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The 2012 Olympic Games in London were a grand spectacle with many, many highlights and wonders. What memories the whole of the sports movement will keep of this spectacular and fantastic event. To be sure, we owe our thanks to everyone involved, the athletes, the organisers, the volunteers, the sponsors, the spectators and the people of London and Great Britain. Bravo, congratulations and well done to all!

For me, it was fitting that, in the centenary year of the IAAF, the sport of athletics provided the highest of the high points. Throughout the week that our sport held centre stage, the energy in the air was remarkable. Every day the 80,000 seat Olympic Stadium was completely full of knowledgeable and supportive spectators - for both the evening’s finals and the morning sessions. This unique achievement underlines the position of athletics with the public and its central importance to the Olympics.

And in this perfect setting, the athletes delivered.

Has a home crowd, in any sport, ever enjoyed a night like August 4, when the British athletes won three gold medals in a single hour? Will we ever forget how, one week later, the stadium literally shook from the crowd’s noise during the last lap of the 5000m, won by the local favourite Farah? And will we ever fully comprehend the extent of the inspiration provided by all the heroes, heroines and great performances, the list of which starts with Bolt, Felix, Rudisha and Ennis and then goes on and on?

I believe many lives were changed by athletics during that week. We can and should be proud of our sport and its success. I also believe that there has never been a greater opportunity or a greater urgency to capitalise and strengthen the position of athletics throughout the world.

Of course, even before the Games, President Diack and the IAAF were looking ahead and working in a variety of areas that will shape the future of athletics. Just to pick one, you may have read that we signed a worldwide partnership agreement with Nestlé to expand our reach in the area of schools and youth athletics by spreading the IAAF Kids’ Athletics Programme in cooperation with Member Federations. This complements the recent introduction of the IAAF Teens’ Athletics Programme, which targets 12 to 15 year-olds and provides a necessary bridge to standard competitive athletics.

The summer of 2012 also featured the IAAF World Junior Championships in Barcelona, where many of the stars of the coming years were on display and no less than 73 countries had athletes finish in the top eight of their events. Right after the competition, we invited coaches from around the world to participate in the first “International Youth Training Conference” with financial contributions from the IAAF’s Centenary Celebrations, the International Athletic Foundation and Spain’s International Athletics Documentation, Research and Development Centre (CIDIDA) Foundation. Some of the presentations and findings of this very interesting conference will be published in future issues of NSA.

But for now, the first order of business should be a thorough debriefing of the London Olympic experience. To this end we have asked a number of NSA contributors to share their impressions, views and ideas so that we can learn lessons from and build on what has taken place. We need to look not just at the technical performances, but at the implications for coaching, for supporting athletes, for talent development and even for the organisation and promotion of the sport. Work on this project is currently underway and the results will feature in our next issue.
Finally, I take this opportunity to inform you that I shall be stepping down from my position as Director of the IAAF Member Services Department to take up new challenges at the end of December 2012. With the London Games and soon the debriefing behind us, it is a natural point for making personal and organisational changes for the next Olympic cycle and beyond.

I want to thank President Diack and the IAAF Council for the opportunity to serve our great sport through this job. I also want to thank all my many colleagues in Monaco and around the world, as well as the readers of NSA, for their valuable cooperation over the years. I believe that together we have made great strides in promoting all aspects of athletics and that the sport is well positioned for even more development in the future.

My capable long-time colleague Abdel Malek El-Hebil will be taking over as Director of the Department and I know you will join me in wishing him every success.

I am looking forward to being closely involved in some way with the magazine and its readers for some time to come. More information on any changes that will come into effect next year will be published in issue 4/2012.

In the meantime, your comments on any aspect of NSA are always welcome.

Elio Locatelli
Editor in Chief
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High Jump

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Plyometric Training and the High Jump

by Jürgen Schiffer

Introduction

Plyometric training is an important element of the training programme of most top-level jumpers, including high jumpers. Although it has developed over more than half a century and been reported in the literature, its proper utilisation is still not fully understood by many coaches. Some apply plyometrics incorrectly, which can reduce the positive training effects or even lead to injuries, while others avoid the means, and thus compromise the potential performances of their athletes.

The aim of this article is to address this situation by providing a summary of the main aspects of plyometric training, drawn from the current literature, as a general guide and as a starting point for further study and discussion. Special emphasis is given to the use of plyometrics in training for the high jump.

The main points to be covered are:

- The history of plyometric training,
- The scientific basis of plyometric training,
- Plyometric training compared to traditional resistance training and ballistic training,
- Integration of plyometric training in the athlete’s training programme,
- Practical aspects of plyometric training,
- Plyometrics and resistance training,
- Plyometrics and circuit training,
- Plyometric drills,
- Plyometrics and the high jump.

The History of Plyometric Training

Although western training scientists became aware of plyometrics in the mid-1970s, this form of training was developed in the Soviet Union in the 1950s and early 1960s (DUKE, 1990). The term was initially synonymous with triple jumpers and triple jump training (see, for example, YOUNG & MARINO, 1985). To develop the type of loads that the plant leg had to withstand in the hop and step phases, athletes trained by jumping down from one box onto the plant leg and instantly jumping up onto another box. The terms “stretch-shortening” training, “depth jump” training, “reactive” training, “drop jump” training and “eccentric-concentric” training started appearing in the literature more and more in the 1960s.

A particularly important piece of literature at the time was a study by Verhoshanski (1967), where he advocated depth-jump heights between 0.75 and 1.15m. According to REID (1989), many coaches took this to mean athletes could develop the stretch reflex by jumping down from boxes higher and higher, landing on pre-stretched plant leg and bound back up onto another box. Such training was not substantiated by scientific research and the injury score increased. However, over-zealous coach-
es often rationalised that athletes who could not complete the drill were simply too weak.

Valeriy Borzov’s (URS) double victory in the sprints at the 1972 Olympic Games in Munich 1972 made everyone aware of how plyometrics can be incorporated into a sprint training programme. Borzov made extensive use of various jumping exercises in his training but was by no means the first sprinter to utilise plyometric training. Armin Hary (FRG), the 100m gold medallist in the 1960 Olympics, made use of various jumping exercises throughout his training programme. Many sprinters have also participated in the long jump, the training for which serves a similar purpose. A good example is Irena Szewinska (POL), the multiple Olympic medallist, who incorporated extensive jump training into her programme (GAMBETTA, 1987).

However, plyometric training has by no means been the exclusive domain of the sprinters/jumpers. Throwers, too, have used plyometrics, both for the upper and lower body. Upper body plyometrics has mainly taken the form of medicine ball exercises using 3-6kg balls. Janis Lusis (URS), former javelin world record holder and Olympic champion, made extensive use of jump training in the form of hurdle jumps, hopping, and bounding to develop the explosive power in his legs.

Plyometric type training has also been utilised in the realm of middle distance and distance training. Hill bounding, advocated by Arthur Lydiard in the late 1950s, was designed to yield a powerful stride but is nothing more than bounding with the added resistance of the hill. Pekka Vasala (FIN), the 1972 Olympic champion over 1500m, used a six-week period of a ‘bounding endurance phase’ in his training. This was performed up a 400m slope of 5-15° gradient.

All these examples show that plyometric training in itself is not new, but the proper application as a training method needs further clarification and guidelines (GAMBETTA, 1987).

The Scientific Basis of Plyometric Training

During plyometric, or stretch-shortening, exercises the muscle is rapidly stretched (eccentric contraction) and then shortened to accelerate the body upward, as in a countermovement jump (see Figure 1).

Figure 1: Countermovement jump (Hoffman, 2002)

This stretch-shortening cycle has been demonstrated to enhance power performance to a greater extent than concentric training only (e.g. by performing squat jumps) (BOSCO, VILTASALO, KOMI & LUHTANEN, 1982). The improved performance seen in the countermovement jump is attributed to a greater amount of stored elastic energy acquired during the eccentric phase that is able to be recruited during the upward movement of the jump (BOSCO & KOMI, 1979). In addition, the pre-stretch during the countermovement results in a greater neural stimulation (SCHMIDTBLEICHER, GOLLHOFER & FRICK, 1988) as well as an increase in the joint moment (a turning effect of an eccentric force, also referred to as torque at the start of the upward movement (KRAEMER & NEWTON, 2000)). The greater joint moment results in a greater force exerted against the ground with a subsequent increase in impulse (greater force applied over time) and acceleration of the body upward. BOBBERT et al. (1996) have suggested that this latter mechanism may be the primary
1. The primary training method has used traditional resistance training programmes with a relatively high intensity of training (4-6 RM) performed at a relatively slow velocity of movement.

2. Plyometric training is another training method that is used to enhance power performance. Most plyometric exercises require the athletes to rapidly accelerate and decelerate their body weight during a dynamic movement. The athletes’ body weight is most often used as the overload, but the use of external objects such as medicine balls also provides a good training stimulus for certain plyometric exercises.

3. The final method of training to enhance muscular power and explosive sports performance is a combination of traditional resistance training and plyometric training. This form of resistance training is referred to as ballistic training. Ballistic movements (see Figure 2) are forced movements initiated by muscle actions but continued by the momentum of the limbs (KENT, 2006). Ballistic movements are performed at a much lower intensity of training (approximately 30% of 1 RM) using a much higher velocity of movement (WILSON, NEWTON, MURPHY & HUMPHRIES, 1993). The have three main phases: 1) an initial phase of concentric action that starts the movement, 2) a coasting phase that relies on the momentum generated in the initial phase, and 3) a deceleration phase accompanied by eccentric actions (KENT, 2006).

