6 million</td>
</tr>
<tr>
<td>GDP per Capita:</td>
<td>$ 4,500</td>
</tr>
<tr>
<td>Independence:</td>
<td>1991 (from the Soviet Union)</td>
</tr>
<tr>
<td>Government:</td>
<td>Republic (member of the Commonwealth of Independent States)</td>
</tr>
<tr>
<td>Source:</td>
<td><a href="http://www.nationalgeographic.com">www.nationalgeographic.com</a></td>
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</tbody>
</table>

In everyday culture, sport plays an outstanding role. Football is especially popular; the most well known clubs are Dynamo Kyiv and Shakhtar Donetsk, the biggest current star is Andrej Schewtschenko from Dynamo Kyiv and the most famous coach is the leader of the national team, Oleg Blokhin. Also popular is boxing, where the country can boast world champions Wladimir and Vitali Klitschko, Andriy Kotelnik and Sergey Dotsenko.

Interestingly, polls show that athletics is also among the most popular sports with the public.

In the tradition of the Soviet Union, the promotion of sport has been important in the political system of the Ukraine and since independence the necessary financing is normally given a high priority.

**Federation**

The headquarters of the Ukrainian athletics federation is located in Kyiv. An executive director, who is also vice-president, leads the office. He is supported by seven full-time staff members including a deputy executive director, who is in charge of international affairs, a director of competitions, who is responsible for the organisation of national championships and other major events, two statisticians, a financial manager, an accounts assistant and a secretary. There is also a part-time press attaché.
Coaches

According to the national athletics federation’s figures, in the mid-1980s there were about 90,000 athletes in the Ukraine. Serving them were 2,700 well-qualified professional athletics coaches as well as countless part-time coaches training children and juveniles. Due to financial reasons, the high level of employment could not be maintained after independence. However, in 2011 there were still about 1,200 full-time coaches, although that number is expected to decline in the coming years (Figure 1).

On the positive side, about 40% of all coaches are female, which is particularly welcome news. Already in the times of the Soviet Union the share of female coaches had reached 30%. However, one of the issues the sport must face is the increasing age profile of the professional coaches (Figure 2). These two situations are related to the facts that there are limited chances of employment for younger coaches and the wages of coaches can be described as low in comparison to the other wages in the Ukraine. Once a young man holds a university degree in the field of sports, a key qualification for coaching, he is unlikely to be satisfied with the salary currently offered in athletics. Therefore, the portion of female

Athletics Infrastructure

The Ukraine has a relatively favourable facilities situation for the benefit of athletics. Today there are three stadia with IAAF-certified tracks and three other stadia are currently being rebuilt. There is at least one athletics ground in each one of the 24 regions and 30 Ukrainian towns have a 400m synthetic track and the equivalent throwing facilities. But in some cases the facilities are outdated and the synthetic surfaces often need to be replaced. Indoor athletics arenas can be found in twelve Ukrainian cities.
Performance Development Structure

Ukrainian athletics is not based on a grass roots club system. Instead, the characteristic structures for all sports in the country are the sport schools and colleges, where talented performers are developed through specialised training programmes applied in parallel to their general education. Some of these place special emphasis on athletics. In this way the problem of the compatibility of school and training is solved in a nearly optimal manner. The cooperation between the federation and each individual school is hence indispensable.

Athletes may also develop through other organisations where they might be employed, such as factories or state authorities. Further development opportunities are then offered by regional clubs, regional athletics teams run by local branches of the federation and the Olympic Preparation Centre (see Figure 3).

Today there are 691 children and youth sport schools, most of them are in small villages and towns. Next in the performance pyramid are 27 special schools for children and juveniles, for the so-called Olympic reserve. Although many different sports are promoted in these, there is usually an athletics branch. Apart from these special schools there are 27 sport schools for higher sports competence, which can be found in all 24 regions.
At the top of the pyramid there are 14 sports colleges, all of which are boarding institutions, allotting an outstanding position to athletics. In these colleges education and training are organised individually in favour of the athletes (Figure 4). Well-qualified coaches are solely responsible for the training of the youths, while specially trained teachers are responsible for the educational aspects. There are presently about 200 athletes training in these colleges, looked after by 70 coaches. The athletes receive full support from the state, while their coaches receive a 20% premium compared to the salaries of other coaches.
Generally the focus of athletics in the sports schools, colleges, etc. is on running (sprints and middle- and long-distance) and the jumping events (see Figure 5).

The funding sources for the sport schools is shown in Figure 6.

In 1998 the Sports Committee of the Ukrainian Ministry of Education and Science was founded. This committee is responsible for all respects of sports in Ukrainian schools, educational facilities and universities. The federation cooperates with this committee very closely. Athletics is the crucial part of the mandatory curriculum in Ukrainian schools, being taught chiefly in the warm seasons. Many schools have multi-functional sports facilities.

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**Figure 5: Specialisation of athletics events in Ukrainian sport schools**

**Figure 6: Funding sources for sport schools in the Ukraine**
Reward Systems

The most important reward in Ukrainian athletics is the admission to a sports college. This means that the athlete’s education, training and food are paid for by the state. Moreover, high-quality coaching and other support is ensured.

The national team includes more than 250 squad athletes older than 18 years. About 150 of them receive an athlete’s wage.

In addition to this basic structure there are performance-oriented bonuses. Once an athlete has achieved a medal in World Championships, European Championships or Olympic Games, he or she receives a financial bonus. One thousand US dollars per month is usually paid for one year if an athlete has achieved a gold medal. This award is called “Scholarship of the President of the Ukraine” (Presidential Scholarship). The coaches of the successful athletes also receive a “Presidential Scholarship” of the same financial amount.

Conclusion

In the face of these remarkable structures and systems in favour of athletics and the focused, professional and extremely competent work of the federation, it is not surprising that Ukrainian athletes are regularly achieving international success. Moreover, it is easy to see why the sport is one of the most popular in the Ukraine and as the most important Olympic sport it can count on continued excellent support.

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Progression of Elite New Zealand and Australian Junior Athletes to Senior Representation

by Stephen Hollings and Patria Hume

ABSTRACT

There is a reasonable probability that athletes who have achieved a high level of success as a junior will go on to be successful seniors. This study tested the idea by following Australian and New Zealand athletes taking part in the IAAF World Junior Championship (WJC) from 1986 to 2006 through to senior global and Commonwealth Games performances - or otherwise. It was found that 22% of Australian and 32% of New Zealand WJC medallists and finalists went on to become global medallists or finalists or to win a Commonwealth Games medal as seniors. The probability is greater if the athlete won a WJC medal and much less if the athlete merely competed in the WJC or did not take part at all. At the same time, the overall attrition rate of Australian and New Zealand athletes who competed at a WJC but did not go on to represent their country at the senior level was high (~72%). The authors suggest that strategies to produce successful senior athletes, should be based on: 1) producing more WJC medallists and finalists; 2) retaining juniors in the sport through to the senior grade; 3) concentrating resources on WJC medallists and junior finalists.

AUTHORS

Stephen Hollings is a former Great Britain Olympian (3000m Steeplechase, Munich 1972). He was formerly High Performance Director for Athletics New Zealand and Senior Manager – Education for the IAAF. He is currently and completing a PhD at AUT University, Auckland, New Zealand.

Patria Hume is a Professor at the Sports Performance Research Institute New Zealand at AUT University, Auckland, New Zealand.

Introduction

There is debate whether success at the IAAF World Junior Championships is a prerequisite for success as a senior athlete at the global level (HOLLINGS, 2006). Usually, however, discussion of the transition from elite junior to elite senior athlete by coaches of junior athletes is based on anecdotal evidence of one or two examples.

Previous studies of this transition have been mainly descriptive, for example ZELICHENOK, (2005) who studied the careers of about 1,500 top athletes who had previously taken part in the IAAF World Junior Championships. He found that 60-70% of the winners and medal-
lists did not go on to achieve any serious success at the senior level. OTTE (2002) made a quantitative study in which he followed the careers of male finalists in the 1986-1996 IAAF World Junior Championships until 2002. Of the 835 athletes tracked, 64% showed further performance development and 26% reached the finals at the IAAF World Championships in Athletics and/or the Olympic Games. JULIN (1995) followed the careers of athletes who medalled at the 1989 European Junior Championships in Varazdin, Croatia, to see what they achieved at the European Athletics (senior) Championships in Helsinki, Finland in 1994. He established that of the 98 individual medallists from the 1989 European Athletics Junior Championships, just seven won a medal five years later at the European Athletics Championships, a further seven were finalists, sixteen others competed and were “also-rans”, whilst 68 (69%) of the junior medallists from 1989 did not compete at the European (senior) Championships five years later.

The rather negative view of the effect of international competitions for younger athletes is not shared by SCHOLZ (2006) who concluded from an analysis of throwing events at the World Junior Championships, that the championships were a springboard for entry into the elite class. This finding compares favourably with those of GRUND & RITZDORF (2006), who studied the performance development of the finalists at the 1999 World Youth Championships and found that 90% of finalists (n=266) at these championships continued to improve in the subsequent years and 88% made the world top 100 ranked performances of the year in their event. Twenty-one percent of the group went on to qualify for the World Championships or the Olympic Games between 2000 and 2004.

Many national athletics federations are dependent on significant financial support from government or other non-government agencies for their operational funding. In New Zealand, SPARC (the government sports funding agency) and, to a similar degree, the New Zealand Olympic Committee have a philosophy of only funding sports that have the ability to produce athletes who will finish in the top 16 at a world championships or Olympic Games or win a medal at a Commonwealth Games. Athletics currently is one of only six “targeted” Olympic sports that is funded by SPARC. Consequently, as a result of this status, Athletics New Zealand’s is dependent on continuing to meet the expected performance outcomes. To keep meeting this criterion, and thereby ensuring its primary source of funding, it must have programmes in place that deliver athletes capable of meeting the necessary performance standards. The pool of elite junior athletes is, of course, a source of future high-achieving senior athletes. However, there is debate regarding whether funding should be made available to junior athletes or it should be held back until the athletes have reached the senior level. The dilemma revolves around the decision of which junior athletes should be supported, since many who have shown a capability of high achievement have terminated their involvement in the sport. The transition period is therefore a critical period for both the athlete and the federation: Athletics New Zealand needs assurance that their investment in an identified junior athlete will pay off when the athlete becomes a senior athlete, and the athlete requires an assurance that Athletics New Zealand will invest in them so they can realise their demonstrated potential.

We aimed to quantify the extent of the transition from elite junior to successful senior, or otherwise. We chose to focus on New Zealand and Australian track and field athletes due to:

- this sample being a cohort of elite junior athletes progressing to the elite senior level internationally;
- there were comprehensive data available on each athlete from these two countries that had competed at a IAAF World Junior Championships, together with a summary of their post junior athletics careers;
- athletics is structured similarly in both countries with respect to administration, organisation, competition structure, development, coaching, and stakeholder and government involvement;
there is a similar philosophy towards junior athletes and towards elite senior athletes in both countries.

In the specific context of New Zealand and Australia, we defined a “successful athlete” as an elite senior and included those who won a medal at a Commonwealth Games. We included this as one of the criteria, because the Commonwealth Games is perceived to be a prestigious competition and results at these competitions often form the basis for future funding decisions. The Commonwealth Games is universally the next level of competition for New Zealand and Australian athletes after the IAAF World Junior Championships. In some events there is a disparity in standard between winning a Commonwealth Games medal and winning or finishing in a final at a global championship, for example the walking events and the throwing events do not have the same depth of standard at the Commonwealth Games as observed at a global championship. However, the men’s sprint events, men’s and women’s middle-distance events, the men’s long jump and the men’s pole vault standards at the Commonwealth Games are on a par with those at a global championship.

More than 12,500 international athletes have competed in the 11 editions of the IAAF World Junior Championships from 1986 to 2006 and there are a number of databases that provide athletic performance data and thus make it possible to track career development. Some countries have their own data bases that can be accessed for performance analysis. Therefore quantification of the extent of the transition from elite junior to successful senior athlete is possible.

Definitions

In the context of this paper the following definitions and terms apply:

**Medallist:** An athlete winning a gold, silver or bronze (i.e., 1st, 2nd, 3rd place) medal in a competition.

**Finalist:** An athlete who qualified for a final at the competition; normally top 8 for a laned event, top 12 for all other events.

**Competitor:** An athlete who did not make a final or win a medal.

**Global:** World Championships (Senior), outdoor or indoor, held every two years, or Olympic Games, held every four years.

**Elite:** A Global Medallist, Finalist or Competitor.

**Senior:** Open-age athlete.

**Junior:** An athlete competing at the IAAF World Junior Championships.

**Successful athlete:** An Elite Senior including those who won a medal at a Commonwealth Games.

**Transition time:** The number of years between an athlete first becoming a Junior Medallist or Junior Finalist and becoming, for the first time, a Global Medallist or Global Finalist.
Methods

Data extraction

Biographical data and competition performance results of 536 Australian and New Zealand (406 Australian and 130 New Zealand) athletes who competed in individual events at the IAAF World Junior Championships from 1986 to 2006 were identified from the federations’ web-based databases (Athletics Australia, 2010; Athletics New Zealand, 2010). Each Australian and New Zealand junior competitor was tracked through to 31 December 2009 on their performance outcomes and their participation at senior global competitions or Commonwealth Games or otherwise. Only athletes who had competed in an individual event (i.e., not uniquely in a relay event) at a IAAF World Junior Championships were included. Australian athletes who competed for another country as an elite junior and subsequently competed for Australia as an elite senior and athletes who arrived into Australia as an elite senior and then represented Australia at a global competition or a Commonwealth Games were not included. There were no New Zealand athletes who fell into the two aforementioned categories. Where an athlete competed in two or more IAAF World Junior Championships (n = 27), they were only recorded as one individual athlete and their best performance at any IAAF World Junior Championships was used for the analysis. In the majority of the cases, the best performance was recorded in their second or third appearance at the IAAF World Junior Championships – but there were three exceptions.

Data statistical analysis

Data obtained were analysed in Excel to calculate frequency and percent. The following ranking order was used to categorise subsequent achievement for the Australian and New Zealand athletes: 1) global medallist; 2) global finalist; 3) global competitor; 4) medal at a Commonwealth Games; 5) competitor at a Commonwealth Games. A number of athletes who were categorised 1 – 3, and who also won a medal at, or competed at a Commonwealth Games (category 4 & 5), had only their highest achievement recorded. We did not differentiate between a competitor at a Commonwealth Games and a finalist at a Commonwealth Games as in some events all of the competitors were automatically (i.e., not having to qualify) finalists due to the small numbers taking part.

Results

Table 1 summarises the transitional characteristics of the New Zealand and Australian junior competitors who competed in individual events at IAAF World Junior Championships (1986 – 2006).

Successful seniors who were elite juniors

Australia had three times as many junior competitors, five times more junior medallists and seven times more junior finalists than New Zealand. The general population of Australia is five times that of New Zealand (Australia – 16.0 mil. in 1986). New Zealand had marginally more success than Australia turning its junior medallists and junior finalists into successful seniors: 32% of New Zealand junior medallists and junior finalists compared to 21% of Australian junior medallists and junior finalists. The number of junior competitors who did not make a final, but subsequently went on to be successful senior athletes was the same (4%) for each country. Of the four New Zealand athletes who did not make a final but went on to be a successful senior, only one achieved success at a global championship. The other three won Commonwealth Games medals in what were considered to be “weak” events at the time. Of the 10 Australians who were not junior medallists or junior finalists, three won a Commonwealth Games medal but did not compete for Australia on the global stage. The other seven all became global finalists, with three becoming global medallists. Overall from both countries, 43% of junior medallists went on to become a global medallist or global finalist, compared with 13% of junior finalists and just 3% of junior non-finalist competitors.
Table 1: Transitional characteristics for WJC athletes: Frequencies and percentages of Australian and New Zealand IAAF World Junior Championship (WJC) medallists, finalists and non-finalist competitors (1986 – 2006) who went on to compete at global competitions and had their highest level of success as a global medallist, global finalist, global non-finalist competitor, Commonwealth Games medallist, Commonwealth Games non-finalist competitor, or did not compete further.

<table>
<thead>
<tr>
<th></th>
<th>Australia &amp; New Zealand</th>
<th>Australia</th>
<th>New Zealand</th>
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<tr>
<td><strong>WJC Athletes</strong> (n=536)</td>
<td><strong>Global</strong></td>
<td><strong>CG</strong></td>
<td><strong>No Further Rep.</strong></td>
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<tr>
<td><strong>WJC Medalists</strong> (n=40)</td>
<td>7 M; 18%</td>
<td>9 F; 23%</td>
<td>8 O; 20%</td>
</tr>
<tr>
<td><strong>WJC Finalists</strong> (n=131)</td>
<td>6 M; 5%</td>
<td>9 F; 7%</td>
<td>16 O; 12%</td>
</tr>
<tr>
<td><strong>WJC Competitor</strong> (n=365)</td>
<td>3 M; 1%</td>
<td>5 F; 1%</td>
<td>33 O; 9%</td>
</tr>
</tbody>
</table>

* Four Australian athletes won two individual medals at one or two IAAF World Junior Championships – making a total of 39 individual medals won by 35 athletes.

M: Medallists (gold, silver or bronze)
F: Finalists not including medallists
O: Other non-finalist competitors
CG: Commonwealth Games
No Further Rep.: Did not represent the country at a senior level.
Successful seniors who were not elite juniors

Eleven Australian and three New Zealand athletes have become successful senior athletes despite not having competed at an IAAF World Junior Championships although eligible by age to do so. Of the three New Zealand athletes, two of them were global finalists, whilst the other was a Commonwealth Games medallist in what was considered at the time to be a “weak” event. Each of the 11 Australian athletes who were not an elite junior but went on to senior success was at least a global finalist, with four of them becoming a global medallist. Three of the global medallists also won Commonwealth Games medals, whilst five of the seven global finalists won a medal at a Commonwealth Games.