Plyometric Training Compared to Traditional Resistance Training and Ballistic Training

Three methods of training are generally used to improve the power of athletes who participate in dynamic, explosive sports:
Integration of Plyometric Training in the Athlete’s Training Programme

The use of traditional resistance training programmes that require lifting a heavy load at a slow velocity of movement has generally been considered the primary method of increasing power production. This has been based on the notion that because power is equal to force multiplied by velocity, increasing maximal strength enhances the ability to improve power production. However, to maximise power production, it is imperative to train both the force and velocity components.

In novice resistance-trained athletes, large increases in strength are common during the beginning stages of training. Improvements in various power components of athletic performance, such as vertical jump height and sprint speed, may also be evident. This is primarily the result of the athlete being able to generate a greater amount of force. As the athlete becomes stronger and more experienced, the rate of strength development decreases and eventually reaches a plateau. At this stage of an athlete’s career, not only are strength improvements harder to achieve, but improving maximal strength does not provide the same stimulus to power performance as it did during the earlier stages of training. In addition, training for maximum force development may have its limitations on improving power performance. An important factor for maximising power production is exerting as much force as possible in a short period of time. By training for maximal strength through heavy resistance training, the rate of force development does not appear to be enhanced (KRAEMER & NEWTON, 2000). This is supported by a number of studies that showed improvements in vertical jump performance in novice or recreationally-trained individuals after heavy resistance training programmes but limited improvements in individuals or athletes with substantial resistance training experience.

However, if plyometric exercises or a combination of plyometric and resistance training (using a light resistance such as might be used...
Practical Aspects of Plyometric Training

Injury prevention

A primary concern when beginning a plyometric training programme is the increased potential for injury, because the drills place high forces on the musculoskeletal system. The risk of injury can be minimised by heeding the following recommendations:

• Make sure that the athlete has developed a reasonable strength base through a prolonged (>1 yr) resistance training programme.
• Use footwear and landing surfaces with good shock-absorbing qualities.
• Allow for proper warm-up before beginning the exercise session.
• Use proper progression drills; master lower-intensity drills before beginning more complex plyometric exercises.
• All boxes used for drills should be stable and have a nonslip top surface.
• Make sure that there is sufficient space for the desired drill. For most bounding and running drills 30-40m of straightway are required, whereas for some of the vertical and depth jumps, only 3-4m of space are enough. For jumping drills, ceiling height should be approximately 4m.
• Select exercises that have a high degree of specificity within the athlete’s sport to enhance performance gains.
• Ensure that all drills are performed with proper technique.
• Allow for sufficient recovery between exercise sessions, and do not perform plyometric drills when fatigued.

Similar to the development of a resistance training programme, the exercise prescription for plyometric training involves the control of a number of programme variables (HOFFMAN, 2002).

Exercise variables

Intensity

In plyometrics, intensity is controlled by the type of exercise performed. Plyometrics ranges from simple tasks to highly complex and stressful exercises. Starting out with skipping
is much less stressful than alternate bounding. Double-leg hops are less intense than single-leg bounds.

The intensity of plyometric exercises can be increased by adding light weights in certain cases, by raising the platform height for depth jumps, or simply by aiming at covering a greater distance in longitudinal jumps. As far as exercises are concerned, jumps-in-place are the lowest-intensity plyometric exercises while depth jumps represent the highest intensity. Between these extremes there are standing jumps, multiple hops and jumps, and box drills (see Figure 3).

Figure 3: Box drill (DUKE, 1990)

**Volume**

In plyometric training, volume is often measured by counting foot contacts. For example, an activity like the standing triple jump, comprised of three parts, counts as three foot contacts.

The recommended volume of specific jumps in any one session will vary with intensity and progression goals. A beginner in a single workout in an off-season cycle could do 60-100 foot contacts of low-intensity exercises. The intermediate exerciser might be able to do 100-150 foot contacts of low-intensity exercises and another 100 of moderate-intensity exercises in the same cycle. Advanced exercisers might be capable of 150-250 foot contacts of low- to moderate-intensity exercises in this cycle.

The volume of bounding (exaggerated running) activities is best measured by distance. In the early phases of conditioning, a reasonable distance is 30m per repetition. As the season progresses and the athletes’ abilities improve, the distance may be progressively increased to 100m per repetition.

Low-intensity exercises used during warm-up are generally not included in the number of foot contacts when computing volume. Thus warm-ups should stay low in intensity and progressive in nature so they do not overtax the athlete.

**Frequency**

Frequency is the number of times an exercise is performed (repetitions) as well as the number of times exercise sessions take place during a training cycle.

Beginners should have at least 48 hours of recovery between plyometric sessions. If the athlete does not get enough recovery, muscle fatigue will make him or her unable to respond to the exercise stimuli (ground contact, distance, height) with maximal, quality efforts. The overall result is less efficient training for athletic development.

There are varied methods for establishing frequency in plyometric training. Some coaches prefer to use a Monday and Thursday schedule during the preparation cycle. Using the principle of 48-72 hours of recovery for lower extremity training many programme variations can be developed. Running programmes can also be integrated into the training cycle along with or replacing weight training on certain days, although it is recommended...
that weight training be a priority in developing and maintaining the strength base necessary to carry out a successful plyometric training programme.

Because of the stressful nature of plyometrics and the emphasis on quality of work, plyometric exercises should be performed before any other exercise activities. They can be integrated into weight training (this combination is called complex training) in a later cycle in the training year if desired, or they might comprise the entire workout. This is quite conceivable, in fact, if the athlete is involved in athletics, where the plyometric training might be very specific to the event or to skill development.

**Recovery**

Recovery is a key variable in determining whether plyometrics will succeed in developing power or muscular endurance. For power training, longer recovery periods (45-60 sec) between sets or groupings of multiple events, such as a set of 10 rim jumps (=continuous jumps trying to reach the rim of a basketball goal), allow maximum recovery between efforts. A work to rest ratio of 1:5 or 1:10 is required to assure proper execution and intensity of the exercise. Thus, if a single set of exercises takes 10 sec to complete, 50-100 sec of recovery should be allowed.

Less than two seconds of recovery time in a 12 to 20 min workout makes it aerobic. Exercise for both strength and endurance is usually achieved through circuit training, where the athlete continues from one exercise to another without stopping between sets.

**Plyometrics and Resistance Training**

Resistance training is the ideal counterpart of plyometric training as it helps prepare the muscles for the rapid impact loading of plyometric exercises. In resistance training one works to develop the eccentric phase of muscle contraction by first lowering the body or weight and then overcoming the weight using a concentric contraction.

Open-chain resistance training (using machines that isolate a single joint) is useful for developing strength in specific muscle groups. However, the user of plyometrics also needs to perform closed-chain exercises that involve multi-joint activities such as free-weight exercises. These exercises, which are generally performed with the feet fixed to the ground as in squatting, are more functional for athletes, allowing them to assume positions specific to their events when they exercise. Closed-chain exercises have proven themselves to have much higher carryover value than isolated joint exercises in developing athletic ability.

Plyometric training can be successfully integrated with resistance training by imposing a speed-strength task immediately on muscles that have been subjected to pure strength movements like those in weightlifting.

The more intense plyometric exercises become, the more crucial the need for strength. Poor strength in the lower extremities results in loss of stability when landing, and high-impact forces are excessively absorbed by the soft tissues of the body.

Early fatigue also becomes a problem without adequate leg strength. Together, these will result in the deterioration of performance during exercise and an increased chance for injury (CHU, 1998).

**Plyometrics and Circuit Training**

Plyometric training can easily be organised into circuits. By moving from station to station, the athlete can do a variety of exercises that stress either the vertical or linear components of various movement patterns, or both.

By using circuits, athletes can perform activities of even greater duration than with anaerobic, sprint, and interval training. This may move the level of cardiovascular stress toward improvement in aerobic conditioning, resulting in increased stamina (CHU, 1998).
## Plyometric Drills

The following drills are proposed by HOFFMAN (2002):

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<th>Intensity</th>
<th>Starting position</th>
<th>Action</th>
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<tr>
<td>Standing long jumps</td>
<td>Low</td>
<td>Stand in semi-squat position with feet shoulder-width apart.</td>
<td>With a double arm-swing and countermovement with the legs, jump as far as possible.</td>
</tr>
<tr>
<td>Squat jumps</td>
<td>Low</td>
<td>Stand in squat position with thighs parallel-to floor and interlocked fingers behind head.</td>
<td>Jump to maximum height without moving hands. On landing, return to starting position.</td>
</tr>
<tr>
<td>Front cone hops</td>
<td>Low</td>
<td>Stand with feet shoulder-width apart at the beginning of a line of cones.</td>
<td>Keeping feet shoulder-width apart, jump over each cone, landing on both feet at the same time. Use a double arm-swing and attempt to stay on the ground for as little time as possible.</td>
</tr>
<tr>
<td>Tuck jumps with knees up</td>
<td>Moderate</td>
<td>Stand with slightly bent knees and feet shoulder-width apart.</td>
<td>Jump vertically as high as possible, bringing the knees to the chest and grasping them with the hands before returning to floor. Land in a standing vertical position.</td>
</tr>
<tr>
<td>Lateral cone hops</td>
<td>Moderate</td>
<td>Stand with slightly bent knees and feet shoulder-width apart beside a row of 3-5 cones stretched 2-3 ft apart.</td>
<td>Jump sideways down the row of cones, landing on both feet. When the row is complete, jump back to starting position.</td>
</tr>
<tr>
<td>Double-leg or single-leg zigzag hops</td>
<td>Moderate</td>
<td>Place 6-10 cones 50-75cm apart in a zigzag pattern. Begin with slightly bent knees and feet shoulder-width apart.</td>
<td>Jump diagonally over the first cone. On landing, change direction and jump diagonally over each of the remaining cones.</td>
</tr>
<tr>
<td>Standing triple jumps</td>
<td>Moderate</td>
<td>Stand with feet shoulder-width apart, bending at the knee with a slight forward lean.</td>
<td>Begin with rapid countermovement and jump as far up and forward as possible with both feet, as in the long jump. On landing, make contact with only one foot and immediately jump off. Get maximal distance and land with the opposite foot and take off again. Landing after this jump is with both feet.</td>
</tr>
<tr>
<td>Pike jumps</td>
<td>Moderate-high</td>
<td>Stand with slightly bent knees and feet shoulder-width apart.</td>
<td>Jump up and bring the legs together in front of the body. Flexion should occur only at the hips. Attempt to touch the toes at the peak of the jump. Return to starting position.</td>
</tr>
<tr>
<td>Drill</td>
<td>Intensity</td>
<td>Starting position</td>
<td>Action</td>
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<tr>
<td>Split squats with cycle</td>
<td>High</td>
<td>Stand upright with feet split front to back as far as possible. The front leg is 90°</td>
<td>Perform a maximal vertical jump while switching leg positions. As the legs switch, attempt to flex the knee so that the heel of the back foot comes close to the buttocks. Land in the split squat position and jump again.</td>
</tr>
<tr>
<td>Single-leg hops</td>
<td>High</td>
<td>Stand with one foot slightly ahead of the other, as in initiating a step, with the arms at the sides.</td>
<td>Using a rocker step or jogging into the starting position, drive the knee of the front leg up and out as far as possible while using a double-arm action. The non-jumping leg is held in a stationary position with the knee flexed during the exercise. The goal is to hang in the air as long as possible. Land with the same leg and repeat.</td>
</tr>
<tr>
<td>Single-leg push-offs with box</td>
<td>Low</td>
<td>Stand in front of a box 15-30cm high. Place heel of one foot on the box near the closest edge.</td>
<td>Push off the top foot to gain as much height as possible by extending through entire leg and foot. Use double-arm action for gaining height and maintaining balance.</td>
</tr>
<tr>
<td>Front box jumps</td>
<td>Low-moderate</td>
<td>Stand in front of a box 30-100cm high (depending on ability) with feet shoulder-width apart and hands behind head.</td>
<td>Jump up and land with both feet on the box and step down. For a more advanced exercise, hop down and immediately hop back on top. Use a variety of box heights.</td>
</tr>
<tr>
<td>Multiple box-to-box jumps</td>
<td>Moderate</td>
<td>Stand in front of 3-5 boxes 30-100cm high (depending on ability) with feet shoulder-width apart.</td>
<td>Jump onto the first box then off and jump onto the next box. Continue to the end of the line, using a double-arm action for gaining height and maintaining balance.</td>
</tr>
<tr>
<td>Multiple box-to-box squat jumps</td>
<td>High</td>
<td>Stand in front of 3-5 boxes 30-100cm high (depending on ability) in parallel squat position with feet shoulder-width apart and hands behind head or on hips.</td>
<td>Jump onto the first box, maintaining squat position, then jump off and onto the next box. Continue to the end of the line. Keep the hands behind the head or at the hips.</td>
</tr>
<tr>
<td>Depth jumps</td>
<td>Low-moderate</td>
<td>Stand on a box 30-100cm high (the higher the box height, the greater the intensity of the exercise) with toes close to edge and feet shoulder-width apart.</td>
<td>Step from box and drop to ground with both feet. As soon as there is foot contact, jump explosively as high as possible. Try to have as little ground contact as possible.</td>
</tr>
<tr>
<td>Drill</td>
<td>Intensity</td>
<td>Starting position</td>
<td>Action</td>
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</tr>
<tr>
<td>Depth jumps to prescribed</td>
<td>Moderate</td>
<td>Stand on a box 30-100cm high (the higher the box height, the greater the intensity of the exercise) with toes close to edge and feet shoulder-width apart in front of a box of similar height.</td>
<td>Step from box and drop to ground with both feet. As soon as there is foot contact, jump explosively as high as possible onto the second box. Try to have as little ground contact as possible.</td>
</tr>
<tr>
<td>Single-leg depth jumps</td>
<td>High</td>
<td>Stand on a box 30-45cm high with toes close to edge and feet shoulder-width apart.</td>
<td>Step from box and drop to ground with both feet. As soon as there is foot contact, jump explosively as high as possible with that single foot. Try to have as little ground contact as possible.</td>
</tr>
<tr>
<td>Skipping</td>
<td>Low</td>
<td>Stand comfortably.</td>
<td>Lift one leg with knee bent to 90° while lifting the opposite arm with elbow also bent to 90°. Alternate between both sides. For added difficulty, push off ground for more upward extension.</td>
</tr>
<tr>
<td>Power skipping</td>
<td>Moderate</td>
<td>Stand comfortably.</td>
<td>With double-arm action, move forward in a skipping motion, bring the lead leg as high as possible in an attempt to touch the hands. Try to get as much height as possible when pushing off on back leg. Each repetition should be performed with alternate leg.</td>
</tr>
<tr>
<td>Alternate leg bounding</td>
<td>Moderate</td>
<td>Begin with one foot slightly in front of the other with arms at the sides.</td>
<td>Using a rocker step or jogging into the starting position, push off the front leg and drive the maximal horizontal and vertical distance with either an alternate or double-arm action. Try to hang in the air for as long possible. On landing, repeat with opposite leg. The goal is to cover maximal distance with each jump. This is not designed to be a race or sprint.</td>
</tr>
<tr>
<td>Single leg bounding</td>
<td>High</td>
<td>Stand on one foot.</td>
<td>Bound from the one foot as far forward as possible, using other leg and arms to cycle in air for balance and increase forward momentum.</td>
</tr>
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</table>
**Plyometrics and the High Jump**

According to REID (1989), the discussion of plyometrics and high jumping has to be preceded by a brief discussion of the relationship of fast-twitch and slow-twitch fibers.

Athletes have a combination of the two and their resultant technique in high jumping terms has led to the descriptive terms speed flopper and power or strength flopper (REID, 1984). The approach speed, the gather, the mechanics leading up to and observed in the plant and the take-off time differ between speed and power/strength fappers. For example, the approach velocity of a speed flopper is 7.8-8.4m/sec, whereas the approach velocity of a power/strength flopper is 6.5-7.5m/sec; the approximate take-off time of a speed flopper is 0.13-0.18m/sec, whereas the approximate take-off time of a power/strength flopper is 0.17-0.21m/sec.

The plant is the crucial phase of high-level high jumping. In principle, high jumpers should try to spend as little time in contact with the ground on take-off as possible. Since speed fappers spend a shorter time on the ground than power/strength fappers (due mainly to the fact that they approach the bar faster, slow down less in the gather phase, and are quicker in the take-off portion of the jump), they are more likely to produce world-class high jumps.

Much of the training time for high jumpers, especially speed fappers, is spent working on the take-off mechanism. As the plant foot is about to touch down, not only are the leg muscles pre-flexed or tensed, but accelerating the free leg is the key to continuing the horizontal velocity into vertical acceleration and displacement, providing, of course, the jumper has planted with an almost perfectly straightened leg and not allowed it to flex any further during the plant.

There are two interconnected ways in which the eccentric phase of muscle contraction during the ground contact of jumping can improve the concentric phase of take-off: (a) the activation of the muscle spindles during stretch-
be accomplished with boxes no higher than 15 to 20 cm with the jumper standing on the edge of box number 1 on the toes with both feet together. A little forward momentum and as the jumper leaves the box, the legs are pre-stretched and the jumper lands on the toes, knees held tightly at about 170 or 160°. The jumper pops (or explodes) up onto box number 2 as quickly as possible, landing on the toes; forward lean, drops down onto the floor and pops back up onto box number 3, repeating for box numbers 4 and 5. The athlete then walks back to the start and repeats. The stress on the pre-tensed legs is considerable. The work, with legs hardly flexed at all, is also considerable. The injury factor is negligible. If more loading is required a weight vest is employed. The key is to jump and rebound as quickly as possible, but not by a deep flex at the knee. The athlete can start at five rounds of five boxes and work up from there.

According to REID (1989), the next best plyometric exercise for high jumpers is actual jumping – particularly the scissors technique in practice. It teaches the jumper:

- the feeling of the proper loading on the plant leg (practising pre-tensing);
- the stiff leg plant and the quick trail leg pull-through;
- staying vertical and not leaning in with the head or inside arm;
- a quick take-off, running off the end of the approach and not sinking or settling.

The quicker the execution, the more characteristics of the speed flopper can be trained/exhibited. Raising the bar can give the jumper’s neuromuscular system the “learning” that may modulate the preparatory activity of pre-activation or pre-stretching (DIETZ et al., 1981, quoted by REID, 1989). The key is to teach the high jumper to pre-stretch the plant leg muscles to avoid knee flexion to the point where he/she does this automatically. Then the athlete’s concentration is on the penultimate step, which involves the free leg. The push-off and pull-through of the knee of the free leg with maximal knee flexion to produce a short but powerful lever becomes a key technical skill to learn and concentrate on. It is the combination of the strong, pre-tensed leg plant and the simultaneous push-off and pull-through of the free leg that will provide the greatest vertical velocity and vertical displacement of the jumper’s center of gravity providing the plant and take-off technique is flawless (REID, 1989).