Years to make the transition from junior to successful senior athlete

Three New Zealand athletes who were global medallists, and a junior medallist or a junior finalist, took three years in one case and five years and six years in the other two cases (mean 4.6 ±1.5 y) to make the transition to a successful senior athlete. Ten Australian athletes had the same profile i.e., junior medallist or junior finalist progressing to become a global medallist. Their transition time was more varied (mean 6.8 ±4.6 y): two years n=2; three years n=2; four years n=1; eight years n=2; 12 years n=2; 14 years n=1. Three Australian athletes who became a global medallist, but were just a junior competitor, had transition periods of 6 years, 6 years and 8 years respectively.

Attrition rates of junior athletes

Amongst the athletes who were junior medallists and junior finalists who did not go on to represent their country at the senior level, New Zealand had a higher attrition rate (68%) than Australia (50%). The “overall” attrition rate, i.e., the number of junior competitors from each country who did not progress and represent their country as a senior was similar (Australia 71%, New Zealand 74%).

Discussion

Successful Seniors who were Elite Juniors

Junior medallists and junior finalists were more likely to become an elite senior than their peers who were not junior medallists or junior finalists. Proportionally, four times more junior medallists than junior finalists became global medallists and global finalists, giving rise to the accepted notion that an athlete has to be very good as a junior in order to be very good as a senior athlete. Only 3% of Australian and New Zealand junior athletes did not make a final at an IAAF World Junior Championships, but subsequently went on to achieve success at a global championship, giving further credence to the notion that junior success is a prerequisite for senior success. There was a similar pattern with athletes whose highest level of success as a senior athlete was winning a Commonwealth Games medal. More Commonwealth Games medallists were junior medallists rather than junior finalists or junior competitors, further emphasising that better performed juniors are likely to be successful senior athletes. Forty percent of each country’s junior medallists went on to become a global medallist or global finalist, which was more favourable than the 34% of all junior medallists from 1986 – 2004 who went on to become global medallists or finalists (HOLLINGS & HUME, 2010), showing that New Zealand and Australia had more success in progressing junior medallists and junior finalists though to successful seniors than most other countries in the world.

Successful seniors who were not elite juniors

The 11 Australian and three New Zealand athletes who became successful senior athletes despite not having competed at an IAAF World Junior Championships although eligible by age to do so, could have been either late comers to the sport or they did not show sufficient talent as a junior. Given the same 11 Australian athletes produced four global medallists and seven global finalists between them, it is a demonstration that athletes who are sub-elite juniors can become successful senior athletes.
In New Zealand’s case, the three athletes produced two global finalists and one Commonwealth Games medallist, hence, jointly the Australian and New Zealand sub-elite Juniors produced four global medalists, nine global finalists and one Commonwealth Games medallist. However, their achievements are overshadowed by the junior medallists and finalists who produced 13 global medals, 18 global finalists and eight Commonwealth Games medals. National federations that have sub-elite Juniors becoming successful senior athletes are placed in an invidious situation. The question as to whether a broader scope programme to identify the as yet sub-elite juniors is promoted must be matched with the knowledge that many of the sub-elite juniors will not progress to senior athletics. Expend resources on a group where there is an unknown certainty of a return on the investment is questionable. National federations need to accept that sub-elite juniors becoming successful seniors are a “bonus” to the federation. However, once a sub-elite junior starts to demonstrate a degree of performance that matches or exceeds the performance of his/her elite junior peers, then they need to be accepted into a programme where they will enjoy the same benefits and support as their elite junior colleagues.

**Years to make the transition from junior to successful senior athlete**

It took from two to 14 years for junior medallists or junior finalists to make the transition to become a global medallist. The Australian athletes had a wider range (2-14 years) than the New Zealand athletes (3-6 years). Notwithstanding, the mean of the range was greater than one single Olympic Cycle of four years, indicating that in many cases the junior medallists or junior finalists persevered until they reached the zenith in their sport. Athletes were probably also supported by their national federation throughout this extended transition period by key support programmes being in place. Whether it was the athlete’s personal ambition or the national federation’s support programmes or a combination of both that enabled these talented athletes to achieve global success requires further investigation.

National federations are faced with the dilemma of gauging how long they continue to support an elite junior athlete. The time period can be quite long before the full potential of the athlete is realised. Whether to terminate support or not during the transition period is a difficult decision. Federations therefore need robust performance evaluation procedures in place to ensure that the appropriate decision is made.

**Attrition rates of junior athletes**

The high attrition rate of successful junior athletes who won medals or made a final at the IAAF World Junior Championships but were never seen again on the global stage is a concern. More than half (in New Zealand’s case 68% and in Australia’s case, 51%) of athletes who had shown some outstanding ability by being a junior medallist or junior finalist, did not go on to be a representative senior athlete. Compared to the attrition rate (54%) of all junior medallists from 1986 – 2004 (HOLLINGS & HUME, 2010), New Zealand’s attrition rate of junior medallists was 60% and Australia’s was 37%. In New Zealand’s case the higher attrition rate is probably due to the low number (n=5) of junior medalists, compared to the larger number (n=35) for Australia. The general attrition rate must also be of concern. In New Zealand’s and Australia’s cases, 70% of athletes who competed at an IAAF World Junior Championships did not progress to the senior representative level. Therefore, given the limited resources available, it may be more favourable to concentrate the resources on the junior medallists and junior finalists who “retired” from the sport been retained. There may be many reasons (e.g. social, psychological, economic, educational, career, and
lack of competition opportunity issues) why many of these elite junior athletes have not continued to progress as would be expected. Further investigation needs to be undertaken to determine whether the cause is based upon performance output criteria or upon environmental issues or a combination of the two.

**Strategies to help the transition from junior to successful senior athlete**

Given there was a higher probability of junior medallists and junior finalists becoming an elite senior than would a junior non-finalist, competitor or athlete coming into the sport having not competed at the IAAF World Junior Championships, it is suggested that New Zealand’s and Australia’s strategies to produce successful senior athletes, should be based on: 1) producing more junior medallists and finalists; 2) retaining juniors in the sport through to the senior grade; 3) concentrating resources on junior medallists and junior finalists.

**Conclusions**

There is a higher probability of medallists and finalists in the IAAF World Junior Championships becoming elite seniors than junior non-finalist competitors or athletes coming into the sport having not competed at the IAAF World Junior Championships. The attrition rate is four times greater amongst junior non-finalist competitors and three times greater amongst junior finalist than amongst junior medallists. Given the high attrition rate of elite junior athletes, particularly those who have won medals or made finals at a World Junior Championships, together with evidence that medallists and finalists, rather than just competitors, are more likely to succeed as senior athletes, research is needed to ascertain why some elite junior athletes make the transition to become successful senior athletes, while others of similar ability do not. Qualitative data collected through semi-structured interviews with current and past successful elite junior athletes should help identify factors that have facilitated or thwarted successful transition to the senior level. Quantitative trend analyses for the successful transition of Australian and New Zealand juniors to senior athletes will better inform the national athletics’ federations and other agencies in identifying those junior athletes who have the ability, from a performance perspective, to progress to being a successful senior athlete.
REFERENCES


Introduction

The following is the third bibliography in NSA dealing with the horizontal jumps. The first was published in NSA 3/1989, the second in NSA 3/1991. An exclusive triple jump bibliography appeared in NSA 4/2004, and the first dedicated solely to the long jump was published in two parts in NSA 1 and 2/2005.

The present bibliography contains 88 articles and books about the horizontal jumps from the years 2004 to the present. It is divided into three sections:

1. Long jump (41 documents)
2. Triple jump (34 documents)
3. Horizontal jumps in general (13 documents)

The following long jump articles deserve particular attention:

DAPENA (2005) points out important basic facts of the long jump. For example, a long jumper needs to have high horizontal velocity at the end of the approach. Then he/she needs to generate vertical velocity during the take-off phase. However, this is not possible without sacrificing some horizontal velocity; the larger the gain of vertical velocity, the larger the loss of horizontal velocity. Therefore, a compromise is needed to the extent that the gain in vertical velocity should be rather limited. Empirical data shows that the optimum take-off angle is roughly around 20°, which implies a vertical velocity about 40% of the horizontal at the end of the take-off.

However, MACKENZIE (2004, 2005) has proposed that long jumpers should use a steeper takeoff angle, up to 45°. According to Dapena, this would only be possible if long jumpers were really able to maintain their velocity while they make large changes in its direction during the take-off phase. However, they are not able to do so: There is a loss of velocity as the athlete changes the direction of the body’s motion, and the loss of velocity becomes greater with larger changes in direction. Based on this, the author shows that Mackenzie’s results do not fit with data from elite long jumpers obtained using the best methods currently available. The discrepancies may be due to inaccuracy in Mackenzie’s calculations. Another problem might be Mackenzie’s predominant use of novice high school students as subjects. Dapena shows (a) that the energy losses during the take-off phase are larger than what Mackenzie believes, and (b) that larger changes in direction increase the energy losses. The implication is that a large change in the direction of motion of the centre of mass (CM), takes a toll on the total amount of velocity available at the end of the take-off. In turn, this implies that the optimum angle will have a compromise value lower than 45°. Dapena also shows that it is
unreasonable to expect long jumpers to use steep take-off angles, because such angles would require them to reach heights that are way beyond their capabilities.

Another interesting article comes from JONES (2008), who is convinced that the last stride in Bob Beamon’s 1968 world record jump was, contrary to the recommendations found in most of the current literature, longer than the penultimate, or second to last stride. Jones bases his opinion on evidence from file/video and biomechanical analysis. The question arises: Why does most of the current literature recommend a shorter last stride, when in fact a world record that stood for 24 years indicates a stride pattern that is the opposite? Although the recommendation to a shorter last stride biomechanically makes sense, the product of Beamon’s approach speaks for itself. Beamon, and the current world record holder, Mike Powell, too, are simply using a different technique of creating optimum forces to generate improved performance. Theory explains that in order to generate vertical velocity without adversely affecting the horizontal component, the CM should be lowered slightly prior to take-off. In the case of Beamon, he was able to achieve this by a shortening of the penultimate stride. This shortening also sets up the potential to drive or push into the take-off, which in turn allows an athlete to continue that drive as he or she runs over his or her take-off leg with a spring-like motion. Beamon was able to accomplish this very effectively. So it appears that Beamon and Powell are on to something different that has not been observed in other world-class jumpers: a shortening of the penultimate stride which allows for a lowering of the CM, combined with an exaggerated drive or push into the take-off stride. In other words, both start their take-off with the penultimate stride and complete the launching process with a longer, or close to the same length, last stride that sets up the support leg to act as a spring – very resilient, with limited collapsing, and short contact time. Jones concludes by emphasising that all athletes are unique and there is no magic formula that works for everyone. Individual differences need to be considered when analysing a model and designing a training programme for optimum results.

The placement of the planting foot in relation to the long jumper’s body is also covered by MACKENZIE (2008). He has found out that the longest jumps result from the planting foot being placed around 35° to 40° in front of the body. Coaching long jumpers to plant their feet under their bodies or even “not far out in front” of their bodies, while trying to “run off the board” in the take-off is shown to be incorrect because it results in poorer distances. The result is a meter or more loss with incorrect technique.

As far as the triple jump is concerned, the following articles are particularly worth reading:

GRAHAM-SMITH & LEES (2000) deal with the ratio of the hop, step and jump phase distances that describes the triple jumper’s distribution of effort in any given jump. They point out that there is widespread agreement that there is no single optimal distribution of effort that suits all triple jumpers. Research has indicated that individual athletes have their own optimal phase ratios dependent on factors such as speed, strength, technique, anthropometric measures and psychological profile. As these factors can also be related to temporal changes, i.e. training age, growth and experience in the event, there may well be a dynamic nature to the optimal distribution of effort. For example, novice athletes may have an optimum phase ratio that is likely to be different from that of an elite athlete jumping in excess of 17m.

The arm movements of female triple jumpers were examined by MILADINOV & BONOV (2004). Most, if not all, elite women triple jumpers use opposite arm movements, known as the single arm technique, with individual peculiarities between athletes. Against this background, the main purpose of the study conducted was to determine the effect of ‘mixed arm movements’, a combination of single and double arm techniques, in which the hop and the transition to the step are performed with opposite movements of the arms and legs and then, during the step, the arms are returned
back together so that the jump is performed with both arms swinging forward. On the basis of a one-year long pedagogical experiment with a female triple jumper (personal best of 13.78m) to introduce the change in technique described, the authors conclude that the change led to a significant improvement in performance (to 13.98m) and predict the technique will be more widely used in the future.

The study by WILSON, SIMPSON & HAMILL (2009) aimed at determining the effectiveness of training drills in replicating the lower extremity coordination patterns used during the triple jump. Three-dimensional kinematic data and synchronised ground reaction force data were collected during the hop-step transition of a triple jump and four related training drills. Relative motion plots and a modified version of the vector coding technique were used to quantify the coordination patterns of the lower extremities. Differences were observed in the coordination patterns between the triple jump and static drills, but not between the triple jump and dynamic drills, and these differences were mainly in the swing (free) leg. The results suggest that if the primary purpose of the training drills is to replicate the movement patterns used in the triple jump, then dynamic drills are more effective than static drills. In addition, coaches should focus on the use of the free leg during these training drills so that the coordination patterns more closely replicate the triple jump.

The improvement of long jump and triple jump facilities is the topic of the article by LINTHORNEe (2005). He believes that plasticine indicator boards (the boards upon which the plasticine is applied) should be a different colour from the white takeoff board. While the white colour of the take-off board is mandated by the rules, there is no such requirement for the indicator board. The idea is that if both boards are white, it is more difficult for the horizontal jumper to correctly target the takeoff board, and this seems to be borne out by the higher number of fouls committed in meets where the boards are both white.

This bibliography has been compiled by using
- SPOLIT, the sports literature database of the Federal Institute of Sport Science (BISp) in Cologne, Germany (www.bisp-datenbanken.de, free access), and
- SPORTdiscus, the database of the Sport Research and Information Centre in Ottawa, Canada (www.sirc.ca, no free access).

In addition, some of the articles were found by a “free search” in the Central Library of Sports Science at the German Sports University in Cologne and others are from the private library of the author.

Readers interested in obtaining one or more articles from this bibliography should contact:

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As always, this bibliography does not claim to be complete but rather is a selection of publications considered particularly interesting for NSA readers.

Bibliography

1 Long jump

Baarck, K.
Weitsprung im Siebenkampf: Der Siebenkampf-Bundestrainer analysiert die Weitsprungtechnik von drei deutschen Siebenkämpferinnen aus drei verschiedenen Altersklassen [The long jump in the heptathlon: The German national heptathlon coach analyses the long-jump technique of three heptathletes from three different age groups]
Leichtathletiktraining, Münster, 17, (2006), 7, pp. 16-21

On the basis of picture sequences, the long jump technique of the German heptathletes Claudia Tonn (long jump PB: 6.60 m, heptathlon PB: 6,373 points), Julia Mighty (long jump PB: 6.37 meters, heptathlon PB: 6,066 points) and Diana Rach (long jump PB: 5.95 meters, heptathlon PB: 6,807 points) is analyzed.
Several studies have stated that performance in long jump is directly related to different mechanical and muscular mechanisms that occur from the touchdown to the take-off phase. It is well known that the greatest gain in vertical velocity is during the compression phase, which is associated with a loss of horizontal velocity. This paper aims to report the three-dimensional variables that affect the touchdown to take-off phase for elite jumpers in a situation of real competition, and to examine the relationships between these variables in order to understand how they affect their performances.

Dapena, J.  
Steep takeoff angles near 45 degrees are not reasonable for the long jump  
Track Coach, Mountain View, (2005), 172, pp. 5481-5485

A long jumper needs to have a large horizontal speed at the end of the run-up. Then the athlete needs to generate vertical speed during the take-off phase. Ideally, the athlete would like to generate the largest possible amount of vertical speed without losing any horizontal speed. However, this is not possible, and some horizontal speed will have to be sacrificed while generating vertical speed. The larger the gain of vertical speed, the larger the loss of horizontal speed. Therefore, a compromise is needed between the gain of vertical speed and the loss of horizontal speed. Conventional coaching wisdom holds that the gain in vertical speed should be rather limited. The optimum takeoff angle is assumed to be roughly around 20°, which implies a vertical speed about 40% of the size of the horizontal speed at the end of the takeoff. The basis for this assumption is empirical: All long jumpers use takeoff angles near 20°. However, Mackenzie (2004, 2005) has recently proposed that long jumpers should use a steeper takeoff angle. According to him, the change in the energy of the athlete is minimal during the takeoff phase, both in the long jump and in the high jump (Mackenzie, 2003). In essence, this means that the total size of the athlete's speed (horizontal and vertical speeds combined) changes very little during the
takeoff: The athlete is able to change the direction of motion of the body from horizontal to a diagonal upward angle with little loss in the total amount of speed. Mackenzie assumes that this will hold true for large changes in direction, and thus concludes that it would be advantageous for long jumpers to produce the largest possible takeoff angles, up to 45°. If long (and high) jumpers were really able to maintain the size of their speed while they make large changes in its direction during the takeoff phase, it would indeed be advisable for long jumpers to strive to use the steepest possible takeoff angle, up to 45°. The problem is that they are not able to do so: There is a loss of speed as the athlete changes the direction of the body’s motion, and the loss of speed becomes larger with larger changes in direction. Based on this, the author shows that Mackenzie’s results do not fit with data from elite long jumpers and high jumpers obtained using the best methods currently available. The reason for the discrepancies is not clear. Maybe they are due to inaccuracy in Mackenzie’s calculations. He seems to calculate the position of the body center of mass (c.m.) through a direct estimation on a photograph, while the standard methodology requires the measurement of the positions of about 20 anatomical body landmarks in the photo, and then calculating the position of the c.m. from the positions of the landmarks. Since the speed of the c.m. is calculated from the changes in the position of the c.m., Mackenzie’s rough method for the location of the c.m. may result in large errors in the calculated speed of the c.m. Another problem might be Mackenzie’s predominant use of novice high school students as subjects. The present paper consists of two parts. In Part 1, data from elite long jumpers and high jumpers are used to show (a) that the energy losses during the takeoff phase are larger than what Mackenzie believes, and (b) that larger changes in direction increase the energy losses. The implication is that a large change in the direction of motion of the c.m. takes a toll on the total amount of speed available at the end of the takeoff. In turn, this implies that the optimum angle will have a compromise value lower than 45°. In Part 2, the author shows that it is unreasonable to expect long jumpers to use steep takeoff angles, because such angles would require them to reach heights that are way beyond their capabilities.