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REFERENCES


A time to focus on peaking for the main competition of the year, for example the European Championship, World Championships or Olympic Games, is a key element of current training theory and is known as Direct Competition Preparation. Proper training in this period can have a positive impact on the results achieved. However, improper, e.g. excessive, training may lead to disappointing results. It is therefore very important for the coach to plan appropriate training loads and select appropriate drills and other training content in this period. Moreover, the programme should be individualised for the athlete and conditioned on the demands of the competition schedule and the extent to which the annual training plan has been implemented. The author, who is a national coach for the jumping events in Poland, outlines the principles for planning the Direct Competition Preparation and provides typical workouts for elite high jumpers based on relevant literature and his personal experience.
Of particular importance is the need to make final preparations prior to the season’s major event, for example European Championship, World Championships or Olympic Games. A time for focus on this work, known as peaking or Direct Competition Preparation (DCP), is a key element of current training theory (BOMPA, 1999; BORA, 2010; KIELAK, 2004). The main task of the DCP is to produce a state of the highest readiness to compete in the specific conditions in which the main event of the season will take place (BORA, 2010; KIELAK, 2004).

Proper training in the DCP can have a positive impact on the results achieved in the main event of the year. However, improper, e.g. excessive, training in this period may lead to disappointing results (KIELAK, 2004; LASOCKI, 1998, PLATONOW & SOZAŃSKI, 1991).

In the following sections I outline the key points for planning the DCP and typical workouts for elite high jumpers based on relevant literature and my personal experience as a national coach.

Structure of the Competition Period

The competition period of an elite athlete can be divided into three mesocycles of varying duration, each with a different set of tasks and objectives, including the DCP (see Table 1).

Many proposals for planning the DCP mesocycle can be encountered in the training literature. In these, the volume of the load differs depending on the discipline, the extent to which the annual training plan has been implemented, the competition requirements (one-day competitions or longer), and the conditions of the competition (climate zone, altitude, temperature, etc.).

Table 1: Mesocycle structure for an elite high jumper in the competition period (DCP = Direct Competition Preparation)

<table>
<thead>
<tr>
<th>Mesocycles</th>
<th>Competitions I</th>
<th>DCP</th>
<th>Competitions II</th>
</tr>
</thead>
<tbody>
<tr>
<td>N° of weeks</td>
<td>5-6</td>
<td>6</td>
<td>5-6</td>
</tr>
</tbody>
</table>

The date of the last important competition (often a qualification event or national championships) and the date of the main competition of the season condition the duration and structure of the DCP mesocycle. The design of the training contents in this period depends on the size and nature of loads in the earlier training periods (LASOCKI, 1998, SOZAŃSKI, 1999). The training in DCP mesocycle is a summary of the whole year of the athlete’s preparation for the main event.

For the elite high jumper, the DCP mesocycle normally lasts five to seven weeks and is divided into three phases: accumulation, intensification and transformation. Based on his/her knowledge, experience and creativity, the coach will elaborate the training contents for each phase.

Accumulation Phase

The first part of the DCP is called the Accumulation Phase. It involves the regeneration of the athlete’s physical strength and mental relaxation after the first competitions of the season and the transition to the new conditions of training. The aim here is to increase the body’s adaptation to large loads. The first and second microcycles of this phase are very challenging.

In this phase, the number of training sessions is increased and an elite high jumper will train twice a day. However, this period also includes two free days (rest), biological recovery and swimming. The work is concentrated on flexibility, strength, speed and elements of technique. The basic structure of the phase is shown in Table 2.
### Typical workouts for an elite high jumper in this phase consist of the following:

#### STRENGTH I
- Half-squat
- Quarter-squat
- Calf-rise
- Step-up
- Half-squat jumps
- Abdominal muscles
- Back muscles

**Series:** 4-6, repetitions: 5-10

#### JUMPING DRILLS
- Multi-bounds > RL(right leg)-LL(left leg), RL, LL, RLRL-LLLL

**Series:** 3-5, repetitions: 5-8

#### TECHNIQUE
- Rhythms of take-off every 1,3,5 strides - series: 3-6, 4-8 repetitions
- Scissor technique > approach 4-6 strides - 4-6 repetitions
- Special acrobatic drills 10-15 min
- Flop technique > approach 2-6 strides - 8-12 repetitions

### Table 2: The structure of the accumulation phase of Direct Competition Preparation in elite high jump

<table>
<thead>
<tr>
<th>Microcycle</th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
<th>Saturday</th>
<th>Sunday</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Accumulation</td>
<td>Elements of high jump technique</td>
<td>Flexibility + speed</td>
<td>Warm up</td>
<td>Shot throwing (medicine ball)</td>
<td>Elements of high jump technique</td>
<td>Flexibility + speed</td>
<td>-------</td>
</tr>
<tr>
<td>Strength I</td>
<td>Swimming / biological recovery</td>
<td>Jumping</td>
<td>Biological recovery</td>
<td>Strength II</td>
<td>Swimming / biological recovery</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td>II Accumulation</td>
<td>High jump technique</td>
<td>Flexibility + speed</td>
<td>Warm-up</td>
<td>Shot throwing (medicine ball)</td>
<td>High jump technique</td>
<td>Flexibility + speed</td>
<td>-------</td>
</tr>
<tr>
<td>Strength I</td>
<td>Biological recovery</td>
<td>Jumping</td>
<td>Biological recovery</td>
<td>Strength II</td>
<td>Biological recovery</td>
<td>-------</td>
<td></td>
</tr>
</tbody>
</table>

#### STRENGTH II
- Quarter squat
  - Bench press
  - Snatch
  - Ankle hops
  - Jumps
  - Abdominal muscles
  - Back muscles
  - Adductor muscles of thigh
  - Hamstring muscles

**Series:** 4-6, repetitions: 5-10

#### SPEED
- Acceleration > 20-30m - 2-3 repetitions, recovery 5-6 min
- Flying sprints through curve > 30m - 2-3 repetitions, recovery 5-6 min

#### FLEXIBILITY
- Hurdle Drills > 6x6 hurdles (walking)

#### SWIMMING
- Different strokes (about 30-40 min)

#### BIOLOGICAL RECOVERY
- Massage
- Hydro massage
- etc.
Intensification Phase

In the second phase of the DCP the number of training sessions and the training load are decreased, but the intensity of the loads is very high. As a result, this sets up the athlete for the phenomenon of supercompensation to occur in the following phase.

In the microcycles of the intensification phase, the high jumper trains once a day only. Special drills dominate the general training loads and the work is concentrated on strength, speed and technique. There are four free days (rest) and biological recovery in this period. In the last microcycle at the end of the phase the jumper should take part in a control competition (Table 3).

Typical workouts for an elite high jumper in this phase consist of the following:

STRENGTH I
- Half-squat
- Quarter-squat
- Quarter-squat jumps
  - Series: 1-3, repetitions: 1-6
- Abdominal muscles
- Back muscles
  - Series: 6, repetitions: 10

STRENGTH II
- Quarter-squat
- Ankle hops
  - Series: 1-3, repetitions: 1-6
- Abdominal muscles
- Back muscles
  - Series: 4, repetitions: 10

SPEED
- Flying sprints > 30m - 2-3 repetitions, recovery 6-8 min
- Flying sprints through curve > 30m - 2-3 repetitions, recovery 6-8 min

BIOLOGICAL RECOVERY
- Massage
- Hydro massage
- etc.

Table 3: The structure of the intensification phase of Direct Competition Preparation in elite high jump
Transformation Phase

In the transformation phase, the athlete should achieve the highest readiness to compete in the main competition of the year. Training in this phase is conditioned by the length of the preparation and competition periods that preceded the DCP and the time needed for travel to the venue of the main competition, adaptation to the time zone and acclimatization.

For the elite high jumper, the training sessions of these microcycles are of shortened duration and medium intensity. The focus of the training is on elimination of minor technical errors. The basic structure of the microcycles of this phase is shown in Table 4 but training in this phase is subject to modification and adaptations.

Table 4: The structure of the transformation phase of Direct Competition Preparation in elite high jump

<table>
<thead>
<tr>
<th>Microcycle</th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
<th>Saturday</th>
<th>Sunday</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transformation I</td>
<td>Strength I</td>
<td>High jump technique</td>
<td>Speed + Jumping</td>
<td>Strength II</td>
<td>--------</td>
<td>Competition High Jump</td>
<td>--------</td>
</tr>
<tr>
<td>Transformation II</td>
<td>Strength I</td>
<td>Speed + elements of high jump technique</td>
<td>Strength II</td>
<td>Competition High Jump</td>
<td>Qualification</td>
<td>Competition High Jump</td>
<td>Final</td>
</tr>
</tbody>
</table>

Typical workouts for an elite high jumper in this phase consist of the following:

STRENGTH I
- Half-squat
- Quarter-squat
- Quarter-squat jumps

Series: 1-3, repetitions: 1-6

- Abdominal muscles
- Back muscles

Series: 4, repetitions: 10

JUMPING DRILLS
- Standing long jump – 3 repetitions
- Standing triple jump – 3 repetitions

TECHNIQUE
- Rhythms of take off every 3 steps - series: 1-3, 4 repetitions
- Flop technique > 6 steps approach - 2-3 repetitions
- Flop technique > full approach - 5-6 repetitions

STRENGTH II
- Ankle hops - series: 3, 6 repetitions
- Jumps on the box - series: 3, 6 repetitions
- Abdominal muscles
- Back muscles

Series: 4, repetitions: 10

SPEED
- Flying sprints > 30m - repetitions: 2, recovery 6-8 min
- Flying sprints through curve > 30m - repetitions: 2, recovery 6-8 min
Conclusion

The DCP can significantly improve an athlete’s disposition and readiness for competition (even by a few %) and thereby have a positive impact on the results achieved in the main event of the year. However, improper, e.g. excessive, training in this period may lead to disappointing results. It is therefore very important for the coach to plan appropriate training loads and select appropriate drills and other training content. It is certainly the case in the high jump that the process of training in the DCP should be individualised for each athlete.

In this article I have provided the basic principles for planning the DCP and typical training sessions for elite high jumpers from which the coach can develop as specific programme for his/her athlete.

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REFERENCES


3D Biomechanical Analysis of Women’s High Jump Technique

by Vassilios Panoutsakopoulos and Iraklis A. Kollias

ABSTRACT

The purpose of the present study was to investigate the three-dimensional kinematics of contemporary high jump technique during competition and to compare the results with findings from previous elite-level events. The participants in the women’s high jump event of the European Athletics Premium Meeting “Thessaloniki 2009” served as subjects. The jumps were recorded using three stationary digital video cameras, operating at a sampling frequency of 50 fields/sec. The kinematic parameters of the last two strides, the take-off and the bar clearance were extracted for analysis through software. The results indicated that the kinematic parameters of the approach (i.e. horizontal velocity, stride length, stride angle, height of body centre of mass) were similar to those reported in the past. However, a poor transformation of horizontal approach velocity to vertical take-off velocity was observed as a greater deceleration of the swinging limbs could be seen at the instant of take-off. Considerable backward lean at take-off, large take-off angle and inefficient bar clearance were also noted. The authors recommend that the athletes studied consider giving a greater emphasis to the key technique elements of the take-off phase and of the bar clearance.

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Introduction

Currently, most top high jumpers use one of the versions of the Fosbury Flop technique. The technique, which comprises the approach, the preparation for the take-off, the take-off, the flight phase and bar clearance and the landing, is differentiated from the other jumping styles mainly by the so called “J” approach and back lay-out position used to cross the bar.

The single most important factor and essential contributor to the height cleared, is the height of the flight of the body’s centre of mass (BCM), which is a result of the vertical impulse produced during the take-off phase.

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Key biomechanical factors that describe the take-off are the knee angle of the take-off leg, the angle of the lead leg thigh, the angle of the trunk position and the angles of forward/backward and inward lean.

The support and flight times, the stride lengths and frequencies, the path of the BCM, the angle of the run-up and the horizontal, vertical and resulting BCM velocities are the parameters that are usually used to analyse the approach.

Research data for female high jumpers exist from the Olympic Games, IAAF World Championships in Athletics, IAAF World Junior Championships and IAAF World Indoor Championships. Furthermore, data are also available from longitudinal observations of elite female high jumpers. In the present study, international level female high jumpers were analysed in order to observe the three-dimensional kinematics of contemporary high jump technique during competition and to compare the results with findings from previous elite-level events.

Methods

Subjects & Data Collection

The participants in the women’s high jump of the European Athletics Premium Meeting “Thessaloniki 2009” in Thessaloniki, Greece, on 10 June 2009 served as the subjects.

All jumps were recorded using three stationary JVC digital video-cameras (GR-DVL9600EG; GR-D720E; GR-D815; Victor Co., Japan), operating at a sampling frequency of 50 fields/sec. The video-cameras were fixed on tripods and were positioned on the stands (Figure 1). The synchronisation of the captured videos from the three video-cameras was accomplished with the use of the audio signals recorded, using the audio synchronisation method provided by the analysis software.

The area used by the jumpers for the approach and the take-off was calibrated by placing 2.5m x 0.02m poles at predefined spots on the field, in order to produce three-dimensional coordinates with the use of a 3D-DLT technique. The Y-axis was parallel to the long side of the cross-bar; the X-axis was perpendicular to the Y-axis; the Z-axis was perpendicular and vertical to the X- and Y-axes. The accuracy of the 3D reconstruction was determined by Root Mean Square error. Errors of 2.5cm, 1.8cm and 1.5cm were found for the X-, Y- and Z-axes, respectively.

Data Analysis

All trials above 1.84m were recorded and each jumper’s highest valid jump was selected for further analysis. Eighteen anatomical points on the body (tip of the toe, ankle, knee, hip, shoulder, elbow, wrist and fingers on both sides of the body, the neck and the top of the head) and selected parts of the crossbar and the uprights were manually digitised in each field (Figure 1, page 33). The coordinates of the BCM were calculated for every field using the segment parameters derived with the method proposed from PLAGENHOEF.

A 6Hz cut-off frequency, based on residual analysis, was selected for smoothing.

The coordinates of the digitised points were used for the calculation of the biomechanical parameters presented in this study. Spatial parameters (i.e. stride length, stride angle, BCM height) and the body configuration (i.e. joint angles and inclination of body segments) were calculated using the extracted coordinates of the digitised points at selected time-instants of the jumpers’ attempts.

Video synchronisation, digitisation, smoothing and analyses were conducted using the A.P.A.S.-XP software (Ariel Dynamics Inc., Trabuco Canyon, CA). Descriptive statistics (average ± standard deviation) were utilised for the presentation of the results.

Results

Seven jumpers cleared 1.84m, with the mean official result being 1.90m (Table 1). Vlasic won the competition with a jump of 2.01m, the 16th best result in 2009. Four of the studied jumpers (Vlasic, Radzivil, Stergiou, Forrester) used the double-arm technique while the other three (Spencer, Dusanova, Klyugina) used running-arm technique.
Figure 1: The filming views, the digitizing process and the 3D reconstruction of Vlasic’s successful attempt at 2.01m using the APAS-XP software (Ariel Dynamics Inc., Trabuco Canyon, CA)

Table 1: The height of the body centre of mass at the instants of touchdown and take-off (H0 and H1, respectively), the height of the flight (H2) and the height of bar clearance (H3), along with the maximum height achieved (H_max) (The values are also presented as percentage (%) of the official result (H_off))

<table>
<thead>
<tr>
<th>ATHLETE</th>
<th>NAT</th>
<th>RANK</th>
<th>H_off (m)</th>
<th>H0 (m)</th>
<th>H1 (m)</th>
<th>H2 (m)</th>
<th>H3 (m)</th>
<th>H_max (m)</th>
<th>H0%</th>
<th>H1%</th>
<th>H2%</th>
<th>H3%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vlasic</td>
<td>CRO</td>
<td>1</td>
<td>2.01</td>
<td>0.99</td>
<td>1.41</td>
<td>0.65</td>
<td>0.05</td>
<td>2.06</td>
<td>49.3</td>
<td>70.1</td>
<td>32.3</td>
<td>-2.4</td>
</tr>
<tr>
<td>Spencer</td>
<td>LCA</td>
<td>2</td>
<td>1.93</td>
<td>0.89</td>
<td>1.33</td>
<td>0.70</td>
<td>0.10</td>
<td>2.03</td>
<td>46.1</td>
<td>68.9</td>
<td>36.3</td>
<td>-5.2</td>
</tr>
<tr>
<td>Radzivil</td>
<td>UZB</td>
<td>3</td>
<td>1.91</td>
<td>0.91</td>
<td>1.31</td>
<td>0.63</td>
<td>0.03</td>
<td>1.94</td>
<td>47.6</td>
<td>68.6</td>
<td>33.0</td>
<td>-1.6</td>
</tr>
<tr>
<td>Dusanova</td>
<td>UZB</td>
<td>4</td>
<td>1.88</td>
<td>0.89</td>
<td>1.30</td>
<td>0.64</td>
<td>0.06</td>
<td>1.94</td>
<td>47.3</td>
<td>69.1</td>
<td>34.0</td>
<td>-3.1</td>
</tr>
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<td>Klyugina</td>
<td>RUS</td>
<td>4</td>
<td>1.88</td>
<td>0.91</td>
<td>1.38</td>
<td>0.62</td>
<td>0.12</td>
<td>2.00</td>
<td>48.4</td>
<td>73.4</td>
<td>33.0</td>
<td>-6.4</td>
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<td>Stergiou</td>
<td>GRE</td>
<td>6</td>
<td>1.88</td>
<td>0.89</td>
<td>1.29</td>
<td>0.62</td>
<td>0.03</td>
<td>1.91</td>
<td>47.3</td>
<td>68.6</td>
<td>33.0</td>
<td>-6.4</td>
</tr>
<tr>
<td>Forrester</td>
<td>CAN</td>
<td>7</td>
<td>1.84</td>
<td>1.08</td>
<td>1.48</td>
<td>0.51</td>
<td>0.15</td>
<td>1.99</td>
<td>58.7</td>
<td>80.4</td>
<td>27.7</td>
<td>-8.1</td>
</tr>
<tr>
<td>Mean (n=7)</td>
<td></td>
<td></td>
<td>1.90</td>
<td>0.94</td>
<td>1.36</td>
<td>0.62</td>
<td>0.08</td>
<td>1.98</td>
<td>49.3</td>
<td>71.3</td>
<td>32.8</td>
<td>-4.1</td>
</tr>
<tr>
<td>SD</td>
<td></td>
<td></td>
<td>0.05</td>
<td>0.07</td>
<td>0.07</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>4.3</td>
<td>4.4</td>
<td>2.6</td>
<td>2.6</td>
</tr>
</tbody>
</table>
The results indicate that almost one third of the height of the jump was the actual flight. Radzivil and Stergiou better exploited their maximum flight height, since the bar was only 0.03m beneath the maximum point of their BCM flight paths. Spencer, Klyugina and Forrester had the potential for a height closer to 2.00m with ideal technique, since each was able to lift her BCM more than 0.10m over the bar height at their best valid jump.

Stergiou and Klyugina took off nearer to the end of the bar (less than 0.40m), while Vlasic and Forrester took off closer to the centre of the bar (more than 1.1m from the end of the bar). With the exception of Radzivil and Klyugina, the jumpers took-off about 0.9m away from the bar (Table 2).

Dusanova and Klyugina cleared the bar in the descending part of their BCM flight path, while Radzivil reached the highest point of her flight curve 0.21m behind the bar (Figure 2).

The jumpers’ body configuration at the instant of take-off is presented in Figure 2. With regard to the fulfilment of the key elements of high jumping technique\textsuperscript{1,2,21,22} the following deviations were observed:

- the inadequate backward lean of the body at touchdown,
- the inadequate knee extension of the take-off leg at take-off,
- the lead knee angle (not “locked” in a proper position at take-off),
- the inability to set the body parallel to vertical at takeoff,
- the improper swing of the arms during the clearance of the bar.