Florczak, U.  
*Deutsche Weitenjäger im Technik-Check*  
[An examination of the technique of the best German long jumpers]  
*Leichtathletiktraining, Münster, 19, (2008), 8, pp. 28-33*  
The picture sequences in this article show the winning jumps of the current German long jump champion Sebastian Bayer and the German indoor champion in the long jump in 2008, Christoph Stolz. The discussion of the picture sequences is divided into the following sections: 1. Approach run, 2. take-off preparation, 3. take-off, 4. flight phase and landing.

Florczak, U.; Killing, W.  
*Sebastian Bayers 8,71-Meter-Flug: Weitspringer Sebastian Bayer wurde mit 8,71 Metern Hallen-Europameister*  
[Sebastian Bayer's 8.71-meter flight: long jumper Sebastian Bayer won the European Indoor title]  
*Leichtathletiktraining, Münster, 20, (2009), 5, 12-16*  
The authors analyze the 8.71-meter long jump by Sebastian Bayer at the European Indoor Championships 2009 in Turin, with which he won the title of the European indoor champion and at the same time set a new European indoor record, based on a picture sequence of this jump. The jump is compared with Sebastian Bayer’s winning jump at the German Championships in 2008.

Großkopf, N.  
*Vergleichende Analyse des sporttechnischen Könnens von Athletinnen mit unterschiedlichem Kaderstatus in der Disziplin Weitsprung*  
[A comparative analysis of the sport-technical skills of female athletes with different squad status in the long-jump event]  
The aim of this study is to investigate the technical skills of various female athletes from different squads using technically relevant kinematic parameters, to compare them with a model and to evaluate them.
weight again and resume a normal running gait. Once a competent level of take-off mechanics has been established, the best way to develop the long jump action is by way of a simple stride jump (similar to a hurdle action) into the long jump pit. This can be done off an 8-10 stride run in and gradually lengthened by two strides at a time.

Huber, A.; Elster, H.; Heger, H.; Kramer, S.; Wank, V.
Trainingsbegleitende Leistungsdiagnostik im Weitsprung [Performance diagnostics during long-jump training]

As part of a complex project for performance diagnostics, a platform for training-accompanying performance diagnostics for the jumping-event squad athletes was installed at the Olympic Training Centre in Stuttgart. For this purpose, a test battery including different exercises was assembled. In addition to traditional exercises such as 30-m sprint from a flying start, five hops with the right and left leg, bounding runs consisting of 10 jumps, drop jump, countermovement jump and clearing action with the barbell, performance parameters such as jump distances, run-up and take-off velocities, as well as additional information for biomechanical movement analyses of long jumps from different run-up lengths were recorded and reported back to the athletes. Thus, the tests could be used as the basis for targeted interventions in technique training.

Jones, M.
The last three-to-five strides in the long jump approach
Track Coach, Mountain View, (2008), 182, pp. 5814-5817

Based on film and videotape analysis, the author is convinced that Beamon’s last two strides were contrary to the recommendations found in most of the current literature, which is that the last stride is shorter than the penultimate, or second to last stride. He is of the opinion that Beamon’s penultimate stride was shorter than his last stride, which has been confirmed through file/video and biomechanical analysis. The question arises: why does most of the current literature recommend
a shorter last stride, when in fact a world record that stood for 24 years indicates a stride pattern that reveals a shorter penultimate stride? There are other examples of articles that suggest a shorter last stride, but these are representative. It should not be argued that these recommendations are incorrect because biomechanically they make sense, as does the Beamon approach. Beamon, and the current world record holder, Mike Powell, 29ft. 4.5 in., are simply using a different technique of creating optimum forces to generate improved performance. Theory explains that in order to generate vertical velocity without adversely affecting the horizontal component, the center of gravity should be lowered slightly prior to takeoff. In the case of Beamon, he was able to achieve this by a shortening of the penultimate stride. This shortening also sets up the potential to drive or push into the takeoff, which in turn allows an athlete to continue that drive as he or she runs over his or her takeoff leg with a spring-like motion. Beamon was able to accomplish this very effectively. So it appears that Beamon and Powell are on to something different that “has not been observed in other world class jumpers.” A shortening of the penultimate stride which allows for a lowering of the center of gravity, combined with an exaggerated drive or push into the takeoff stride. In other words, both start their takeoff with the penultimate stride and complete the launching process with a longer, or close to the same length, last stride that sets up the support leg to act as a spring – very resilient, with limited collapsing, and short contact time. It is also important to note the contribution of the free leg and arms towards the generation of optimum forces (limb acceleration with corresponding deceleration), as well as the timing of these movements. So it appears that all athletes are unique and there is no magic formula that works for everyone. There are fundamental principles that should be considered, including running speed, limb movements and timing, lowering of the center of gravity, and other variables including flight, landing, training, etc., that affect how an athlete performs a given task. The long jump is like any other track and field event, in that you rarely see athletes who are identical in performance technique. In other words, everyone has to find what works the best for him/her. That is not to say that world class performances should not be studied and emulated, but individual differences need to be considered when analyzing a model and designing a training program for optimum results.

Katzenbogner, H.
Lernen und Üben des Schrittweitsprungs
[Learning and practising the stride long jump]

Leichtathletiktraining, Münster, 17, (September/October 2007), 9+10, pp. 14-21

In the long jump, jumping distances are especially dependent on a run-up as fast as possible and a vigorous take-off. Also necessary are an effective body posture during flight and landing. The suitable long-jump technique for children is the stride jump, which should be developed using the following steps: 1 General run-up and take-off exercises, 2. distance-oriented jumping exercises, 3 flying experiences.

Killing, W.
Saison-Periodisierung eines Springers
[Seasonal periodisation of a jumper]

Leichtathletiktraining, Münster, 18, (September/October 2007), 9+10, S. 22-29 (part 1); 19, (2008), 2/3, pp. 22-27 (part 2)

The author describes the seasonal periodisation of a 17-year-old long jumper with a personal best of 6.70 m and a target distance of 7.00 m. It is a double periodisation pattern, because in the speed-strength events this pattern has proven advantageous for the development of form.

Killing, W.; Knapp, U.
Der Jahresweltbeste im Weitsprung
[The best long jumper of the year]

Leichtathletiktraining, Münster, 21, (2010), 11, pp. 4-11

With a jumping distance of 8.47 m, the German long jumper Christian Reif is the best long jumper in the world for the year 2010. With this jump, he also won the gold medal at the European Athletics Championships 2010 in Barcelona. In this paper, his training is described in detail.

Killing, W.; Schulz, J.; Mendoza, L.
Sebastian Bayer – Weitspringer des letzten Versuchs
[Sebastian Bayer – long jumper of the last attempt]

Leichtathletiktraining, Münster, 21, (2010), 2+3, pp.80-67
Due to the susceptibility to injury of his take-off foot jump, the German long jumper Sebastian Bayer, who with a jump distance of 8.49 m is the German and European long-jump record holder for the year 2009, does not take part in many competitions. His susceptibility to injury also explains why Sebastian Bayer in competition concentrates on only a few attempts. It is also remarkable that Sebastian Bayer several times in his career has achieved his best performances in the last attempt. Sometimes, the distances achieved in these attempts were considerably above the level of his previous attempts. That is why Sebastian Bayer’s coach (Joachim Schulz) and the athlete himself have decided to make a first “safety jump” and to wait then for the strong final attempts. Against this background, the author describes both Sebastian Bayer’s training and presents a technical analysis of his winning jump at the German Championships in 2009. In addition, important biomechanical elements of the long jump are explained (starting speed, vertical speed, balance and speed, lowering of the CG, and take-off preparation).

Knapp, U.
Das Einmaleins des Weitsprungs [Long jump basics]
Leichtathletiktraining, Münster, 19, (2008), 9+10, pp. 28-34
An optimal long-jump performance is possible only on the basis of a very well developed sprint and run-up ability, and on a highly developed jumping strength. Consequently, these components must be developed in training as a priority. The technical training in the long jump is primarily a learning-oriented training with the aims to improve the neuro-muscular interaction.

Knapp, U.
Die Jüngste flog am weitesten [The youngest athlete achieved the longest jumping distance]
Leichtathletiktraining, Münster, 22, (2011), 8, pp. 4-13
Using picture sequences, the different implementations of the running- and the hang-style long jump by the three medal winners at the German Junior Championships 2011 is presented. The female long jumpers are: Lena Malkus (17 years, PB: 6.70 m, 1st place at the German Championships in 2011), Sos-
use of the swing leg and a two-legged landing. Particularly jumps from higher spots can help children to learn the rough form of the long jump.

Mackenzie, R. J.  
**A reexamination of the optimum takeoff angle in the long jump**  
*Track Coach, Mountain View, (2005), 174, pp. 5561-5569*  
In this study, earlier data was reexamined and found to show anomalously high speed retention with increased takeoff angle in the long jump. This led to the prediction of a theoretically optimal, even if unattainable, jump that was too high – around 42°. New data was taken to see if speed falls off significantly with increased takeoff angles, as Dapena suggested in *Track Coach #172, Summer 2005*. It was found to do so. This greatly affected the maximum practical takeoff angles that should be advocated for long jumpers. Significant variations among jumpers were observed and it was found that it can be important to test an individual jumper’s performance to determine that individual’s optimum takeoff angle. Recalculated optima for experienced jumpers ranged from 24° to 33°. Low optimum takeoff angles resulted from excessive speed losses with increased angles. This was shown by all of the beginners. Reasons why the speed retention differences exist among various jumpers were not examined in this study.

Mackenzie, R. J.  
**A test of the applicability of the depth jump force pattern to the long jump takeoff**  
*Track Coach, Mountain View, (2008), 184, pp. 5873-5876*  
The previously published depth jump pattern of forces [Track Coach #183, #184] was tested for one of the volunteers in the depth jump and leg press research. The force patterns from the depth jump model accurately predicted the takeoff velocity and the distance of the center of mass travel in the long jump for all eight of her trial jumps. The experience of this one athlete suggests that the pattern of forces utilized by athletes in the depth jump is very similar to the pattern used in the long jump takeoff and that force models can be constructed for athletes that will fairly accurately predict their performance under varying conditions.

Mackenzie, R. J.  
**Why the long jump takeoff must be planted far in front of the body**  
*Track Coach, Mountain View, (2008), 184, pp. 5877-5884*  
Even though it sounds paradoxical, it is shown that in order to go farthest in a forward direction, a force must push up and back in the long jump. This is proven by reasoning, by theory, and by examination of film. Four models of force application are used that represent average force patterns, below-average force patterns and superior-to-any-observed patterns of force in the takeoff. Using numerical iterations, each of the models reveals that the longest jumps result from the planting foot being placed around 35° to 40° in front of the body. Coaching long jumpers to plant their feet under their bodies or even “not far out in front” of their bodies, while trying to “run off the board” in the takeoff is shown to be incorrect because it results in poorer distances. The result is a meter or more loss with incorrect technique.

Makaruk, H.  
**Adjusting the training of experienced long jumpers**  
*New Studies in Athletics, Aachen, 22, (2007), 4, pp. 11-17*  
Near the end of an athlete’s career, the adaptation capacities of the organism decline. Increasing the training load, or even maintaining the current level, becomes difficult and it is imperative to find new quality solutions. The aim of this study was to identify a training structure that would make it possible for long jumpers to extend their careers. Data characterising the training of elite long jumpers was analysed from two points of view: informative (the type of exercises implemented) and energetic (the type of energy sources). The results show that it is indispensable to maintain a high level of maximum intensity loads and, unexpectedly, contradict the common belief that the training of experienced athletes should be mainly specialised. It is suggested that experienced long jumpers should make regular use of “oriented” loads, which are structurally and functionally similar to their event but not as close to the performance movement as “special” exercises.
jumpers was videotaped (250 Hz) from the right side of the runway. Ground reaction forces were also recorded (1 kHz). The forward-backward component of the force platform was set parallel to the runway. The plantar-flexors and knee extensors exerted great negative JP during the first phase and positive JP during the second phase, and, thus, they functioned as great mechanical energy absorbers in the first phase and as mechanical energy generators in the second phase. The hip joint exerted extension torque immediately after touchdown and supported the body against the impact force and contributed to an increase in vertical CG velocity by pivoting the body over the takeoff foot during the first phase. There were no relationships of the magnitude of the peak joint torques of the takeoff leg and angular impulse and work of the takeoff leg joint torques to horizontal CG velocity at touchdown or jumping distance.

Nunn-Cears, G.
Long jump is not a rocket science
The long jump is a relatively simple discipline that can be divided into five phases: 1. Run-up, 2. take-off preparation, 3. take-off, 4. flight phase, and 5. landing. Speed, precision, power and technique play an important role in the long jump. The author gives a general overview of the technique of the long jump with particular emphasis on the run-up, the flight phase, and the landing. With regard to the flight phase, the hang- and the hitch-kick technique are described in more detail.

Panoutsakopoulos, V.; Kollias, I. A.
Biomechanical analysis of sub-elit performers in the women’s long jump
Biomechanical analysis of sub-elit competitions enriches the pool of knowledge about technique in athletics events. The purpose of this study was to describe the kinematics of the approach and take-off of competitors in the women’s long jump competition at the 2006 European Cup 1st League-Group B. It was found that all the participants utilise the “longer penultimate-shorter last stride” ratio previously described for top-level performers. All but one increased their horizontal
of a long jumper. In this context, the organisation of the final three steps before the takeoff is critical. The rhythm of these steps should be “short – long – short” and the touchdown for the takeoff should be quick with the knee being almost stretched and the takeoff foot performing an actively gripping backward and downward movement on the whole sole of the foot. These two elements are therefore also the author’s main points of concentration when he describes the jumping technique of the German long jumpers Nils Winter (8.03 m) and Christian Böhm (7.23 m) based on picture sequences.

Panoutsakopoulos, V.; Papaakovou, G. I.; Katsikas, F. S.; Kollias, I. A.
3D Biomechanical analysis of the preparation of the long jump take-off

The purpose of the present study was to describe the kinematics of the long jump approach and take-off and their effect upon the flight and the landing. Three video cameras were used to capture the last two strides of the approach, the takeoff phase, the flight and the landing of the eight jumpers participating in the men’s long jump competition at the 2006 European Cup 1st League-Group B Event in Thessaloniki, Greece, on 17 June 2006. A 3D-DLT analysis was conducted for the two final strides of the approach and the takeoff and a 2D-DLT analysis for the landing. Results indicate that all participants seemed to utilise the “longer penultimate-shorter last stride” ratio. Two types of approach were revealed, the “straight forward” and the “imbalanced”. These approach types did not affect the long jumping technique, but the stride angles of the last stage of the approach were highly correlated (r > .70, p < .05) with the placement of the take-off foot on the board and with the lateral flight path of the Body Centre of Mass. Verf.-Referat

Pottel, R.
Deutschlands beste Weitspringer [Germany’s best long jumpers]
Leichtathletiktraining, Münster, 15, (2005), 12, pp. 14-19

The main criterion for a good long-jump performance is a high run-up speed. To be able to translate this velocity into distance is the technical difficulty in the long jump and makes the skill
The author shows how the methodical network of long-jump exercises can be used to learn and improve the hang-style of the long jump from a competitive run-up. The prerequisites are the ability to perform the different exercises of the running and jumping ABC in a controlled way and with correctly positioned body axes, as well as the ability to perform sprint and acceleration runs with high knee lift and a high centre of gravity.

Sustova, E. V.
Povysenie effektivnosti obucenija technike pryzka v dlini na osnove realizacii specificheskih koordinacionnych sposobnostej [The increase of the effectiveness of technical training in the long jump on the basis of the development of the specific coordinative abilities]
Teorija i praktika fiziceskoj kul’tury, Moscow, (2006), 4, pp. 35-39
According to the author, the dynamic balance and the spatial differentiation ability are the most important coordinative abilities for increasing the long-jump performance.

Schrader, A.
Das methodische Übungsnetz Weitsprung: Das methodische Übungsnetz verbindet Vielseitigkeit mit Zielorientierung [The methodical network of long-jump exercises combines versatility and goal-orientation]
Leichtathletiktraining, Münster, 21, (2010), 2+3, pp. 14-21
By using observation sheets, video cameras and light barriers when teaching the long jump in the upper forms of grammar schools, the students will be enabled to improve their long-jump performances on the basis of “self-determined movement criteria” (run-up, take-off, flight and landing).

2 Triple jump

Akinsanya, F.
Measuring a triple jump run up
The Coach, Peterborough (England), (January/February 2002), 8, pp. 49-52

Getting a triple jump run-up worked out accurately is not as complicated as it might seem. All it takes to produce one that will ensure you hit the board just right is a bit of careful preparation. If you are working with young athletes it’s a good plan to base run-up lengths on the formula of one stride for every year of age. For example a 14-year-old runs off 14 strides, a 15-year-old off 15. Athletes above that age work on a 16-stride run. In the early stages, much shorter runs may be beneficial until the basics have been mastered. There are two ways to get the initial measurement – using long walking strides or exaggerated running strides. Coaches may want to get their athletes to try both and see which works best for them.