Vlasic and Stergiou executed the last stride with a minimum knee angle of about 130°, while the other jumpers had a more flexed knee angle (about 120°). The average touchdown angle of the support leg was 34° ± 3, with the jumpers who cleared less than 1.90m having a larger inclination (Table 3). Stergiou had the lowest touchdown knee angle (151°), the lowest minimum knee angle (128°) and the second largest range of motion of the knee joint during the concentric phase of the take-off (36°). In contrast, Vlasic had the largest touchdown knee angle (151°), the largest minimum knee angle (146°) and the second lowest range of motion of the knee joint during the concentric phase of the take-off (25°). Vlasic and Dusanova almost extended their knee of the support leg at the instant of take-off. On the contrary, Radzivil took-off with a more flexed knee (158°), since she executed the jump with the lowest range of motion of the knee joint during the concentric phase of the take-off (22°).

Differences concerning the relationship of the magnitude of knee flexion of the take-off leg and the development of vertical BCM velocity in the take-off phase among jumpers were detected. Figure 3a compares the development of vertical BCM velocity between Vlasic and Stergiou, who had the largest and smallest touchdown and minimum knee angle, respectively. Figure 3b shows the development of vertical BCM velocity between two jumpers (Spencer, Forrester) with almost equal knee flexion, but different vertical take-off velocity of the BCM. Figure 3c represents the alterations of the development of vertical velocity of the BCM during the take-off phase among the jumpers who cleared 1.88m (Dusanova, Klyugina, Stergiou). Finally, Radzivil and Klyugina achieved different jumping heights, although the development of the vertical BCM velocity compared to the knee joint angle of the take-off leg during the take-off phase seemed to be identical (Figure 3d).

Vlasic’s performance was characterised by the largest horizontal and vertical take-off velocities of the BCM recorded in the present study (Table 4). Spencer was the only jumper who had a positive vertical velocity of the BCM at the touchdown. The horizontal velocity of the BCM was reduced in a range of 2.5-3.3m/sec (Spencer and Radzivil, respectively), while the change of the vertical velocity of the BCM varied from 3.4m/sec (Forrester) to 4.5m/sec (Vlasic). The mean take-off angle was 51.6° (±5.2). These factors led to the achievement of heights of flight ranging from 0.51m (Forrester) to 0.70m (Spencer).
Figure 2: Stick figures of the examined jumpers at the instant of take-off (The path of the body centre of mass is also displayed)

Table 2: Toe-to-post (TP; Y-axis)* and toe-to-bar (TB; X-axis) distances at the instant of the touchdown for the take-off ($BB_{TO}$ and $BB_{Hmax}$ represent BCM-to-bar distance in the X-axis at the instant of take-off and at the instant of maximum BCM height during the flight, respectively.)
Table 3: The take-off leg’s touchdown angle (θTD) and the knee angles (θK) at the instant of the touchdown (TD), the minimum knee angle (AM) and take-off (TO). θK,ROM represents the range of motion of the knee joint during the concentric phase of the take-off (θK,1LS represents the minimum knee angle during the support phase of the last stride.)

<table>
<thead>
<tr>
<th>ATHLETE</th>
<th>H_{OFF} (m)</th>
<th>θ_{K,1LS} (°)</th>
<th>θ_{TD} (°)</th>
<th>θ_{K,TD} (°)</th>
<th>θ_{K,AM} (°)</th>
<th>θ_{K,TO} (°)</th>
<th>θ_{K,ROM} (°)</th>
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<td>168</td>
<td>146</td>
<td>171</td>
<td>25</td>
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<tr>
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<td>1.93</td>
<td>115</td>
<td>31</td>
<td>155</td>
<td>131</td>
<td>162</td>
<td>31</td>
</tr>
<tr>
<td>RADZIVIL</td>
<td>1.91</td>
<td>118</td>
<td>31</td>
<td>158</td>
<td>136</td>
<td>158</td>
<td>22</td>
</tr>
<tr>
<td>DUSANOVA</td>
<td>1.88</td>
<td>123</td>
<td>34</td>
<td>160</td>
<td>134</td>
<td>171</td>
<td>37</td>
</tr>
<tr>
<td>KLYUGINA</td>
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<td>-</td>
<td>37</td>
<td>155</td>
<td>136</td>
<td>168</td>
<td>32</td>
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<tr>
<td>STERGIOU</td>
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<td>131</td>
<td>37</td>
<td>151</td>
<td>128</td>
<td>164</td>
<td>36</td>
</tr>
<tr>
<td>FORRESTER</td>
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<td>123</td>
<td>37</td>
<td>157</td>
<td>134</td>
<td>167</td>
<td>33</td>
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<td>123</td>
<td>34</td>
<td>158</td>
<td>135</td>
<td>166</td>
<td>31</td>
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<td>3</td>
<td>5</td>
<td>6</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>
Table 5: The maximum ($V_{L_{MAX}}$) and toe-off ($V_{L_{TO}}$) vertical velocities ($V_{Z}$) of the lead leg ($L$) and the arms ($A$; mean of left and right arm) during the take-off ($DV_{L}$ and $DV_{A}$) and the projection angle of the BCM (AngPr)

<table>
<thead>
<tr>
<th>ATHLETE</th>
<th>$H_{OFF}$ (m)</th>
<th>$V_{L_{MAX}}$ (m/sec)</th>
<th>$V_{L_{TO}}$ (m/sec)</th>
<th>$DV_{L}$ (m/sec)</th>
<th>$V_{Z_{MAX}}$ (m/sec)</th>
<th>$V_{Z_{TO}}$ (m/sec)</th>
<th>$DV_{Z}$ (m/sec)</th>
<th>$\omega_{H}$ (rad/sec)</th>
<th>$\omega_{K}$ (rad/sec)</th>
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<tbody>
<tr>
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<tr>
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<td>7.04</td>
<td>4.76</td>
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<td>6.62</td>
<td>6.06</td>
<td>-0.56</td>
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<td>6.63</td>
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<td>-2.55</td>
<td>6.82</td>
<td>6.18</td>
<td>-0.63</td>
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<tr>
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<td>6.35</td>
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<td>4.55</td>
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<td>3.06</td>
<td>-2.73</td>
<td>6.11</td>
<td>3.83</td>
<td>-2.33</td>
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<tr>
<td>Mean (n=7)</td>
<td>1.90</td>
<td>6.65</td>
<td>4.46</td>
<td>-2.23</td>
<td>6.61</td>
<td>5.53</td>
<td>-1.11</td>
<td>6.6</td>
<td>11.5</td>
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<td>0.80</td>
<td>0.70</td>
<td>0.70</td>
<td>0.60</td>
<td>2.30</td>
<td>2.9</td>
<td></td>
</tr>
</tbody>
</table>

With regard to the swinging limbs’ contribution to the take-off action, four jumpers had greater arm than lead leg maximum vertical velocity (Table 5). Results revealed a considerable contribution to Vlastic’s vertical take-off velocity of the BCM from the movement of her lead leg in the vertical axis. On the contrary, the vertical velocity of Stergiou’s arms was the highest among the jumpers examined. Furthermore, the greatest deceleration regarding vertical velocity of the lead leg was observed for Klyugina (-3.2m/sec), while Forrester had greater deceleration concerning the vertical velocity of the arms (-2.3m/sec). Stergiou seemed to exploit the vertical velocity of the swinging segments, since the deceleration of both her lead leg and arms were about 1.0m/sec. It is worth noting that Forrester’s low vertical take-off velocity of the BCM of was accompanied by low values for the lead leg and arm vertical take-off velocities (3.1m/sec and 3.8m/sec, respectively).

Table 4: The horizontal ($V_{H}$) and the vertical ($V_{Z}$) velocity values at the instant of touchdown (TD) and toe-off (TO) for the jump, their change during the take-off phase ($DV_{H}$, $DV_{Z}$) and the projection angle of the BCM (AngPr)
With the exception of Dusanova, the maximum angular velocity of the lead leg’s knee joint was greater than that of the hip joint. Stergiou extended her knee faster (16.5 rad/sec), while Spencer flexed her hip faster (9.5 rad/sec) than the other examined jumpers (Table 5). The slowest hip flexion was observed for Radzivil and Forrester (3.6 rad/sec and 3.9 rad/sec, respectively) while the slowest knee extension was observed in Dusanova (7.7 rad/sec).

Although the average stride length was almost equal for the last two strides of the approach (2.08m ± 0.35m and 2.05m ± 0.12m for the penultimate and the last stride, respectively), three of the analysed jumpers reduced the length of their last stride compared to the penultimate (Table 6). For those who decreased the length of the last stride, the change was of a magnitude of 0.33m. The average increment of the length of the last stride for the other three jumpers was 0.28m.

The development of the approach velocity was connected to the trend observed for the stride length. Vlasic and Stergiou decreased their stride length with a near to zero reduction of their horizontal velocity between the last two strides of their approach. Furthermore, both exhibited the smoothest development of BCM horizontal velocity during the last strides of the approach (Figure 4). In contrast, four of the examined jumpers increased their horizontal velocity during the last stride. The stride angle was constantly decreasing as the jumpers reached the bar (69° ± 6, 45° ± 5 for the penultimate and last stride, respectively).

Although the fact that the BCM path during the last strides of the approach was internally of the foot placements for all of the jumpers, Spencer, Stergiou and Forrester took off with their BCM projection aside of their take-off point (Figure 5). Moreover, Ratzivil took off with her BCM projection behind of her take-off point, mainly because of the large backward lean of her body at take-off.

The average lowering of the BCM from the instant of the toe-off of the penultimate stride till the touchdown for the take-off was 0.10m (Table 7). Spencer was the only jumper who lowered the BCM height during the support phase of the penultimate stride. In contrast, Ratzivil did not lower her BCM height during the support phase of the last stride (Figure 6). The larger vertical BCM displacement during the take-off phase was observed for Klyugina (0.47m).

**Discussion**

The mean official height cleared by the jumpers examined in the present study was 1.90m ± 0.05, almost 0.10m lower than the jumps analysed in biomechanical studies for female high jumping during the IAAF World Championships.
Figure 4: Horizontal and vertical velocity of the body center of mass (BCM) from the take-off of the penultimate stride until the maximum height of the body centre of mass achieved during the flight. (The shaded areas between the vertical lines represent the support phases for the last stride (1LS) and the take-off (TO).)

Figure 5: Overhead view of foot placements, i.e. support phase of the penultimate (2LS), the last stride (1LS) and the take-off (TO) and the trajectory of the body centre of mass (BCM) (RS and LS represent the right and left uprights, respectively. Red data points (•) represent the touchdowns, while green data points (○) represent the toe-offs.)
Table 7: The body centre of mass’ height alteration between the instants of touchdown (TD) and toe-off (TO) for the penultimate (2L), the last stride (1L) and the take-off for the jump (J)

<table>
<thead>
<tr>
<th>ATHLETE</th>
<th>2L&lt;sub&gt;TD&lt;/sub&gt;→2L&lt;sub&gt;TO&lt;/sub&gt; (support, m)</th>
<th>2L&lt;sub&gt;TO&lt;/sub&gt;→1L&lt;sub&gt;TD&lt;/sub&gt; (flight, m)</th>
<th>1L&lt;sub&gt;TD&lt;/sub&gt;→1L&lt;sub&gt;TO&lt;/sub&gt; (support, m)</th>
<th>1L&lt;sub&gt;TO&lt;/sub&gt;→J&lt;sub&gt;TD&lt;/sub&gt; (flight, m)</th>
<th>J&lt;sub&gt;TD&lt;/sub&gt;→J&lt;sub&gt;TO&lt;/sub&gt; (support, m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VLASIC</td>
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<td>-0.05</td>
<td>-0.01</td>
<td>-0.06</td>
<td>0.42</td>
</tr>
<tr>
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<td>0.00</td>
<td>-0.01</td>
<td>-0.04</td>
<td>0.44</td>
</tr>
<tr>
<td>RADZIVIL</td>
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<td>-0.04</td>
<td>0.01</td>
<td>-0.03</td>
<td>0.40</td>
</tr>
<tr>
<td>DUSANOVA</td>
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<td>-0.03</td>
<td>-0.02</td>
<td>0.41</td>
</tr>
<tr>
<td>KLYUGINA</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.47</td>
</tr>
<tr>
<td>STERGIOU</td>
<td>0.04</td>
<td>-0.06</td>
<td>-0.04</td>
<td>-0.03</td>
<td>0.40</td>
</tr>
<tr>
<td>FORRESTE</td>
<td>0.04</td>
<td>-0.06</td>
<td>-0.08</td>
<td>0.00</td>
<td>0.40</td>
</tr>
<tr>
<td><strong>Mean (n=6)</strong></td>
<td><strong>0.02</strong></td>
<td><strong>-0.04</strong></td>
<td><strong>-0.03</strong></td>
<td><strong>-0.03</strong></td>
<td><strong>0.42</strong></td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td><strong>0.02</strong></td>
<td><strong>0.02</strong></td>
<td><strong>0.03</strong></td>
<td><strong>0.02</strong></td>
<td><strong>0.03</strong></td>
</tr>
</tbody>
</table>

* It was not possible to calculate BCM height for the last strides of Klyugina’s analysed attempt because of a random incident during the filming of the event.

Figure 6: Body centre of mass (BCM) height from the toe-off of the penultimate stride until the maximum body center of mass height achieved during the flight (The vertical lines represent the support phases for the last stride (1LS) and the take-off (TO). The horizontal line represents the height of the bar.)
The height of the BCM at the touchdown for the jump (1.00m ± 0.09) was notably higher than found previously (0.86m)6,9,10. Furthermore, the BCM at its lowest position during the take-off phase was at a height of 0.93m ± 0.07. Taking into consideration that the minimum knee angle during the take-off phase was an average 10° lower than found in the 1986 IAAF World Junior Championships6, the higher BCM height could be attributed to lower backward trunk inclination, which is also an important body adjustment for the take-off6. However, it has been supported that the BCM height at touchdown does not reveal a performance-related trend, since the initial height at the take-off phase is not a performance-determining factor10. The overall vertical BCM displacement during the take-off phase was 0.42m ± 0.03, a value within the range observed in IAAF World Championships6,10.

The average of the taken touchdown angle of the leg (34° ± 3) was identical to the optimum suggested by GREIG & YEADON28. The range of motion of the take-off leg's knee (31° ± 6) was larger than those reported before (26°)6. The effectiveness of the magnitude of the knee flexion has been found to be related with factors such as strength and leg stiffness11,16,25,28,29. Although the minimum knee angle during the support of the last stride was an average 10° greater, the minimum knee angle during the take-off was an average 10° less than found in past6,16,24. The higher knee flexion in the last support decreases the BCM height, but increases contact time. It has been suggested that the maintenance of BCM velocity is accomplished by using effective double arm techniques30, which was used by the majority of the jumpers analyzed in the present study.

As expected6,8,26,31,32, the stride angle was constantly decreasing as the jumpers reached towards the bar. The last stride (2.05m ± 0.12) was found to be longer than reported in the past (1.92m)6,9. The greater lowering of the BCM height during the last stride did result in lower vertical BCM touchdown velocity at the take-off phase for Stergiou and Forrester, as suggested by AE et al.30.
Although the vertical of the BCM take-off velocity was lower, the vertical velocities of the body segments during the take-off were higher than those reported by BRÜGGEMANN & LOCH\textsuperscript{10}. This could be attributed to the insufficient backward trunk inclination, since backward trunk inclination contributes, together with knee flexion, to the compensation of: 1) the large approach velocity, 2) the development of large vertical BCM displacement, and 3) gaining time for the coordination of the swing of the body segments\textsuperscript{5}. The low BCM height at touchdown is advantageous concerning the effective stretch-shortening cycle during the take-off phase, allowing a larger vertical BCM displacement during the take-off phase, the development of greater vertical BCM take-off velocity and the efficient contribution of the swinging movement of the arms\textsuperscript{25,33}. It has been reported that female high jumpers gain less than men from the arms’ swing\textsuperscript{10,25}. In general, in order to maximise the contribution of the arms and lead leg to high jump performance, it is essential to combine their coordinated movement at touchdown, their vigorous upward movement during the push-off, an optimum timing of their movements and the completion of their action just before take-off are important\textsuperscript{34}.

Finally, in the case of Vlasic, the results of the present study revealed that there was a consistency concerning the elements of her technique compared to her previous 2.00m jumps\textsuperscript{13,14}. In detail, toe-to-bar distance and the height of the flight were identical (0.80m and 0.65m, respectively). Similar 2009 vs. 2003 values were observed concerning the lowest take-off leg knee angle (146° vs. 145°), the height of bar clearance (0.05m vs. 0.04m), the horizontal BCM take-off velocity (4.38m/sec vs. 4.33m/sec) and the horizontal velocity in the last steps of the approach (7.4m/sec vs. 7.5m/sec). The stride length for the penultimate (2.37m vs. 2.41m) and last stride (2.23m vs. 2.19m) were of the same magnitude. Her BCM height at touchdown and take-off was considerably lower in the past (0.99m vs. 0.95m and 1.41m vs. 1.38m, respectively). Significant alterations were observed concerning the horizontal and vertical BCM velocities at the touchdown for the jump (7.13m/sec vs. 6.50m/sec and -0.37m/sec vs. 0.04m/sec, respectively), the vertical BCM take-off velocity (4.09m/sec vs. 3.75m/sec) and the take-off angle (47.5° vs. 40.8°).

- In conclusion, the technique of the international-level female high jumpers analysed in the present study was characterised by:
  - the slight dominance of double arm techniques,
  - the similarity of the kinematic parameters of the last strides of the approach (i.e. horizontal velocity, stride length, stride angle, BCM height) to those reported in the past,
  - the poor transformation of horizontal approach velocity to vertical take-off velocity, since a greater deceleration of the swinging limbs was observed at the completion of the take-off action,
  - the variability observed in the relationship between the knee angle of the support leg and the vertical BCM velocity,
  - the notable backward lean and inadequate knee extension of the support leg at the instant of take-off,
  - the large take-off angle,
  - the inefficient bar clearance.

In general, we can recommend that the athletes studied consider giving a greater emphasis to the key technique elements of the take-off phase and of the bar clearance.

**Acknowledgments**

The authors wish to thank the Organising Committee of the European Athletics Premium Meeting “THESSALONIKI 2009” for allowing the recording. Appreciation extended to P.E. students Panagiotis Fotinopoulos, Georgios Chortiatinos and Evangelos Psomadelis for their assistance during the recording.