Bartschat, E.; Hutt, E.
Mit Hop, Step und Jump in den Fokus: Der Dreisprung ist eine technisch anspruchsvolle Disziplin [Getting into the focus with hop, step, and jump: The triple jump is a technically complex event]
Leichtathletiktraining, Münster, 20, (2009), 4, 24-32

The authors describe the technique model of the triple jump taking into account the run-up, hop, step, and jump. In this basis, they analyze the jumps of the German triple jumpers Kristin Gierisch (13.65 meters at the German Indoor Championships in 2009 in Leipzig) and Katja Demut (14.06 meters at the German Indoor Championships in Leipzig) on the basis of picture sequences. In addition, the article includes information about the training contents and training planning of these athletes.
The jumping drills performed by the athletes include bunny hop, single leg jumps and bounding. Several drills that he likes to use that are very helpful for the triple jump are categorized into pit entry drills and phase work drills. He thinks working on the grass as much as possible, doing cone drills and maintaining speed through all phases has helped the jumpers be successful.

Graham-Smith, P.; Lees, A. Developmental aspects of the triple jump


The breakdown of the triple jump performance into hop, step and jump phase distances has helped to examine how an athlete distributes his/her effort and to identify areas of strength and weakness. The contribution of each phase to the overall performance is determined by expressing each phase distance as a percentage of the effective distance. The three phase percentages form a phase ratio that describes the athlete’s distribution of effort in any given jump. There is widespread agreement that there is no single optimal distribution of effort that suits all triple jumpers. Research has indicated that individual athletes have their own optimal phase ratios dependent on factors such as speed, strength, technique, anthropometric measures and psychological profile. As these factors can also be related to temporal changes, i.e. ‘training age’, growth and experience in the event, there may well be a dynamic nature to the optimal distribution of effort. For example, novice athletes may have an optimum phase ratio that is likely to be different from that of an elite athlete jumping in excess of 17 metres.

There has been very little research investigating the developmental aspects of phase distances and ratios. One of the few reports is an early study by Verhoshanski (1961), who noted a regularity in the changes that take place in each phase distance as the total distance increased. He suggested that to progress in the men’s event from 12 to 14 metres, increases in the step distance and to a lesser extent the jump distance were required. From 14 to 16 metres, where the ‘athlete’s mastery of sprinting improves’, performance is raised through increases in the hop distance, while the jump tends to stabilise. Finally, improvements from 16 to 18 metres are said to be the result of...
increases in the jump distance, brought about through improvements in balance and the maintenance of speed during the transition to the final phase. However, considering that it takes several years for an athlete to raise their performance by 2 metres, these intervals are probably too broad and the suggestions too general. Closer examination of the trends or changes in phase distances and ratios are required to be more specific. The aim of this study was to investigate developments in approach speed and phase distances with respect to increases in performance and to examine the existence of ‘dynamic’ optimal phase ratios. Method: This study examined approach speed and phase distances data from all triple jump performances at major domestic competitions in Britain from June 1991 to August 1996. From a total of 343 jumps, 156 were performed by female athletes and 187 by males. The levels of ability ranged from Junior and Senior British National squad members to world class performers. In the women’s triple jump, the effective distance ranged from 11.73 to 14.94 metres, while in the men’s event performances ranged from 14.44 to 17.43 metres. Approach speeds were measured using photoelectric timing devices positioned at 11, 6 and 1 metres from the front of the board. Split times for the two 5-metre intervals were then converted to the average speeds over 11 to 6 metres and 6 to 1 metres. The average of these two speeds was then taken to reduce errors caused by athletes breaking the light beams early with the hands, arms or legs. This is termed the average speed from 11 to 1 metres. Video recordings of the entire movement sequence were used to measure the phase distances. Markers placed at 1m intervals on both sides of the track gave a visual reference scale in which to locate the position of the toe at mid-support in each landing. The displacement of the toe from the front of the take-off board was measured to the nearest centimetre in the hop take-off, and to the nearest 5 cm in the step and jump take-offs. The definitions of the hop, step and jump distances and their relationship with the ‘official’ and ‘effective’, or ‘actual’ distances are those given by Hay (1992). The sum of the hop, step and jump distances equals the effective distance, which is also equivalent to the sum of the official distance and the toe-to-board distance. The hop distance therefore contains the toe-to-board distance in its measurement. The phase distances were then expressed as percentages of the effective distance. Conclusions: This report has examined the trends in approach speed and phase distances with developments in performance. As with other studies that have examined wide ranges of performance, strong positive relationships have been found between speed and phase distances with the effective distance. However, noticeable stepwise developments are observed as distance increases. This supports the notion that an ‘optimal’ phase ratio is a dynamic phenomenon and will change with respect to developments in speed, strength, and experience in the event.

Höhne, M. Katja Demut – Deutschlands stärkste Dreispringerin [Katja Demut – Germany’s strongest female triple jumper]
Leichtathletiktraining, Münster, 22, (2011), 2+3, pp. 60-63

In January 2011, the German triple jumper Katja Demut set a new German indoor record of 14.45 mm. In 2010, she was the only German triple jumper who qualified for the European Championships in Barcelona. In this paper, her coach Michael Höhne describes her training planning during her preparation for the German and the European Championships in 2010.

Hutt, E. The triple jump: Model technique analysis sheet for the horizontal jumps

The author describes the different phases of the triple jump: 1. The approach; 2. the takeoff; 3. the hop; 4. the step; 5. the jump, 6. the landing. In a technique analysis sheet, the criteria which are characteristic of the ideal triple jump technique are related to the individual phases.

Hutt, E. Drei Sprünge – dreifacher Spaß: Springen ist ein Ausdruck der Freude, warum also nicht die derzeitige DLV-Marktlücke Dreisprung nutzen? [Three jumps mean triple joy. Jumping is an expression of joy, so why not making use of the current triple jump “market niche” in German athletics?]
Leichtathletiktraining, Münster, 21, (2010), 5, pp. 20-28

The author describes how triple jumpers can be systematically developed by following the following guideline: 1. Preparing for multiple jumps; 2. preparing for the triple jump; 3. learning the triple-jump technique; 4. trying to achieve the model technique of the triple jump.

Hutt, E.
Mit hoher Geschwindigkeit weit springen [Jumping far from high speed]

Leichtathletiktraining, Münster, 22, (2011), 6, pp. 20-25

The triple-jump technique of the German triple jumpers Katja Demut (14.20 m) and Jenny Elbe (13.75 m) is analysed on the basis of two picture sequences.

Ilie, M.
Elements of kinematics specific to the jump of the male triple jump event


In this article, the results of a kinematic analysis of the last phase of the triple jump, the jump, are presented.

Jürgens, A.
Mit Tempo in die Grube! [With speed into the pit]

Leichtathletiktraining, Münster, 19, (2008), 5, pp. 10-16

The author analyses the picture sequences of two jumps of the two German triple jumpers Anne Neubauer (born September 2, 1989, PB: 13.31 m, 2007) and Philipp Melchers (born June 12, 1989, PB: 15.14 m, 2008).

Maraj, B.; Elliott, D.; Allard, F.
Cognitive constraints in the performance of the triple jump approach run (Abstract)

Journal of Sport and Exercise Psychology, Champaign (Ill.), 17, (1995), Suppl., p. S77

This experiment examined changes in the characteristics of the triple jump approach run in response to three situation contexts: Control (standard approach and jump), Distance (jumping for maximum distance) and Accuracy (jumping for distance but foot position not to exceed 20 cm board). A group of skilled (n = 5) and less skilled (n = 5) triple jumpers were filmed performing 6 trials in each condition. The results indicated that footfall position variability increased through the early phase of approach and then decreased as the jumpers neared the takeoff board. While there was no significant difference between the Distance and Accuracy condition in terms of average approach velocity, there was a significant interaction between Condition and Phase of Approach (early/late) for horizontal velocity. The jumpers altered horizontal velocity patterns differently in response to the situational demands: speeding up at takeoff for Distance and slowing at takeoff for Accuracy. The influence of situational demands altering the jumpers’ performance in these and other variables is discussed in terms of cognitive and ecological approaches to visual-motor control.

Martinon, J.-C.
Introduction to the triple jump


The author presents a three-stage step-by-step program to develop young triple jumpers. The first stage proceeds from the ability of an athlete to perform: (a) a run-up, followed by a jump as far as possible, (b) a run-up, followed by three leaps as far as possible. The second stage sets functional performance standards. In the triple jump, the young athlete aims to add three equal leaps to his run-up, preserving forward speed and keeping the trunk upright. The development of the triple jump becomes distinctly specific in the third stage. Higher standards are anticipated in each phase of the jump with more emphasis on each segment, preparing for the next.

Mladenov, O.
Izsledvane dinamikata na natovarvane tov godisnija trenirovacen cikal pri trojnija skok za zeni [An investigation of the load dynamics during the yearly training cycle of female triple jumpers]

Sport i nauka, Sofia, 53, (2009), 1, pp. 24-28

With his study of the dynamics of the total load and the ratio of the main types of exercise in the annual cycle of triple jumpers, the author tries to
solve the following tasks: 1 Examination of the dynamics of the total load; 2 analysis of the dynamics of the individual types of training in the mesocycles; 3 investigation of the relationship between the dynamics of the total load and the distribution of the main types of training.

Miladinov, O.
Izslëdvane dinamikata na pokazatelite za vzrvinost v godisnja cikal pri trojni skok za zeni [An investigation of the explosive parameters during the yearly training cycle of female triple jumpers]

Sport i nauka, Sofia, 53, (2009), 5, pp. 21-26

The author sees the goal of his study in clearing the relationships between the parameters of explosiveness in the vertical take-off from a standing position and the amount of the training load in the mesocycles of elite triple jumpers. The force-plate measurements conducted in this context were used to determine the vertical jump height (from a single- and double-leg take-off) and the support time to get accurate information about the current level of explosive power.

Miladinov, O.; Bonov, P.
Individual approach in the technique of triple jump for women


Most, if not all, elite women triple jumpers use opposite arm movements, known as the single arm technique, with individual peculiarities between athletes. After analyzing 54 jumps by 23 top female jumpers, the authors conclude that even the current best jumpers have some ‘improvement reserve’ because of weaknesses in the ‘hop-step’ link related to this technique. The main purpose of this study was to determine the effect of ‘mixed arm movements’, a combination of single and double arm techniques, in which the ‘hop’ and the transition to the ‘step’ are performed with opposite movements of the arms and legs and then, during the ‘step’, the arms are returned back together so that the ‘jump’ is performed with both arms swinging forward. A one-year long pedagogical experiment with a female triple jumper (personal best of 13.78 m) to introduce the change in technique is described, including the special exercises used and details of the applied training load. The authors conclude that the change led to a significant improvement in performance (to 13.98 m) and predict the technique will be more widely used in the future. They also conclude that the approach used for introducing the change was efficient.

Neumann, P.
Wie springe ich beim Dreisprung am weitesten? Schüler untersuchen systematisch verschiedene Sprungfolgen [How do I achieve the longest distances in the triple jump? Students systematically look for different jump sequences]

Sportpädagogik, Seelze, 30, (2006), 1, pp. 49-51

The author presents a teaching unit to introduce the triple jump for the advanced level of high school. The students are asked to find different jump sequences and to decide on the most effective jump sequence to reach the longest jumping distances. This also means that the focus of the teaching project is not the standard triple jump technique.

Niessen, M., Burgardt, K., Jürgens, A., Hartmann, U.
Visualisation of selected technical aspects in elite triple jumpers


The triple jump (TJ) includes the specificity of complex abilities, particularly jumping rhythm and management, good take-off coordination into hop (H), step (S) and jump (J) as well as balance during jumping flight. Quoted TJ performance limited characteristics: low horizontal velocity (vhoriz) deficits during take-off phases (t-oP), improvement of jump-distance relation of H & S concerning duration, jump-height, vhoriz and percentage optimisation of the phase distances (PD) (H: -36%, S: -31%. J: -34%). The aim of this project is to observe the above mentioned movement characteristics in elite nat. & int. TJ both sexes (m; f). Beyond kinematic data collection a routine visualisation system of selected technical aspects is compiled. 522 TJ (German (DM) & European Championships (EM) 2002) of 46 m and 35 f TJ were analysed, registered by a digital video camera (DV) and laser velocity measurement system (Laveg; 100Hz). DV has been
placed perpendicular to H-S transition to capture the side movement: markers placed each meter between 5 m prior to board and landing pit to calculate PD; 2D-kinematic analysis (DartTrainer; AdGraph). Laveg was placed in jumping direction to measure distance between laser detector and reflecting object; directed on lower back to register instant speed. TJ-movement was visualised by StroMotion. Technology includes image line in one picture, i.e. breaks down a mov. object into frame-by-frame sequence to highlight position & trajectory. Videos were combined with synchronised velocity curves. Both techniques provided excellent multiplex information. Results of finalist DM vs. EM: av. TJ performance: delta-7-8%; av. max. velocity (Vmax) in run-up: delta-3-4%; %-PDrelation of DM (EM): 36.6(37.3)%H, 28.4(27.5)S, 35.0(35.2)J (f) & 36.9(37.4)H, 29.9(29.5)S, 33.3(33.0)J (m); elite TJ's peak Vmax: 10.6 m/s; PD of H & J: each >6 m; sig. coherences of Vmax resp. vtransition H and effective (official + toe-to-board) distance in m & f (p < 0.05). In summary it was found nat. H-dominated jumps in contrast to more J-dominated or balanced (bal.) techniques in elite TJ (> 17.4m (m); > 14.5m (f)). High run-up velocity (vrun), paired with short contact times and more bal. jump technique or lower peak vrun, combined with lower jump-height and bal. jump technique leads to big overall distances. An elevated reduction of vhorizontal can be influenced due to large H, translactoric & rotatoric instabilities of upper body and above-av. deflections of knee & hip during the H-S- & S-J-transition.

Niessen, M., Jürgens, A. & Hartmann, U. 
Technique alternatives in elite triple jumping: influence of speed

Cross-section analyses point out three technique alternatives in elite triple Jumping (TJ), primarily in men, but no well-defined technique model. Through visualisation and kinematic analyses of selected technical aspects, a classification of so-called “Speed-Jumper” (SpJ), “Power-Jumper” (PoJ) and “Twin-ArmJumper” (TwJ) can be stated. Due to scarcely information in literature, the aim of this competition-accompanying project is to analyse the behaviour and influence of speed on above mentioned technique alternatives in elite TJ. Within a perennial scientific project competition-velocity profiles (CVP) of among several of elite TJ during outdoor-seasons were compiled. Velocity (v) was registered by a laser distance device (LDM 300C) through run-up and jumps, placed in approach direction and directed on the lower back of the athlete. Collected speed curves were edited and filtered by 67pt moving average of distance and speed (Sport 3.9, LavegDrei). Additional side movement video-capture and 2D-kinematic analysis was performed. SpJ reached high Vmax > 10.4m/s in run-up and performed flat phase-jumps with short transition (Trans) contact times (< 110 ms) to hop (H) & step (S). PoJ obtained high Vmax (-10.2m/s) too and solved steep take-offs (TOP) to H resp. jump (J), therefore with higher center of mass in flight phases and lower hip- and knee angles during Trans H-S & S-J. TwJ performed superior coordinative dual-arm-kick-technique with Vmax < 10.0m/s, flat TOP and flight phases. Between techniques there were high sig. differences in Vmax, CVP-15 to 0m & TOPH (p < / = 0.001) and TOPS ((p < / = 0.05). Although there were slight sig. correlations of Vmax resp. CVP H-S and effective distance in m & f (p < 0.05), we retrieved any sig. corr. between Vmax, CVP-indices and eff. dist. in elite TJ, but found individual sig. positive & negative corr. (p < / = 0.05) for selected phase distances (PD) and CVP-indices in mentioned techniques. The achieved dist. in TJ strongly depend upon available Vhorizontal in run-up in general and each of the take-offs in particular. Compared to literature no evidence in coherence of Vrun-up and eff. dist. in elite TJ was found, but sig. links of CVP-board, TOP resp. Trans to PD with specific relevance in mentioned techniques. SpJ need high Vmax and Vboard to achieve larger PD in H & J as well as to compensate speed drops in S & J. PoJ suffice higher CVP-5m and little speed drop in Trans H-S and TOP to reach mainly larger H & J. TwJ achieve improved H & J PD with lower Vboard and by little speed drop in Trans S-J. In conclusion, results point out necessity to analyse movement and velocity pattern of elite TJ more individual to customise training and finally performance.
requisites for elite TJ performance. Elite female TJ attain lower Vmax and therefore closer Vmax position to board compared to elite male TJ (e.g. Niessen et al. 2006). Furthermore decisive in TJ1 vs. TJ2 or TJ3 the higher absolute horizontal velocity combined with an optimum TO angle at TO H and TO S the bigger phase distances of H and S. Summarizing, the analysis of velocity profiles (especially last strides of run-up and TO H & S) and time management is necessary to individually adjust training and finally TJ performance.


Progression of female triple jumping (TJ) took place rapidly within the last few years. Since 2000 international championship tenner crosscut TJ results were > 14.5m. Achieved distances in TJ depend upon ideal kinetic energy production and conversion into height and distance through approach speed in every take off (TO) (e.g. Hay 1992). Aim of the study is to describe behaviour and influence of selected approach characteristics of time management (TM) and horizontal velocity (v (m/s)) profiles in elite female TJ. Numerous competition-velocity profiles were compiled among several elite female TJ during outdoor-seasons between 2002 and 2007 (Niessen et al. 2004). Velocity was registered by a laser distance device (LDM 300C), placed in approach direction and focussed on lower back of the athlete. Speed curves were edit and filtered by 67pt moving average of distance & speed (Sport 3.9, LavegDrei). Additional 2D-kinematic video-analysis of side movement was performed (Niessen et al. 2003). Descriptive and group-specific parametric statistics were applied. Elite female TJ (n = 52: performance: 14.3 ± 0.4m) achieved maximum velocities (Vmax) of 9.0 ± 0.2m/s around 0.6s or 5.5m prior to board. No statistically relevant relationship was noticed between Vmax and effective distance (Def: official plus toe-to-board distance) (Kyröläinen et al 2005, Niessen et al. 2005). All TJ decreased horizontal V during the TO to hop (H), and subsequently step (S) (phase distance ratio 27%) and jump (J). TJ > 14.5m (TJ1) achieve still 8.7m/s at TO to H, TJ < 14.5 (TJ2) 8.5m/s (p < 0.05 vs TJ1) and < 14m (TJ3) only 8.4m/s (p < 0.01 vs. TJ1) yet. Although speed loss dramatically increase during S and J phases (mainly TJ1 (-26%. Vmax), the Vmax reduction at TO H (-0.4m/s) differs not between TJ 1, TJ 2 and TJ3. In conclusion, high Vmax combined with its maintenance during H, S and 1 by short contact times enable good pre-


In contrast to well known statements regarding dependency of achieved triple jump (TJ) distances upon available horizontal velocity in run-up in general (e.g. Hay 1992) and each of the take-offs in particular (e.g. Niessen et al. 2004 & 2005) there is scarcely information about velocity profiles and stride pattern in preparation for hop-take-off in elite TJ. Multiannual competition-velocity profiles (CVP) of among several male elite TJ during outdoor-seasons (Niessen et al. 2004) were compiled. Velocity (v) was registered by a laser distance device (LDM 300C), placed in approach direction and focused on lower back of the athlete. Speed curves were edited and filtered by 67pt moving average of distance & speed (Sport 3.9, LavegDrei). Additional 2D-kinematic video-analysis of side movement was performed (Niessen et al. 2003). Descriptive and group-specific parametric statistics were applied. Elite TJ (n = 85: > 16 m) achieved, independent to technique alternatives, maximum velocities (Vmax) of 10.1 ± 0.1 m/s without a significant coherence to effective distance (Def: official plus toe-to-board distance) (Niessen et al. 2005). There were several significant linear correlations between Vmax and position of Vmax (Posmax) Ir = 0.65, p&amp;#8804;0.001, Posmax and difference of Posmax to take-off position of 2nd last (r = 0.95, p&amp;#8804;0.001) resp. last stride (r = 0.98, p&amp;#8804;0.001) as well as Posmax versus CVP Im (r=0.20, p&amp;#8804;0.05) resp. CVP 0m (r =
mov. av. of distance and speed) were registered real-time and stored in PC (Sport 3.9, LavegDrei and AdGraph). Additionally a digital video camera (CANON XM-1) was placed perpendicular to Hop-Step transition in order to capture the side movement of the plane of motion. 2D-kinematic analysis was performed with DartTrainerPro 2.5.3. World class performances in TJ reached peak velocity values in run-up (Vmax) of > 10.2 m s⁻¹ in men (TJ > 17 m) and > 9.1 m s⁻¹ in women (TJ > 14.5 m).

Further results of male and female TJ pointed out sig. corr. between run-up velocity indices (VI) (p < / = 50.001) and effective distance as well as 2nd last stride (p < / = 0.05). High sig. diff. were observed for CVP indices in run-up and TOPHop as well as for TM indices in run-up (15-2m (men (m)) and 15-0m (women (w)) prior to board and hop-step transition between high (m: > 16.5m; w: > 14m) and low (m: < 16.5m; w: < 14m) level TJ. In summary TM profiles were similarly in male and female elite TJ, but point out sig. diff. in run-up and hop to step between high and low level TJ. CVP behaviour was analogue in both gender, but inter-individual (delta 12%) and intra-individual (R: 0-12%) different. High level TJ achieved higher VI prior to board due to stride pattern "long-short" (2nd & last stride) as well as short contact times during H-S transition. Horizontal velocity drops during TOP hop, step and jump were higher in male (-1 m/s) than female (-0.7 m/s) TJ due to larger phase distances. In conclusion high Vmax, scarcely loss of horizontal velocity in TOPH and Trans H-S are important factors for top level TJ distances in particular.

Niessen, M.; Hartmann, U.; Jürgens, A.
Bewegungsanalyse und Bewegungssteuerung im Dreisprung [Movement analysis and the targeting of movement in the triple jump]


The achieved distances in triple jump (TJ) are strongly dependent upon the available horizontal velocity in run-up and each of the take-offs (TO). Kinetic energy is produced through the approach speed in every TO and is converted into height and distance. Due to less information in literature, the aim of this competition-accompanying project is to detect velocity profiles and individual time managements (TM) in different performance levels, techniques and between gender. Up to 435 competition-velocity profiles (CVP) of 37 male and 30 female elite triple jumpers during the outdoor seasons were analysed. The run-up and jumps were registered by a laser velocity measurement system (LDM 300C), placed in approach direction to measure the distance between laser detector and reflecting object (100 Hz). To determine instant speed values throughout run-up until land in the pit, the laser beams were directed on the lower back. Raw data and calculated speed curves (67pt

Niessen, M.; Hartmann, U.; Jürgens, A.
Bewegungsanalyse und Bewegungssteuerung im Dreisprung [Movement analysis and the targeting of movement in the triple jump]
In this article, the focus is on the following questions: 1. How do athletes behave in the technical implementation and how can technical aspects be visualized? 2. How can a high run-up speed be optimally and economically be translated into a quantitatively measurable success and what parameters affect the design of the partial jumps?

The purpose of the present research was to present the magnitude of the kinematic parameters of the triple jump observed in male and female junior athletes regarding the technique and its effect upon the load subjected to junior athletes. The male (14.25m, standard deviation: 0.7) and female (11.93m, standard deviation: 0.5) jumpers competed in the finals of the Greek National Junior Championships served as samples. Three JVC GR-DVL 9600EG (Victor Company of Japan, Ltd) and a Panasonic NV-DS29 (Matsushita Electric Industrial Company, Osaka, Japan) digital video cameras were used to capture the jumpers’ attempts and a 2D-DLT kinematic analysis was conducted. Separate Independent Samples Student’s T-Tests were used in order to examine the gender effects an the kinematic parameters describing the approach, the hop, the step, the jump and the landing. The male jumpers utilized a 36.7% (1.7) – 29.7% (1.6) – 33.6% (1.2) hop-step-jump ratio, while the female jumpers used a 38.0% (1.5) – 26.1% (2.6) – 35.9% (2.6) phase ratio. Statistically significant differences (p < .05) between male and female jumpers occurred concerning the horizontal and vertical velocity of the body centre of mass (BCM), the length of each phase and the BCM height during the support phases. Both males and females lost approximately 35% of the BCM horizontal velocity attained during the last two strides of the approach at the instant of the take-off for the jump. In comparison with seniors, juniors seem to utilize hop-dominated techniques, fall to convert successfully horizontal BCM velocity to vertical for the take-offs and seem to execute the touchdowns with less “pawing” action of the support leg.

Panoutsakopoulos, V.; Kollias, I. A.
Essential parameters in female triple jump technique
New Studies in Athletics, Aachen, 23, (2008), 4, pp. 53-61
The purpose of the present study was to examine the performance of female triple jumpers under competitive conditions. The jumps of the ten participants in the women’s triple jump at the European Athletics Premium Meeting “Thessaloniki 2008” were recorded using two digital video cameras operating at 100 fields per second and a 2D-DLT kinematic analysis was used for the
calculation of selected biomechanical parameters. The author’s findings confirmed a strong correlation ($r = .816$, $p < .01$) between approach velocity and triple jump performance. They found that the average phase distribution for the athletes studied was 36.5%, 29.3% and 34.2% for the hop, the step and the jump respectively and that the horizontal takeoff velocity of the body’s centre of mass (BCM) decreased approximately 1m/sec in each support from the hop to the jump. The results showed that the female triple jumpers who jumped over 15 m in the competition had: i) maintained most of their BCM’s horizontal velocity and exhibited a better conversion of horizontal-to-vertical velocity during the transition from the hop to the step, ii) greater BCM vertical velocities at the take-offs of the hop and the step, and iii) shorter support times and lower support time to flight time ratios.

Qing Lu
A comparative study on athletes’ competition ability performance in the 29th Olympic Games triple jump final

The article presents a study which examines the triple jump final in the 29th Olympic Games using methods of literature review, comparative analysis and live test. The study evaluates several aspects of the event including the basic condition of the athletes, the results of the six jumps, and their success rate. It reveals that 98.13% of males and 99.80% of females attained their personal best of competition ability in the finals, while the first and second jumps have the highest success rate.

Schiffer, J.
Selected and annotated bibliography No. 68: Triple jump

The present bibliography contains a total of 501 articles and books about the triple jump published from 1950 to the present. The bibliography is subdivided into fourteen chapters: 1. Technique of the triple jump (61 documents); 2. Biomechanics of the triple jump (104 documents); 3. Photo sequences and kinegrams of the triple jump (30 documents); 4. Videos of the triple jump (10 documents); 5. Training, conditioning and coaching aspects of the triple jump (80 documents); 6. Teaching and learning the triple jump (including novice technique, training, and related problem) (62 documents); 7. Talent identification in the triple jump (1 document); 8. History of the triple jump, performance development and prognosis (11 documents); 9. Psychological aspects of the triple jump (4 documents); 10. Medical (i.e., traumatological, preventive, morphological and anthropometric) aspects of the triple jump (7 documents); 11. Women’s triple jump (26 documents); 12. Interviews with and profiles of prominent triple jumpers (30 documents); 13. Comprehensive and general articles about the triple jump (75 documents).

Schlottke, K.
Jahresplanung im Dreisprung: Wie ein gezielter Trainingsaufbau im Aufbautrainings eines Springers aussieht, wird am Beispiel einer jugendlichen Dreispringerin gezeigt [Annual planning for the triple jump: the target-oriented training structure during the buildup training of a jumper shown with the example of a young female triple jumper]
Leichtathletiktraining, Münster, 15 (Januar/Februar 2004), 1+2, pp. 42-49

The author presents a concept of the annual training planning for female triple jumpers focusing on three aspects: 1. analysis (as a prerequisite for accurate planning), 2. multi-annual planning, 3. annual planning.

Wilson, C.; Simpson, S.; Hamill, J.
Movement coordination patterns in triple jump training drills

The aim of this study was to determine the effectiveness of training drills in replicating the lower extremity coordination patterns used during the triple jump. Three-dimensional kinematic data and synchronized ground reaction force data were collected during the hop-step transition of a triple jump and four related training drills. Relative motion plots and a modified version of the vector coding technique were used to quantify the coordination patterns of the lower extremities. Differences were observed in the coordination patterns between the triple jump and static drills, but not
between the triple jump and dynamic drills, and these differences were mainly in the swing (free) leg. The results of this study suggest that if the primary purpose of the training drills is to replicate the movement patterns used in the triple jump, then dynamic drills are more effective than static drills. In addition, coaches should focus on the use of the free leg during these training drills so that the coordination patterns more closely replicate the triple jump. Finally, to provide a more holistic evaluation of training drills, future studies should investigate the similarity of the physical and musculoskeletal demands of jumps and drills.

3 Horizontal jumps in general

Bourne, G.
An analysis of the women’s horizontal jumps in Athens
Modern Athlete and Coach, Adelaide, 43, (2005), 3, pp. 3-16

In the women’s long jump, the major upward trends observed across 2004 are (1) the increased number of athletes who recorded performances beyond 6.95m across the year, (2) the increase in the number of athletes contained within the core group of elite performers compared to recent years (women who have jumped > 6.80m), (3) the standard required to win an Olympic medal, (4) the standard required to place in 8th position, and (5) the average of the top 8 performers in the final. The distance required to win a medal appears certain to be higher in Beijing in 2008 compared to Athens in 2004 and athletes will need to prepare both physically and mentally for this challenge. As far as the women’s triple jump performances throughout the 2004 season including those at the Athens Olympic Games are concerned, there are indications of a significant rise in the top level of performances along with the depth of elite level performers in the women’s triple jump. This rise can be attributed significantly to some outstanding performances recorded by the athletes of a few nations (Russia, Cuba and Greece in particular) rather than a steady improvement across all nations. Eight women from Russia attained the Olympic “A” qualifying standard in 2004 while there were three each from Greece and Cuba. In addition, two former Cuban nation-als finished prominently in the top eight in the final whilst representing other nations. These nations are clearly dominating women’s triple jumping internationally and other nations who wish to duplicate this success should investigate the talent identification schemes, training plans and training strategies utilized in these countries with a view to implementing similar strategies themselves. There were a relatively small number of “B” qualifiers for the women’s triple jump in Athens. Consequently the IAAF did not alter the “B” standard in the women’s triple jump for the 2005 World Athletics Championships but has increased the “A” standard by 10 cms to 14.30 m. The “B” standard may appear low when looking at the 2004 IAAF Top Lists but very few athletes outside of the dominant countries were able to reach this standard in 2004. The overall depth in this event (across all countries) has not risen much in recent years and many countries have quite a bit of work to do to raise the standard of women’s triple jumping in order to ensure that more women overall and women from a larger number of countries qualify for this event at future major championships.

Crotty, J.
Berlin 2009 : IAAF world class coaches report

In this report, the author analyses the technical aspects of the triple and long jump from the Berlin World Championships. He also reflects on the results and trends from this competition.

Hillard, C.; Pfaff, D.; Boas, J.; Bourne, G.
Roundtable: Horizontal jumps
Track Coach, Mountain View, (2004), 166, pp. 5305-5309

The following questions/aspects are dealt with: 1. Describe the most important physical qualities to be developed in horizontal jumpers and in what priority? 2. What field tests do you employ on a regular basis and which tests do you find most beneficial as expressions of jumping preparedness? 3. How do you view the importance of biomechanics and technological aids as a coaching tool? Specifically, what measures do you utilize to assist in the coaching process and the athlete’s
is more difficult for the horizontal jumper to correctly target the takeoff board, and this seems to be borne out by the higher number of fouls committed in meets where the boards are both white.

Mendoza, L.; Nixdorf, E. 
Angewandte Leistungsdiagnostik in den Sprungdisziplinen [Applied performance diagnostics in the jumping events] 

The authors offer an introduction to techno-motor performance diagnostics, which is explained using the example of the long jump. First, the qualitative and quantitative diagnosis are distinguished and then the different parts of the process are presented in detail by describing the respective methods. As far as the qualitative diagnosis is concerned, the different visual representations are described, in the quantitative diagnosis a difference is made between the kinematic and dynamometric motion analysis. The respective measurement methods are explained and the expression and evaluation of characteristic values are presented. As far as the kinematic analysis is concerned, the run-up, take-off and landing characteristics are considered, while concerning the dynamometric analysis the take-off forces in the vertical direction as well as in the horizontal longitudinal and transverse directions are dealt with. Finally, the author presents recommendations concerning the practical implementation of the results.

Mendoza, L.; Nixdorf, E. 
Biomechanische Wettkampfdiagnostik in den leichtathletischen Horizontalsprüngen [Biomechanical competition diagnosis in the horizontal jumps in athletics: investigation methods for performance diagnostics at the Olympic Training Centers]


The Olympic Training Center in the Federal Land of Hesse is in charge of the squad athletes in the long-jump and triple-jump events of the German track and field team.
Athletics Federation as far as the biomechanical movement analysis and performance diagnosis are concerned. In this paper, the corresponding measurement and analysis methodology is presented. This includes first the measurement setup and then the definition and explanation of the kinematic characteristics included in the diagnosis sheet for coaches and athletes.


Although the approach speed and thus the ability to sprint is a paramount factor influencing the jumping performance, the production of vertical velocity is also very important. For the production of a fast vertical velocity the loss of horizontal speed is inevitable. However, it is important that the loss of horizontal velocity is compensated for by a relatively high vertical velocity. The dimension of this relationship can be used as a criterion for the assessment of an optimal jumping technique.

Miladinov, O. Izsledvane ritama na bjagane pri zasilvaneto v chhorizontalnite lekoatleticeski skokove [An examination of the stride rhythm during the run-up in the horizontal jumps in athletics] Sport i nauka, Sofia, 52, (2008), 5, pp. 29-33

The main goal of this study is the investigation of the speed of the run-up steps for the long and triple jump. This includes two sub-goals: 1. The investigation of the change of speed during the last four steps, and 2. the evaluation of the relationships between the running speed and the athletic performance as well as the speed on the last five meters of the run-up. The subjects of the investigation were 33 Bulgarian athletes (17 male long jumper with an average performance of 7.26 m, 9 female long jumpers with an average performance of 5.97 m, 7 male triple jumpers with an average performance of 15.39 m).

Miladinov, O.; Vangelov, A. Vazrast i postizenija v chhorizontalnite lekoatleticeski skokove [Age and performances in the horizontal jumps in athletics] Sport i nauka, Sofia, 52, (2008), 5, pp. 55-61

Based on an analysis of the world ranking list and the Bulgarian ranking list from the year 2007, the authors arrive at the conclusion that 1. most athletes included in these lists are between 23 and 28 years old; 2. the most favourable age ranges for top performances are: for the men’s long jump: 26 years, for the women’s long jump: 29 years, for the men’s triple jump: 26 years, and for the women’s triple jump: 28 years. Bulgarian jumpers achieve their top performances much earlier. According to the author, this shows that the preparation of these athletes is enforced too early and that their possibility to further increase their performances is reduced.


Take-off velocity is an important factor determining performance in the long jump and triple jump,
und it is influenced by approach velocity. The objectives of this study were: a) to determine the relationship between approach velocity and jumping performance, b) to verify if approach velocity is different when we compare the lung jump and triple jump, and c) to discuss individual relationships, in comparison with values achieved by the group of athletes studied. Thirty-two male athletes competing in Trofeu Brasil de Atletismo 2003 were studied. The official results and the mean velocity measured in the last 5 m of the approach run were investigated. High correlation values were found between approach velocity and long jump performance ($t = 0.72$), but this relationship was not as high for the triple jump ($r = 0.58$). Approach velocity shows a tendency to be higher in the long jump than at the triple jump, even though the difference is not statistically significant. Individual relationships show a tendency to be lower than the group relationship. In some cases, they are negative.

Ogandzanov, A. L. 
**Effektivnost razbega v legkoatleticeskich pryzkach [The effectiveness of the run-up in the athletics jumps]**

*Teorija i praktika fiziceskoj kul’tury, Moscow, (2005), 3, pp. 9-13*

The focus of this analysis is the dynamics of the main parameters of the run-up as related to the enhancement of performance in the long jump and, on this basis, clarification of directions to improve the run-up performance, the optimization of the run-up rhythm and length. The article also includes corresponding data from the triple jump.
The Encyclopedia of Sports Speed is not the first book written by speed experts George B. Dintiman and Robert D. Ward reviewed in NSA. The second edition of their book Sports Speed, published in 1998, was extensively dealt with in NSA 2/2000. This review ended with the remark that in spite of not being specifically geared towards athletics, the book is definitely required reading for all athletics coaches in the business of developing speed in their athletes. This judgement was somewhat qualified in the review of the third edition in NSA 1/2009, because this new edition was much more focused on speed for team sport athletes than the earlier edition.

So, how does their new book, Encyclopedia of Sports Speed, compare with those earlier books?

First of all, it is worth mentioning that the new book is a lot thicker than the earlier books about speed (425 vs. 220 or 280 pages). This, together with its DIN-A4 format, makes the Encyclopedia of Sports Speed the most voluminous book about speed currently available.

The focus of the Encyclopedia of Sports Speed is still on the “playing speed” of athletes. This means that the book deals not only with linear speed but with the speed of all movements in sports, including starting, stopping, cutting, accelerating, changing direction, delivering or receiving a blow, sprinting, and split-second decision making during competition.

What is completely new about Dintiman’s and Ward’s new book is its question-and-answer format. This means that the book does not require to be read from the beginning to the end but can also be used as a reference work for only selective reading.

The content of the Encyclopedia of Sports Speed may be summarized as follows:

In Part I ("Introduction"), all aspects of speed during competition, as well as testing and basic training are examined.
In Chapter 1 ("Playing Speed"), the key areas of playing speed in team sports are described to provide readers with an overview of the differences between training to improve linear velocity and training to improve speed for sports competition. Chapter 2 ("Playing Speed Test Battery") presents a comprehensive test battery, including sport-specific tests, to identify each athlete's strengths and weaknesses and determine the major focus points for designing an individualized speed improvement program. Sport-specific tests used in football, baseball, soccer and basketball are also presented, along with standards that allow athletes to compare their scores to professional athletes.

Part II ("Components of Playing Speed") describes the main factors that come into play when executing short sprints. Stopping, starting, acceleration, faking, and cutting (Chapter 3), mechanics of sprinting (Chapter 4), stride rate and stride length (Chapter 5), and speed endurance (Chapter 6), cover the elements that must be understood and applied to improve speed in short sprints.

Part III ("Training Programs: The 5-Step Model") provides a detailed description of the specific programs designed to impact each of the factors affecting speed presented in Part II. "Step 1: Foundation Training" (Chapter 7) prepares athletes at all levels of competition for the comprehensive speed improvement training programs that follow. "Step 2: Power Output Training" (Chapter 8) describes the critical programs designed to increase ground contact force, or the pushing force against the ground an each step, that affects the start, acceleration, stride rate, stride length, and maximum speed. Detailed programs in speed-strength training, plyometrics, and sprint-resisted training are described. "Step 3: Sustained Power Output Training" (Chapter 9) presents sport-specific speed endurance programs to keep athletes sprinting at the same high speed throughout an entire game. "Step 4: Neuromuscular Training" (Chapter 10) describes numerous sprint-assisted training programs designed to improve stride rate. Finally, "Step 5: Form and Technique Training" (Chapter 11) includes drills and programs to improve starting, stopping, acceleration, sprinting, and faking and cutting.

Part IV ("Putting It All Together") covers sport-specific speed training, periodization, and sample workouts for the in-season and off-season periods (Chapter 12). Chapter 13 ("Speed Improvement for Young Athletes") analyzes all aspects of speed and presents a modified, safe program for pre-adolescent boys and girls.

The Encyclopedia of Sports Speed is rounded off by a bibliography including about 200 important speed-related resources, as well as a glossary of terms associated with speed and speed training to allow quick reference for readers.

Although the book is research-based to the extent that it incorporates the latest scientific findings of hundreds of studies, the details of complicated research design and statistical analysis are avoided. Instead, information is presented in an uncomplicated and practical manner so that it can be easily understood and applied to the training of athletes.

In spite of the fact that the Encyclopedia of Sports Speed goes beyond helping athletes to accelerate and sprint faster in a straight line, it includes a lot of information relevant for track-and-field athletes and coaches. Because of the sheer wealth of useful information included and its practical format, the Encyclopedia of Sports Speed is recommended reading for coaches and athletes in any sport.

Reviewed by Jürgen Schiffer

George B. Dintiman & Robert D. Ward
Encyclopedia of Sports Speed
The Federal Institute of Sports Science (BISp, www.bisp.de), which was founded in 1970, makes use of and supports the available research capacities at the universities, particularly the sports-related sciences in the Federal Republic of Germany, to assist elite sport and elite athletes in delivering top performances.

Through the project-related and application-oriented promotion of scientific research, scientific counselling and knowledge transfer both in sports practice and sports science, BISp provides effective support to elite sport.

Always under the premise of humane performance sport, BISp has had a considerable influence on the development of sports science, including sports medicine, and has acquired a strong national and international reputation.

BISp consists of three departments:
• Department I – Research and Development
• Department II – Scientific Counselling
• Department III – Policy and Controlling

Department I is responsible for the initiation, coordination and funding of sports-science research projects and Department III deals with general matters of the institute that do not concern one department in particular (for example, the supervision of the advisory boards of BISp and legal matters). The primary task of Department II is the documentation and distribution of sports-science findings and results.

BISp databases

The core of the information processing are the three databases run by BISp: SPOLIT, SPOFOR, SPOMEDIA (literature, research and media documentation) as well as the Specialist Sports Information Guide (quality-secured internet sources).

For athletics coaches and officials, the SPOLIT literature database may be particularly interesting.

SPOLIT currently includes approximately 190,000 articles and books, more than 10,000 of which are indexed with the controlled term “Leichtathletik” (athletics). Almost 4,800 of these documents are in English.

SPOLIT includes a simple search and an extended search modus. The simple search screen can be accessed directly via: www.bisp-datenbanken.de.

Search is possible using the name of an author, title and abstract keywords in English or any other language, or controlled terms (Schlagwörter), which can only be in German. The results of a search can be limited by period (e.g., 2000-2012) or by language (e.g., English).

Users who want a more targeted search should go to the menu options on the left and click Profisuche (professional search). When clicking this tab, a sub-menu will open including the tabs Literatur gesamt (general literature), Monographien (monographs), Sammelwerksbeiträge (articles in books), and Zeitschriftenaufsätze (articles in periodicals).
When clicking, for example, “Zeitschriftenaufsätze”, search can be done by filling in the search fields “Freitextsuche” (free text search – the word(s) typed into this field will be searched for in all document subfields), “Titel(-übersetzung)” (title (translation) – word(s) typed here will be searched only in the document titles or their translations), “Person” (author), “Zeitschrift” (periodical), “ISSN” (instead of the periodical title), “Inhalt/Abstract” (contents/abstract – word(s) typed here will be searched only in the abstract), “Schlagwörter” (controlled terms – only German words can be used). Again, the results of a search can be limited by period or by language.

Within the search fields, words that are separated by a blank will be searched as one single term, e.g., “distance running”. If these two terms are separated by a semicolon (without a blank) and the button und (and) on the right is clicked, these terms will be searched both as one single term and separate terms. If the same terms are separated by a semicolon and the button oder (or) on the right is clicked, the search result will include all titles containing only one or both of these terms.

The search results are so-called literature documents that include bibliographic data and an abstract, which is very often in English. Readers who are interested in the full text of a literature document can order the respective article by clicking the Subito button at the top of the individual result page.

The search results can be downloaded in total or in the form of selected documents in PDF, RTF, HTML, or RIS format

Advantages and Disadvantages

The biggest advantage of the SPOLIT literature database for athletics coaches is that access to it is free of charge and that it provides full coverage of the most important international athletics journals, e.g.: New Studies in Athletics, Modern Athlete and Coach, and Track Coach. In addition, the database also includes almost all articles from important international training-science, biomechanics, and sports-medicine periodicals which are relevant to athletics (e.g., Journal of Strength and Con-
Figure 2: SPOLIT extended search

Figure 3: SPOLIT individual search result
ditioning Research, Journal of Applied Biomechanics, or International Journal of Sports Medicine). A list of the so-called “primary journals” (i.e., journals with full coverage) can be obtained by clicking the buttons Sammelprofil (collection profile) –> Zeitschriftenliste (periodical list) –> Primärzeitschriften (primary periodicals) in the menu on the left in the entry page to the SPOLIT database.

The main disadvantage for international users of the database is that the SPOLIT website is only in German and that a search using controlled terms is also possible only in German. However, the sheer volume of the material included in the SPOLIT database together with the fact that a large part of the database content can be accessed using English or other language terms in the title and abstract fields make SPOLIT an indispensable tool for athletics literature search.

Reviewed by Jürgen Schiffer
Introduction

The horizontal jumps in athletics have been studied by a number of international research teams, which have focused on the critical performance factors that determine the distance jumped, e.g. contact time at take-off, take-off angle, horizontal and vertical velocity. The gold standard measurement systems to track and monitor these parameters have traditionally been sophisticated measurement systems such as force plates and 3D kinematic cameras. Such systems have rapidly advanced our knowledge and understanding of all these events.

The limitation with such systems has been the ability to translate and track such measures quickly and easily enough, and at a reasonable cost, to assess the impact of coaching drills or scientific interventions in a field setting. In the past decade, with the miniaturisation of electronics and sensor technologies, there has been an increased attempt to measure such parameters with more portable and lower cost alternatives.

One technology that has developed by an Italian company – Sensorize (www.sensorize.it) - is providing potential to inform the training process across all track and field events. Although the devices are still targeted at the higher end of the performance pathway, in the next decade, these are likely to filter down to club level as costs fall.

Figure 1. The FreeSense device
FreeSense

FreeSense (see Figure 1) is a light, compact measurement system that measure 3D linear accelerations, 3D angular velocities and GPS coordinates. When used in wireless mode, it is possible to see real-time visualisations of data directly on your PC for real time feedback. The device can be worn in a number of locations but tends to be attached to a belt in the lower back (see Figure 2).

The software interface, which has been developed alongside the FreeSense hardware, provides visually appealing graphical images to supplement the feedback process with coach and athlete (Figure 3). The strength is in the simplicity and ease of use for non-technical specialists.

How accurate is the device?

FreeSense is currently being used and tested in research labs around the world. One group at the Bioengineering Laboratory of the University of Rome is currently investigating the biomechanics of sprinters. Getting insight
into crucial information such as trunk inclination during the start phase, foot contact times, flight times, and acceleration profile is fundamental to improving the performance of sprinting and its contribution to horizontal jumps. In some of this initial work the FreeSense was assessed during acceleration phases and maintenance phases of the sprint.

Figure 4 shows show example data from Elena Bergamini and colleagues illustrating the match between FreeSense and a stereophotogrammetric system for the pitch angle of the trunk from across different sprint phases – the key phase of relevance here is the pick up (acceleration). This illustrates the strong relationship between FreeSense and a gold standard method.

### Summary

The use of inertial sensors to measure and track field based mechanics are becoming increasingly popular in sports. FreeSense is one example that has direct application and potential in track and field and particularly in horizontal jumps.

Please note: the author has no involvement with any of the commercial companies or products mentioned in this report.

 Reported by Scott Drawer

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Resúmenes

Análisis Biomecánico de los Saltos Horizontales en el Campeonato Mundial de Atletismo IAAF 2009
por Luis Mendoza y Eberhard Nixdorf
Traducido del original en Alemán por Jürgen Schiffer

El Campeonato Mundial de Atletismo IAAF 2009 realizado en Berlín les dio a los científicos alemanes del deporte una oportunidad poco frecuente de estudiar a los mejores atletas del mundo en una competencia de nivel superior en una sede cerca de casa. Un equipo de 18 investigadores de seis instituciones de todo el mundo planificó, organizó y llevó a cabo un proyecto de investigación biomecánica en el campeonato, con el apoyo de la federación alemana de atletismo (DLV) y la IAAF. Los objetivos del proyecto incluían la realización de un análisis detallado de las finales de todos los saltos horizontales, tanto de hombres como de mujeres. Se midió la velocidad de aproximación para cada intento utilizando un aparato de medición láser y se elaboró un análisis de vídeo 2D basado en grabaciones, realizadas con una cámara de vídeo de alta velocidad, del mejor intento realizado por los ocho mejores posicionados en cada prueba. Este informe, especialmente preparado para NSA, suministra el análisis y los comentarios sobre los datos obtenidos por el equipo del proyecto, con secciones sobre cada una de las pruebas. Los autores concluyen con siete puntos que generalmente confirman los modelos técnicos actuales.

Čoherencia y la Variabilidad de los Parámetros Cinemáticos en el Salto Triple
por Milan Ćoh, Stanko Štuhec, Rok Vertc

El propósito del estudio era examinar la coherencia y variabilidad de los parámetros cinemáticos en la técnica utilizada en el salto triple, una de las disciplinas atléticas más complejas. Se realizó un examen de dos intentos de una saltadora de elite, efectuados en condiciones de laboratorio durante su preparación para los Juegos Olímpicos 2008, donde se ubicó en 6º lugar en la final. Para estudiar los parámetros de la técnica modelo se utilizó el sistema Opto-track y la tecnología cinemática 3-D. El análisis reveló que se pueden obtener resultados óptimos con diferentes estrategias del esquema motor y que el patrón motor está generado por parámetros coherentes y variables. Los parámetros más coherentes del patrón motor en el sujeto fueron: distancias parciales de las fases individuales, duración de las fases de apoyo en las acciones de despegue, los ángulos de despegue y la amplitud vertical del centro de masa corporal. La variabilidad del patrón motor se reveló principalmente en los siguientes parámetros cinemáticos: la velocidad en los últimos 5m de la aproximación, la longitud y proporción de las dos últimas zancadas de aproximación, la velocidad horizontal del centro de masa corporal en las acciones de despegue.
La Importancia de la Velocidad de Despegue Horizontal y Vertical para las Saltadoras de elite de Salto en Largo

por Stefan Letzelter

A pesar que la investigación biomecánica sobre las saltadoras de salto en largo ha ampliado el conocimiento sobre dicha prueba, los análisis llevados a cabo hasta la fecha, sufren de ciertas limitaciones, incluyendo pequeños tamaños de muestra y pocos estudios sobre mujeres. Entre las cuestiones que todavía están abiertas se encuentran la fiabilidad estadística de los hallazgos acerca de los componentes horizontales y verticales de la velocidad de despegue y si los resultados son igualmente válidos para hombres y mujeres. Este estudio, basado en los hallazgos publicados de seis eventos importantes con el propósito de proporcionar un mayor conjunto de datos, analizó ambos componentes de la velocidad de despegue con tres criterios estadísticos diferentes de un total de 42 mujeres que saltaron entre 6,14m y 7,40m. Esto permitió las comparaciones del impacto de ambos componentes sobre el resultado y la posibilidad de examinar cinco hipótesis. Entre los hallazgos se encuentran: a) las mejores saltadoras tienen más que ventajas casuales sobre las demás tanto en los componentes horizontales como verticales de la velocidad de despegue, con la vertical siendo mucho más clara; b) la proporción de velocidad de despegue de horizontal a vertical difiere en las atletas estudiadas de 2,1 a 3,6; y c) los saltos de excelencia pueden lograrse con combinaciones muy diferentes de los dos componentes, pero, en términos generales, la proporción de las atletas más exitosas es significativamente menor.

Posición dentro de la carrera para los Medallistas de Pruebas de Resistencia en Pista en los Juegos Olímpicos 2008

por Joseph W. Duke, Timothy D. Mickleborough, Joel M. Stager, Robert F. Chapman

El principal objetivo de desempeño en las pruebas de medio fondo y fondo en un campeonato es ganar la carrera, calificar para la próxima ronda, o ganar una medalla en la final. Puede ser necesaria la adopción, por parte de un atleta, de una estrategia de ritmo completamente diferente a esa, con la que intenta lograr un mejor tiempo. El objetivo de este estudio era determinar de qué manera el posicionamiento dentro de la carrera y la habilidad de aceleración final en una carrera estaban relacionados al orden de clasificación final de los competidores en las pruebas de pista en los Juegos Olímpicos 2008. Se obtuvieron fracciones de tiempo para cada 100m de todos los finalistas hombres y mujeres de 800m a 10.000m, y se calculó la posición media de carrera sobre cada quinto de la misma, a excepción de los 800m donde se calcularon cuartos. Se descubrió que la posición o estrategia de carrera es diferentes entre pruebas y sexos. Los medallistas en las pruebas más cortas (es decir, 800 y 1.500m) normalmente se trasladaban a una posición de medalla antes que aquellos de las pruebas más largas. Los medallistas hombres de las pruebas más largas tienden a confiar en la habilidad de aceleración final en la carrera para lograr la posición final, mientras que las medallistas mujeres generalmente se trasladan antes dentro de la posición de medalla.
Evolución de los Atletas Juveniles de Elite de Nueva Zelanda y Australia hacia la Representación en Mayores
por Stephen Hollings y Patria Hume

Existe una probabilidad razonable de que los atletas que hayan obtenido un alto nivel de éxito como juveniles, pasarán a ser mayores exitosos. Este estudio examina la idea mediante el seguimiento de los atletas australianos y neozelandeses que participaron en el Campeonato Mundial Juvenil IAAF desde 1986 a 2006, a través de las marcas mundiales de mayores y de los Juegos del Commonwealth, o de otra manera. Se descubrió que el 22% de los australianos y el 32% de los neozelandeses medallistas y finalistas de un Campeonato Mundial Juvenil pasaron a convertirse en medallistas o finalistas mundiales o a ganar una medalla en los Juegos del Commonwealth como mayores. La probabilidad es mayor si el atleta ganó una medalla mundial juvenil y mucho menor si el atleta únicamente compitió en el Campeonato Mundial Juvenil o no participó en absoluto. Al mismo tiempo, fue alto (~72%) el índice general de deserción de los atletas australianos y neozelandeses que compitieron en un Campeonato Mundial Juvenil y no siguieron representando a su país en el nivel mayores. Los autores sugieren que las estrategias para obtener exitosos atletas mayores deben basarse en: 1) producir más medallistas y finalistas de un Campeonato Mundial Juvenil; 2) retener a los juveniles en el deporte hasta el grado de mayores; 3) concentrar los recursos en los medallistas y finalistas juveniles de los Campeonatos Mundiales Juveniles.

Foco de Desarrollo – Ucrania, Un Modelo de Éxito
por Helmut Digel

Ucrania puede mirar hacia atrás su larga y gloriosa tradición en atletismo. Como parte de la Unión Soviética, proporcionó muchas de las victorias famosas de ese país, sobre todo las de los campeones olímpicos Valeriy Borzov y Sergey Bubka, que actualmente se encuentran en posiciones de liderazgo en la organizaciones deportiva ucranianas. Desde su independencia en 1991, los atletas ucranianos han ganado 15 medallas en los Juegos Olímpicos y recientemente el país ha estado constantemente entre los más exitosos tanto a nivel mundial como europeo. Este éxito ha ayudado a que el atletismo se encuentre entre los deportes más populares dentro del público y garantice el apoyo continuo del gobierno. Los logros del deporte pueden atribuirse en gran medida al modelo de apoyo del país. En este estudio de caso, el autor explica resumidamente los elementos claves del modelo y proporciona elementos interesantes. Los puntos contemplados incluyen la federación, la infraestructura atlética, los entrenadores, los oficiales técnicos, el sistema de identificación de talentos, la estructura de desarrollo de desempeños y el sistema de recompensas.
Résumés

Une analyse biomécanique des épreuves de sprints et de haies aux Championnats du monde d'athlétisme de l'IAAF 2009
Par Luis Mendoza et Eberhard Nixdorf

Les Championnats du monde d'athlétisme de l'IAAF 2009 de Berlin ont été pour les scientifiques du sport allemands une opportunité rare de pouvoir étudier, chez eux, les meilleurs athlètes mondiaux évoluer dans une compétition du plus haut niveau international. Une équipe de dix-huit chercheurs, représentant six instituts allemands différents, ont saisi cette occasion pour planifier, préparer et réaliser un projet de recherches biomécanique de grande envergure, avec le soutien de la Fédération allemande d'athlétisme (DLV) et de l'IAAF. Les objectifs du projet comprenaient notamment des analyses détaillées des finales masculines et féminines des concours de sauts horizontaux. La vitesse de la course d'approche de chaque essai a été mesurée à l'aide d'un appareil de mesures laser, et des analyses vidéo 2D ont été effectuées à partir d'images filmées par une caméra vidéo haute-vitesse sur le meilleur essai des huit premiers de chaque épreuve. Ce rapport, préparé spécialement pour la NSA, fournit des analyses et des commentaires sur les données obtenues par l'équipe du projet, avec une section consacrée à chaque épreuve. Les auteurs concluent leurs propos avec l'énumération de sept points qui tendent à confirmer les modèles techniques actuels.

Constance et variabilité des paramètres cinématiques dans le triple saut
Par Milan Ćoh, Stanko Štuhec, Rok Vertic

L'objectif de cette étude était d'examiner la constance et la variabilité des paramètres cinématiques au niveau de la technique utilisée dans le triple saut, une des disciplines les plus complexes de l'athlétisme. Deux essais d'une sauteuse féminine du plus haut niveau mondial accomplis dans des conditions de laboratoire, en amont de sa préparation pour les Jeux olympiques 2008, où elle s'est classée sixième de la finale. Le système Optotrak, ainsi que la technologie cinématique 3D, ont été utilisés pour étudier les paramètres du modèle technique. L'analyse a révélé que des résultats optimaux peuvent être obtenus au travers de différentes stratégies de programme moteurs et que le schéma moteur est généré par des paramètres tant constants que variables. Les paramètres les plus constants du schéma moteur au niveau du sujet étudié ont été: les distances partielles des différentes phases, la durée des phases d'appui lors des actions de décollage, les angles de décollage et l'amplitude verticale du centre de gravité du corps. La variabilité du schéma moteur a été révélée principalement au niveau des paramètres cinématiques suivants: la vitesse atteinte lors des cinq derniers mètres de la course de prise d'élan et la vitesse horizontale du centre de gravité du corps lors de l'action de décollage.
L’importance de la vitesse de décollage horizontale et verticale pour les spécialistes féminines du saut en longueur de l’élite mondiale
Par Stefan Letzelter

Bien que les recherches biomécaniques portant sur les sauteurs en longueur du plus haut niveau mondial aient augmenté les connaissances sur la discipline, les analyses effectuées à date sont sujettes à certaines limites, notamment liées à un échantillonnage restreint et au peu d’études effectuées portant sur les athlètes féminines. Parmi les questions encore ouvertes sont la fiabilité statistique des résultats portant sur les éléments de la vitesse de décollage, tant horizontale que verticale, et le fait de découvrir si les résultats obtenus peuvent s’appliquer aux femmes comme aux hommes. Cette étude, qui s’appuie sur les résultats publiés à l’issue de six compétitions majeures, afin de fournir une base de données plus étendue, a analysé les aspects liés à la vitesse de décollage, horizontale et verticale, avec trois critères statistiques différents, pour un total de 42 femmes qui ont accompli des sauts entre 6,14m et 7,40m. Ceci a permis des comparaisons sur l’impact de ces deux facteurs sur les résultats, et la possibilité de tester cinq hypothèses. Parmi les résultats on retiendra les éléments suivants: a) les meilleurs sauteurs présentent des avantages, allant au-delà des coïncidences, plus élevés que les autres au niveau de la vitesse de décollage verticale et de la vitesse de décollage horizontale, la composante verticale étant bien plus distinctive, b) le rapport entre la vitesse de décollage horizontale et celle du décollage vertical diffère au niveau des athlètes étudiés, se situant entre 2,1 et 3,6 et c) d’excellents sauts peuvent être réalisés au travers de combinaisons très différentes des deux facteurs, mais en général le rapport relevé auprès des athlètes ayant obtenu les meilleurs résultats est significativement moins élevé.

Positions intermédiaires occupées en course par les médaillés des courses de demi-fond et de fond des Jeux olympiques de 2008
Par Joseph W. Duke, Timothy D. Mickleborough, Joel M. Stager, Robert F. Chapman

L’objectif primaire lors de courses de demi-fond et de fond de championnats d’athlétisme est de gagner la course, se qualifier pour le tour suivant ou remporter une médaille en finale. Une stratégie totalement différente au niveau de l’allure peut donc être adoptée par rapport à celle d’un coureur cherchant simplement à réussir le temps le plus rapide possible. Le but de cette étude était de déterminer comment les positionnements en cours de course et les capacités de sprint final des athlètes se rapportaient aux classements finaux des compétiteurs dans les courses d’endurance des Jeux olympiques de 2008. Des temps intermédiaires pour chaque 100m ont ainsi été enregistrés pour les hommes et les femmes sur chaque course entre 800m et 10 000m, tandis que les positions moyennes occupées étaient calculées à chaque cinquième de chaque course (sauf sur 800m, où les places occupées pour chaque quart de la course ont été retenues). Il a été déterminé que la position ou la stratégie de course varie selon les distances et le sexe. Typiquement, les médaillés sur les distances les plus courtes (800m et 1500m), se portent aux trois premières places plus tôt dans la course que ne le font les médaillés des épreuves plus longues. Les médaillés dans les courses plus longues chez les hommes ont ainsi tendance à compter davantage sur leur sprint final, tandis que les femmes médaillées ont généralement tendance à se placer parmi les trois premières plus tôt dans la course.
La progression des meilleurs athlètes juniors néo-zélandais et australiens vers les rangs seniors
Par Stephen Hollings et Patria Hume

Il est généralement considéré probable qu'un athlète qui s'illustre au plus haut niveau junior va progresser pour connaître une bonne carrière chez les seniors. Cette étude s'est penchée sur cette notion en suivant l'évolution d'athlètes australiens et néo-zélandais ayant participé aux Championnats du monde juniors (CMJ) de 1986 à 2006, examinant leurs résultats subséquents lors d'épreuves majeures seniors, tels les Jeux du Commonwealth, ou d'autres championnats mondiaux. Il a été déterminé que 22% des Australiens et 32% des Néo-Zélandais qui ont remporté des médailles ou sont parvenus en finale des CMJ ont, une fois seniors, gagné des médailles, sont parvenus en finale de championnats majeurs ou sont montés sur un podium des Jeux du Commonwealth. Cette probabilité est plus importante si l'athlète a été médaillé aux CMJ, et moins importante s'il n'a, soit pas remporté de médaille, soit n'a même pas participé aux CMJ. Parallèlement, le taux de déperdition d'athlètes australiens et néo-zélandais qui ont pris part aux CMJ mais n'ont pas, par la suite, représenté leurs pays au niveau senior, est élevé (aux alentours de 72%). Les auteurs avancent que des stratégies pour produire des athlètes de haut niveau devraient se baser sur: 1) la production d'un nombre plus important de finalistes et médaillés des CMJ; 2) la rétention de juniors dans l'athlétisme jusqu'au niveau senior; 3) l'introduction d'un plus grand nombre de ressources bénéficiant aux finalistes et médaillés des CMJ.

Gros plan sur le développement - l'Ukraine
Par Helmut Digel

L'Ukraine est riche d'un passé en athlétisme long et glorieux. Lorsqu'elle faisait partie de l'Union Soviétique, elle a fourni un nombre important de ses athlètes les plus réputés, notamment les champions olympiques Valeriy Borzov et Sergey Bubka, deux hommes qui occupent désormais des positions prépondérantes au niveau des instances dirigeantes sportives ukrainiennes. Depuis l'accession à l'indépendance de l'Ukraine, en 1991, des athlètes ukrainiens ont remporté quinze médailles olympiques, et cette nation figure de manière constante parmi les pays connaissant le plus de succès aux niveaux européen et mondial. Cette réussite a contribué à faire de l'athlétisme un des sports les plus populaires du pays, lui assurant un soutien continu de la part de l'État. Les réussites de l'athlétisme ukrainien sont largement imputables au modèle de soutien du gouvernement. Dans cette étude de cas, l'auteur décrit les éléments clés du modèle et avance des avis éclairés sur la situation. Au nombre des points traités figurent la fédération, l'infrastructure de l'athlétisme, les entraîneurs, les officiels techniques, le système de détection de talents, la structure de développement des performances ainsi que le système de récompenses.
Аннотация

Биомеханический анализ горизонтальных прыжков на чемпионате мира по легкой атлетике ИААФ 2009 года
Луис Мендоса, Эрхард Никсдорф
Перевод с немецкого Юрген Шиффер

На чемпионате мира по легкой атлетике ИААФ 2009 года активно работали немецкие специалисты, которым была представлена хорошая возможность изучить действия сильнейших спортсменов мира. Работу бригады, в которую входили 18 исследователей из шести немецких институтов, поддерживали Федерация легкой атлетики Германии (DLV) и ИААФ. Объектом исследования являлись горизонтальные прыжки у мужчин и женщин. Скорость отталкивания в каждой попытке измерялась лазерным прибором, а характеристики движений анализировались с помощью 2D скоростной видео съемки. Анализировались лучшие попытки каждого спортсмена, попавшего в финальную часть соревнований. Данный отчет подготовлен специально для журнала Легкоатлетический Вестник ИААФ. Авторы рассматривают семь основных положений, которые характеризуют современную модель техники прыжков.

Постоянство и вариативность кинематических параметров тройного прыжка
Милан Кох, Станко Стухеч, Рок Ветич

Задачей данного исследования было выявить постоянные и вариативные параметры тройного прыжка, техника которого является одной из самых сложных в легкой атлетике. Были проанализированы две попытки элитной спортсменки, которые были проведены в лаборатории в процессе подготовки к Олимпийским играм, где испытуемая заняла 6 место. Использовалась Opto-track система и 3D кинематическая технология с целью изучения параметров модели прыжка. Анализ позволил обнаружить оптимальные параметры при различной двигательной стратегии и то, что двигательные модели обладают как постоянными, так и вариативными компонентами. Постоянными параметрами двигательной модели были: длина отдельных составляющих целостного прыжка, длительность фаз отталкивания, углы отталкивания и вертикальная амплитуда общего центра тяжести тела. Вариативные параметры были следующими: скорость на последних пяти метрах разбега, длина и соотношение двух последних шагов разбега, горизонтальная скорость перемещения общего центра тяжести тела в процессе отталкиваний.
Аннотация

Соотношение горизонтальной и вертикальной составляющей при отталкивании элитных прыгунов в длину

Стефан Лейтцер

Среди биомеханических исследований техники элитных прыгунов в длину можно отметить некоторые недостатки: незначительное количество исследований женских прыжков и анализ небольших групп спортсменок. Среди публикаций заметны исследования, которые представляют статистические разработки о соотношении вертикальной и горизонтальной составляющих скорости отталкивания у мужчин и женщин. Наше исследование основано на анализе компонентов отталкивания, с помощью трех различных статистических критериев у 42 спортсменок, которые имели результат от 6.14 до 7.40 м. Данные позволили определить взаимное влияние двух компонентов и проверить пять различных предположений. В результате исследования получены следующие выводы: а) сильнейшие спортсменки имели явное преимущество, как в горизонтальной, так и вертикальной составляющей скорости в отталкивании, причем вертикальная составляющая проявлялась наиболее отчетливо; б) соотношение горизонтальной скорости к вертикальной выражается значениями 2.1 – 3.6; в) лучшие прыжки достигаются в результате различного соотношения скоростей, но в среднем у сильнейших спортсменок такое соотношение существенно ниже.

Положение на дистанции у бегунов на длинные и средние дистанции на Олимпийских играх 2008 года

Джозеф В.Дюк, Тимоти Д. Микелборуо, Джоел М. Стагер, Роберт Ф.Чапман

Очевидно, что существуют различные задачи в соревнованиях по бегу на средние и длинные дистанции – победить в забеге, квалифицироваться в следующий раунд, завоевать медаль в финале или провести бег для достижения лучшего времени. Задачей данного исследования было выявить, каким образом позиция во время бега и способность к финишному ускорению определяли приход спортсменов к финишу во время соревнований на Олимпийских играх 2008 года. Время на отрезках 100 метров замерялось в беге от 800 до 10000 метров в финалах, а также определялось положение на дистанции первых пяти спортсменов, за исключением бега на 800 метров, где анализировалось положение только первых четырех спортсменов. Определено, что стратегия бега является различной на разных дистанциях у мужчин и женщин. Медалисты на более коротких дистанциях (800 и 1500 м) перемещались к позиции медалистов раньше, чем на более длинных дистанциях. Медалисты в длинных дистанциях у мужчин стремились завершить дистанцию финишным спринтом, в то время как у женщин спортсменки занимали медальные позиции ранее.
Продвижение сильнейших юниоров Новой Зеландии и Австралии во взрослый спорт
Стефен Холлингс, Патриа Хьюм

Скорее всего, сильнейшие юниоры должны достигать определенного успеха в соревнованиях взрослых спортсменов. Этот тезис мы проверили на основании анализа выступлений юниоров Новой Зеландии и Австралии на юниорских чемпионатах мира в период 1986 -2006 годов и их последующих достижениях на Играх Содружества наций и других международных соревнованиях. Определено, что только 22% австралийцев и 32% представителей Новой Зеландии, которые занимали призовые места на соревнованиях юниоров, достигли успеха в крупнейших международных соревнованиях в разряде взрослых спортсменов. Значительное количество успешных юниоров не смогло достойно соревноваться в разряде взрослых спортсменов (~72%), что позволяет нам сделать следующие выводы для совершенствования подготовки взрослых спортсменов: 1) необходимо готовить большее количество успешных юниоров; 2) стараться уменьшить количество юниоров, уходящих из спорта; 3) поддерживать медалистов и финалистов чемпионатов мира среди юниоров.

Развитие спорта в Украине - Модель успеха
Хельмут Дигель

Украина восстанавливает свои традиции в легкой атлетике. Как часть Советского Союза в прошлом, спортсмены этой страны достигали выдающихся успехов на Олимпийских играх. Теперь Олимпийские чемпионы Валерий Борзов и Сергей Бубка занимают лидирующее положение в спортивных организациях Украины. С момента получения независимости украинские легкоатлеты завоевали 15 медалей на Олимпийских играх и сейчас эта страна находится постоянно среди лидеров на европейских и мировых соревнованиях. Такие достижения делают легкую атлетику одним из самых популярных видов в этой стране, причем такая популярность постоянно поддерживается правительством. Автор отмечает наиболее важные элементы развивающегося спорта в Украине. Рассматривается деятельность федерации, общей структуры легкоой атлетики, подготовка тренеров, система поиска талантов, развитие и поощрения спортсменов и тренеров.
摘要

2009年国际田联世界田径锦标赛水平跳跃项目的生物力学分析

路易斯·门多萨，艾伯哈德·尼克斯道夫

约根·西弗尔泽德文

2009年柏林国际田联世界田径锦标赛为德国运动科学家们提供了难得的机会，在这次家门口赛场举行的世界最高水平比赛中，来研究世界最优秀运动员们。在国际田联和德国田径协会支持下，由来自全国6所院校的18名研究人员组成的团队，在这届锦标赛上计时、组织和实施了一项重要的生物力学研究项目。这个项目的目标包括，为参加全部水平跳跃项目决赛的男子和女子运动员进行详细的分析。在每个项目前8名决赛运动员的比赛中，采用激光测距设备测量运动员每次试跳的助跑速度，并采用高速摄像机把运动员最好一次试跳的成绩记录下来，进行二维录像分析。本报告专门为《田径运动新研究》准备，根据项目团队获得的数据，对各个项目比赛的每个部分进行分析和讨论。在结束部分作者们提出七个方面的观点，总体上证实了目前流行的各种技术模式。

三级跳远运动学参数的一致性和变化性

米兰·科，斯坦科·斯图赫克，洛克·沃提克

本研究的目的是考察在三级跳远，田径运动在最复杂的项目之一，所使用运动学参数的变化性一致性和一致性。采用一名优秀女子跳远运动员为受试者，在她备战2008年奥运会期间，在实验室条件下试跳2次。她在2008年奥运会决赛中取得第6名。采用Opto轨道系统和三维运动学技术，研究规范技术的各个参数。分析揭示出采用不同动作程序策略所达到的最佳结果，以及由各种一致和变化的参数所产生的动作模式。受试者动作模式中最具有一致性的参数为：各个单独阶段的部分距离、起跳动作各个支撑阶段的时间、起跳角度和人体质心的垂直振幅。动作模式的变化性在以下运动学参数中被最大程度地揭示出来：助跑最后5米的速度、助跑最后2步的长度和比例、起跳动作人体质心的水平速度。
优秀女子跳远运动员水平和垂直起跳速度的重要性

斯特凡·勒兹尔特

对于优秀跳远运动员的生物力学研究，虽然已经增加了人们对于这个项目的认识，但至今所进行的这些分析仍然具有特定的局限性，包括样本量小，而且对于女子的研究很少。在这些仍然开放的问题中，包括对于水平和垂直起跳速度研究结果的统计学可靠性，以及这些研究结果是否对于男子和女子同样有效。本研究依据来自6个主要项目已经发表的研究结果所提供的大量数据基础，采用3个不同的统计学标准，分析了42名成绩在6.14米至7.40米之间的女子跳远运动员水平和垂直起跳速度。这使我们能够比较水平和垂直起跳速度的影响，并且有可能验证所提出的5个假设。研究发现：1、成绩更好的跳跃运动员与其他运动员相比，在水平和垂直起跳速度上，具有超出巧合性优势更多的因素，垂直速度更加突出。2、在被研究的运动员中，水平和垂直起跳速度的比值处于2.1至3.6之间。3、水平和垂直起跳速度组合差异很大的运动员也能够取得出色跳跃成绩，但总体上看，更加成功的运动员这个比值显著较低。

2008年奥运会径赛耐力项目奖牌获得者的赛中位置

约瑟夫·W·杜克，提摩西·D·米克尔波拉夫，周·M·斯塔格尔，
罗伯特·F·查普曼

在比赛中，中长跑项目的主要成绩目标是赢得比赛，取得下一轮比赛的资格，或者在决赛中取得奖牌。与让运动员取得某个最好成绩的策略相比，这里可能需要一种完全不同的比赛策略。本研究的目的是，考察在2008年奥运会径赛耐力项目运动员中赛中位置的确定，以及相对于到达终点名次的最后冲刺能力。对于所有男子和女子800米至1000米的决赛运动员，取得每100米距离的分段时间，计算比赛第五名的平均赛中位置。但800米比赛除外，也包括了计算比赛第四名的赛中位置。研究发现，不同项目和性别运动员的位置或比赛策略有所区别，与较短距离项目相比，在较短距离项目的奖牌获得者（如800米和1500米），运动员典型地较早进入取得奖牌的位置。较短距离男子项目的奖牌获得者，倾向于依靠终点冲刺能力取得他们的最终位置，而女子奖牌获得者一般在比赛中较早地进入取得奖牌的位置。
新西兰和澳大利亚优秀青年运动员向成年运动员的参赛车进程

斯蒂凡・霍林斯，帕特里亚・休姆

在青年时期成功地达到高水平运动成绩的人，存在着在成年时期继续保持成功的合理机会。本文作者通过对于澳大利亚和新西兰参加1986年至2006年世界青年锦标赛运动员的成绩，直至他们参加成年世锦赛和英联邦运动会成绩的研究，检验了这种观点的正确与否。研究发现，取得世界青年锦标赛奖牌和进入决赛的22%的澳大利亚运动员和32%的新西兰运动员，进入成年后可以获得国际比赛奖牌，或进入决赛，或取得英联邦运动会奖牌。如果运动员赢得世界青年锦标赛奖牌，这种机率更大，但如果运动员只参加了世界青年锦标赛比赛或根本没有参加比赛，这种机率很小。同时，参加了世界青年锦标赛的澳大利亚和新西兰运动员，而在成年时期不去代表他们的国家参赛的总淘汰率也很高（~72%）。作者们建议，培养成功的成年运动员的策略基于以下因素：1、培养更多的世界青年锦标赛奖牌获得者和进入决赛的运动员；2、把青年运动员保留在运动项目中参加训练直至成年阶段；3、集中使用资源培养世界青年锦标赛奖牌获得者和进入决赛的运动员。

发展焦点-乌克兰，一个成功模式

赫尔穆特・迪格尔

乌克兰具有长期和光荣的田径运动传统。曾经作为前苏联的一部分，她为国家贡献了许多著名的成功故事。那些最引人注目的运动员冠军，如瓦列里・鲍佐夫和塞基・布勃卡，他们二人目前都在乌克兰体育组织中担任领导职务。自从1991年独立后，乌克兰运动员在奥运会中赢得了15枚奖牌，最近这个国家在世界和欧洲水平上，继续处于最成功的国家行列之中。这种成功，帮助田径运动成为在公众中最普的运动之一，并且保证了持续的政府支持。运动成就在很大程度上归功于国家的支持模式。在个案研究中，作者概括了这个模式的各个关键因素，并且提出了有趣的见解。这些观点包括协会、田径运动基础设施、教练员、裁判员、选材系统、成绩培养结构和奖励系统。
تقدم اللاعبين النيوزيلنديين والاستراليين النخبة لتمثيلهم في الدرجة الأولى عموم

بقلم ستيفن هولينغ وباتريا هيوم

ملخص

هناك احتمال معقول أن اللاعبين الشباب الذين حققوا مستوى عالي من النجاح سوف يستطيعون في هذا النجاح عند وصولهم لمستوى الدرجة الأولى. أجريت هذه الدراسة لاختبار هذه الفكرة من خلال متابعة اللاعبين الاستراليين والنيوزيلنديين الذين شاركوا في بطولة العالم للشباب من عام 1986 حتى 2006، أي مع وصولهم لمستوى العموم. وآtinما أثناء دورة ألعاب الكومنولث وغير ذلك، حيث ثبت أن 72% من أصحاب الميداليات الاستراليين والذين وصلوا إلى الدور النهائي و32% من أصحاب الميداليات النيوزيلنديين وذين وصلوا إلى الدور النهائي اشتروا ليصبحوا أصحاب ميداليات عالمية أو يصلوا إلى التصنيفات النهائية أو فازوا بدورة ألعاب الكومنولث لفة العموم، يكون الاحتمال كبير إذا حصل اللاعب على ميدالية بطولة العالم للشباب وأقل من ذلك بكثير إذا تنافس اللاعب فقط في بطولة العالم للشباب أو لم يشارك على الإطلاق. في الوقت نفسه، فإن معدل عام لاستئناف اللاعبين الاستراليين والنيوزيلنديين الذين شاركوا بطولة العالم للشباب ولكن لم يثمروا في تمثيل دولهم كلاعبين في العموم كان مرتفعا حيث وصل إلى (72%). ويتوقع المؤلفان أنه ينبغي أن تتبع الاستراتيجيات الخاصة بصنع لاعبين درجة أولى على (1) تحقيق ميداليات أكثر والوصول إلى الأدوار النهائية في بطولة العالم للشباب، (2) الحفاظ على اللاعبين الشباب في هذه الرياضة حتى الوصول إليهم إلى مستوى العموم؛ (3) تركيز الموارد على ميداليات بطولة العالم للشباب ونهائيات الشباب.

التحليل البيوميكانيكي لمسابقات الوثب الأفقي في بطولة العالم لألعاب القوى 2009

بقلم لويس ميدوزا وليبرارد نيكسورد

ملخص

قدمت بطولة العالم لألعاب القوى التي أقيمت ببرلين عام 2009 فرصة نادرة للاعبين الألمان المتخصصين بالرياضة لأداء أفضل اللاعبين نو مستوى العالم في منافسة نو مستوى عال وفي مكان قريب من موطنهم. فاز فريق موطن من 18 باحثًا من مدارس من ألمانيا بتخطيط مشروع كبير حول الميكانيكا الحيوية وتنظيمه وتنفيذاته أثناء البطولة وذلك بدعم كل من الاتحاد الألماني لألعاب القوى والاتحاد الدولي لألعاب القوى، وتشملت أهداف المشروع إجراء تحليل تفصيلي للأدوار النهائية لمسابقات الوثب الأفقي للرجال والسيدات. كما تم قياس سرعة الإقتراب لكل محاولة باستخدام جهاز قياس الليزر والتحليل بالفيديو ثنائي الأبعاد. يعد تسجيلات الفيديو التي أجريت باستخدام كاميرا فيديو عالية السرعة لأفضل محاولات لأفضل ثمانية مراكز في كل مسابقة من المسابقات، هذا التقييم الذي أعد خصيصًا لمعالجة دراسات جديدة في فئة العموم، يتيح تحليل وتفسير البيانات التي حصل عليها فريق المشروع يتطلبها أقسام خاصة بكل مسابقة من المسابقات. كما أنه الباحثون المقالة برصد سبع نقاط تؤكد بشكل عام النماذج الفيزيائية الحالية.
أهمية سرعة الارتداء الأفقية والعمودية للاعبات الوثب من النخبة

بقلم: ستيفان ليتزيلتر

ملخص

على الرغم من أن نتائج الدراسات المخبرية التي أجربت على لاعبات النخبة للرسب الطويل قد أظهرت من المعرفة الخاصة بهذه المسابقة إلا أن التحليلات التي أجريت حتى الآن تعاني من بعض القصور التي تضمن أحماض صغيرة للغاية وعدد قليل من البيانات التي أجريت على اليمنى. من بين القضايا التي لا تزال البحث لا يدح، هو صناد النتائج الإحصائية حول المكونات الأفقية والرأسية لسرعة الارتداء، إذ كانت النتائج صالحة للرجال والسيدات على حد سواء. هذه الدراسة استندت إلى نتائج دراسات تم نشرها من ستة مسابقات كبيرة التي تعزى مجموعة كبيرة من البيانات التي تحلل كن مكونات سرعة الارتداء بثلاث معايير إحصائية مختلفة لمجموعة مكونة من 42 لاعبة الراقصين تراوح قيائتهم بين 6.14 و 7.40 م. مما يسمح بإجراء مقارنات تأثير كل من مكونات النتائج، وكمية القوة مفصلية. ومن بين نتائج الدراسة ما يلي: 

- تحقق أفضل لاعبات للثب بيزاميا توقع أكثر من غيرهم في المكونات الأفقية والرأسية مع وضع الأسلوب العمودي بشكل كبير. 

- النتائج الإحصائية لدراسة اللاعبين ومواضع الدراسة بين 2.1 و 3.6 و 7.40 م. يمكن تحقيق الولادات الممتازة بتركيبات مختلفة جدا للنصعين ولكن بشكل عام نقل نسبة اللاعبين الأكثر نجاحا بشكل كبير.

الوضع داخل السباق لصاحب ميداليات مسابقات الاضمار للتحمل في دورة الألعاب الأولمبية لعام 2008

بقلم: جوزيف ديلو دوك ويبسو ذي مكلولوج وجويل أم استييور وروبرت في شامان

ملخص

الهدف الأساسي للناشئ في مسابقات المسافات المتوسطة والطويلة يتمثل في الوصول السريع والثابت للدوري الثاني أو الفوز بميدالية في المباراة النهائية. وقد يكون هناك حاجة استراتيجيات سعرية مختلفة تماما عن التي تتخذها اللاعب ليحاول تحقيق أسرع وقت. كان الهدف من هذه الدراسة هو تحديد الترتيب داخل السباق والقدرة على العدو في نهاية السباق المرتبطة بالترتيب النهائي لإنهاء المستويين في مسابقات التحمل في دورة الألعاب الأولمبية عام 2008. تم ترتيب الأزمات المنفصلة لكل 100 م لسباق 800 م رجال وسيدات حتى نهائيات 10000 م. ما يعبى حسب أوضاع السباق لكل خمس من السباق بثبات 800 م التي يحس بها الأجزاء الأربعة، حيث تبين أن ترتيب السباق أو استراتيجيات السباق تختلف فيما بين المسابقات والانجازات. فأصحاب الميداليات في المسافات المتوسطة (مثل 800 م و 1500 م) ينتميون عادة نحو الفوز بالميداليات في وقت سابق عن لاعبي المسافات الطويلة. ولهالأحالي رأى الفيداليات في مسابقات المسافات الطويلة للرجال تعود على القصد الكاف على القدرة على العدو في نهاية السباق مع ترتيبهم النهائي في حين أن اللاعبين المحترفين على الميداليات يخمنون الترتيب الخاص بالميداليات في وقت مبكر من السباق.
Tقدم اللاعبين النيوزيلنديين والاستراليين النخبة لتمثيلهم لاعبي الدرجة الأولى عموم

بقلم ستيفن هولينغ وباتريزا هيومن

ملخص

هناك احتمال معقول أن اللاعبين الشباب الذين حققوا مستوى عالي من النجاح سوف يتمتعوا في هذا النجاح عند وصولهم لمستوى الدرجة الأولى. أجريت هذه الدراسة لاختبار هذه الفكرة من خلال متابعة اللاعبين الاستراليين والنيوزيلنديين الذين شاركوا في بطولة العالم للشباب من عام 1986 حتى 2006 أي مع وصولهم لمستوى العموم وأدائهم أثناء دورة ألعاب الكومنولث - وغير ذلك. حيث تبين أن 22٪ من أصحاب الميداليات الاستراليين والذين وصلوا إلى الدور النهائي و32٪ من أصحاب الميداليات النيوزيلنديين الذين وصلوا إلى الدور النهائي استمروا ليصبحوا أصحاب ميداليات عالمية أو وصلوا إلى التصفيات النهائية أو فازوا بورة ألعاب الكومنولث لفئة العموم. يكون الاحتمال كبير إذا حصل اللاعب على ميدالية بطولة العالم للشباب وأقل من ذلك بكثير إذا تناسب اللاعب فقط في بطولة العالم للشباب أو لم يشارك على الإطلاق. في الوقت نفسه، فإن المعدل العام لاستنزاف اللاعبين الاستراليين والنيوزيلنديين الذين شاركوا في بطولة العالم للشباب ولكن لم يستمروا في تمثيل دولتهم كلاعبين فئة العموم كان مرتفعا حيث وصل إلى (−72٪). ويتضح الموقف أن ينبغي أن تتم الاستراتيجيات الخاصة لصنع لاعبي درجة أولي على 1) تحقيق ميداليات أكثر والوصول إلى الأدوار النهائية في بطولة العالم للشباب، 2) الحفاظ على اللاعبين الشباب في هذه الرياضة حتى الوصول بهم إلى مستوى العموم. 3) تركز الموارد على ميداليات بطولة العالم للشباب ونهائيات الشباب.

تطوير نقاط الاهتمام الجماعية - أوكرانيا، نموذج النجاح

بقلم هيلموت ديجيل

ملخص

يمكن لأوكرانيا أن تنظير إلى تاريخها الطويل والمجرد في ألعاب القوى. فقد ساعد كونها جزءًا من الاتحاد السوفيتي على دعم العديد من انتصارات هذه الدولة الشهيرة، وعلى الأخراش إنجازات الأبطال الأولمبيين فالي بورزوف وسيرجي بويكين الذين بحتلا في الوقت الحاضر مناصب قيادية في المنظمات الرياضية الأوكرانية. ومنذ استقلالها في عام 1991 فاز اللاعبين الأوكرانيين بخمس عشر ميدالية في الألعاب الأولمبية كما أصبحت الدولة مؤخرا من بين أكثر الدول نجاحا على المستوى الأوروبي والعالمي. وقد ساعد هذا النجاح على جعل ألعاب القوى من أكثر الرياضات شعبية عند الجمهور كما ساعدت على ضمان استمرار الدعم الحكومي. ويرجع الفضل في الإنجازات الرياضية إلى حد كبير إلى نموذج الدعم في الدولة. في دراسة الحالة هذه، يحدد المؤلف العناصر الرئيسية لنموذج ويقدم أفكارًا مثيرة للإلهام. وتشمل النقاط الخاصة برداسة الحالة كل من الاتحاد وال المواطنين لألعاب القوى والمدراء والمديرين الفنيين وطرق إنقاذ المواهب وطرق تطوير الأداء ونظم المكافأة.
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