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hkollias@phed.auth.gr
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34. LEES, A.; ROJAS, J.; CEPERO, M.; SOTO, V. & GUTIERREZ, M. (2000). How the free limbs are used by elite high jumpers in generating vertical velocity. Ergonomics, 43(10), 1622-1636. should be very specialised and the length of the breaks between competitions will depend on the athlete’s physical and mental preparation and on the calendar of events.
Applied Research

contents

Energy Production in the 800m
by Enrico Arcelli, Amos Bianchi, Jennifer Tebaldini, Matteo Bonato and Antonio La Torre
Energy Production in the 800m

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ABSTRACT

Understanding the aerobic and anaerobic energy mechanisms in the 800m can have important practical consequences for coaches trying to correctly plan and manage an athlete’s training. This knowledge is especially useful now that low cost, easy to use equipment is available for measuring blood lactate concentration after a competition or in training. The purpose of this study was to examine the contribution of the anaerobic lactate mechanism from the point of view of the total energy expenditure and energy expenditure at different stages of the 800m. Blood lactate concentration was measured in 18 male athletes at the end of a race and after time trials of 300m and 600m run at the same pace as the race. The data confirm earlier findings that blood lactate concentration at the end of the 800m tends to decrease with the increase of the time of the race. It was also found that the contribution of the anaerobic lactate mechanism peaks from the start to 300m, falls between 300m and 600m and is at its minimum at the end of an 800m race. Conclusions include general advice for working with athletes with typical strength–weakness profiles for the two mechanisms studied.

Introduction

From an energetic point of view, both the aerobic and anaerobic mechanisms have considerable quantitative importance in the 800m. Understanding how the two mechanisms affect the energy expenditure required to complete the distance at a competitive or winning speed is, of course, interesting for sport physiologists and can have important practical consequences for coaches trying to correctly plan an athlete’s training.

AUTHORS

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Currently, low cost and easy to use equipment is available for coaches who would like to measure the blood lactate concentration of their athletes after a competition or in training. This means it is practical to plan training to emphasise the aerobic or the anaerobic lactic mechanism in training as required based on objective and quantifiable data and to monitor accurately the changes caused by the selected training.

With this in mind, the purpose of this article is to examine the contribution of the anaerobic lactate mechanism to the 800m from two different points of view: 1) the total energy expenditure, 2) energy expenditure at different stages of the race, as a basis for coaches who wish to follow this line of preparation of their athletes.

Material and Methods

Subjects

Eighteen sub-elite male middle distance runners volunteered for this study. They were fully informed about the nature of the study and the potential risks and each gave written consent to participate.

Before starting with the study protocol, anthropometric measurements and other data were collected from all the subjects. Table 1 gives the mean ±SD and range for their age, height and body weight, body fat, years of training and personal best over 800m.

Experimental design

Data collection measurements were made during the outdoor track season (June-July). The temperature range during this period was between 20°C and 40°C, there was no precipitation and the wind velocity was below 4 m·s⁻¹.

All the subjects took part in 800m competitions on synthetic outdoor tracks in national or international events. Prior to their races they used a standard warm-up, which included jogging and mobility exercises. The final performances were measured to the nearest 0.01 second. Split times were recorded for each subject at the 300m and 600m points of their races. At three and six minutes after the completion of the races, 5 μl blood samples were taken from the each subject’s ear lobe so that blood lactate concentration could be analysed (Lactate Pro™ LT-1710, Kyoto, Japan).

In addition, 14 of the subjects performed time trials of 300m and 600m at the same pace they had run for the 800m races. These trials took place between 48 hours and seven days after the subject’s race. At two and four minutes after the completion of the 300m trial and at three and six minutes after the completion of the 600m trial, 5 μl blood samples were taken from the ear lobe, again so that blood lactate concentration could be analysed.

### Table 1: Anthropometric characteristics, years of training and personal best over 800m of the 18 subjects who participated in the study

<table>
<thead>
<tr>
<th></th>
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<th>Range</th>
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<tbody>
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<td>16.0 - 32.0</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>180.5 ±4.9</td>
<td>175.0 - 189.0</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>66.0 ±5.6</td>
<td>57.0 - 74.0</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>5.3 ±1.1</td>
<td>4.2 - 6.4</td>
</tr>
<tr>
<td>Years of training (years)</td>
<td>9.0 ±6.0</td>
<td>4.0 - 13.0</td>
</tr>
<tr>
<td>Personal Best over 800m (sec)</td>
<td>117.6 ±5.8</td>
<td>109.8 - 128.4</td>
</tr>
</tbody>
</table>
Calculation of the total energy expenditure

According to RITTWEGER et al. the total energy expenditure (J·kg⁻¹) for running a certain distance is the sum of the following three components:

1. **The non-aerodynamic cost**: According to DI PRAMPERO, the non-aerodynamic cost encompasses the energy the athlete spends to lift and accelerate the body for each step, for the friction that the foot meets on each step, for the internal work, for the muscle contraction to maintain the core stability and for the work done by the heart and the respiratory muscles. The cost is equal to 3.8 J·kg⁻¹ times the distance in metres. For the 800m, therefore, it is 3.8 J·kg⁻¹ × 800 = 3040 J·kg⁻¹.

2. **The cost for overcoming air resistance**: This cost is 0.01 J·kg⁻¹ for the distance (m) times the square of the running velocity (m·s⁻¹). For the 800m it is 8 J·kg⁻¹·v².

3. **The cost for accelerating the body**: This cost is 2 J·kg⁻¹ times the square of the velocity. For the 800m it is 2 J·kg⁻¹·v².

Therefore, the total expenditure in J×kg⁻¹ for running an 800m race is:

\[
3040 \text{ J·kg}^{-1} + 8 \text{ J·kg}^{-1} \cdot v^2 + 2 \text{ J·kg}^{-1} \cdot v^2 \\
3040 \text{ J·kg}^{-1} + 10 \text{ J·kg}^{-1} \cdot v^2
\]

To get the total expenditure in mL·kg⁻¹, this formula becomes:

\[
144.08 + 0.48v^2
\]

Calculation of the energy produced by the anaerobic lactic mechanism

Referring to the lactate peak, each increment of 1 mmol·L⁻¹ over the baseline value, assumed to be 1 mmol·L⁻¹ [1,3], corresponds to a production of 3 mL·kg⁻¹ of lactic energy (lactate caloric equivalent).

Results

**Blood lactate concentrations**

In Figure 1 we see the results obtained for blood lactate concentration after the 800m races of the 18 subjects (diamonds) and the trend of the blood lactate concentration as a function of the time when the sample was obtained (p=0.086).

![Figure 1: Trend of the blood lactate concentration after an 800m race as a function of the time obtained (p=0.086) in the 18 subjects evaluated](Image)

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Table 2: Values of blood lactate concentration after time trials of 300m and 600m an 800m race for 14 athletes participating in the study

<table>
<thead>
<tr>
<th>Distance (m)</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>300m</td>
<td>8.6 mmol·L⁻¹</td>
<td>1.6 mmol·L⁻¹</td>
</tr>
<tr>
<td>600m</td>
<td>13.6 mmol·L⁻¹</td>
<td>1.6 mmol·L⁻¹</td>
</tr>
<tr>
<td>800m</td>
<td>14.2 mmol·L⁻¹</td>
<td>1.7 mmol·L⁻¹</td>
</tr>
</tbody>
</table>

Table 2 gives the mean±SD values of the lactate concentration after the 300m and 600m time trials and the 800m race for the 14 athletes who completed all three of the tests. For the two time trials, the peak value of the two samples taken is considered.

In Figure 2 we show the mean blood concentration at 300m, 600m and 800m for 14 athletes who completed all three of the tests. The baseline blood lactate concentration was considered 1 mmol·L⁻¹ [1,3].

Discussion

Blood lactate concentration after an 800m

Table 3 gives the post-800m blood lactate concentration data from five studies that can be found in the current literature plus the data from the present study (last line). Our values do not differ significantly from the average values of the other studies, with the exception of those of LACOUR et al., who were the first to study this area and whose data were obtained from elite-level athletes.

From the data in Table 3 we created Figure 3. The straight line indicating the tendency is different from that in Figure 1 and, indeed, from the one reported by LACOUR et al. Here below are the three different formulas for the calculation of the blood lactate concentrations (in mmol·L⁻¹) as function of the time of the competition (in sec):

- Present study: 27.15 – 0.11 t
- Scientific literature: 42.21 – 0.21 t
- LACOUR et al.: 86.7 – 0.6 t

Figure 2: Blood lactate concentration (Mean±SD) at the start, after a 300m time trial, after a 600m time trial and after an 800m race
To explain the differences between the three formulas, we have to consider that (as shown in Table 3) the different studies were carried out with different criteria. In three cases, for example, the blood lactate concentrations were not taken after a competition, but after a time trial, which could possibly give a different result. Moreover, in most cases the number of subjects in these studies was limited, particularly for LACOUR et al.\(^1\), where there were only five subjects, even if there were a total of 18 tests. In all cases, the blood lactate concentration tends to decrease with the increase of the 800m time recorded.

**Table 3: Mean blood lactate concentration of the scientific literature after 800m (The last line reports the values of the present study.)**

<table>
<thead>
<tr>
<th>Authors</th>
<th>Number of subjects</th>
<th>Time (s)</th>
<th>Velocity (m.s(^{-1}))</th>
<th>Blood Lactate (mmol.L(^{-1}))</th>
<th>Type of test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lacour et al. (1990) (^1)</td>
<td>5 (18 race)</td>
<td>108,4</td>
<td>7,39</td>
<td>21,9±2,1</td>
<td>Race</td>
</tr>
<tr>
<td>Hill (1999)(^3)</td>
<td>5 (17 race)</td>
<td>120,2</td>
<td>6,66</td>
<td>18,1±2,2</td>
<td>Race</td>
</tr>
<tr>
<td>Duffield et al. (2005)(^4)</td>
<td>9</td>
<td>126,0</td>
<td>6,35</td>
<td>12,4±1,9</td>
<td>Race</td>
</tr>
<tr>
<td>Thomas et al. (2005)(^10)</td>
<td>5</td>
<td>120,8</td>
<td>6,52</td>
<td>17,5±1,3</td>
<td>Time trial on outdoor track</td>
</tr>
<tr>
<td>Bosquet et al. (2005)(^7)</td>
<td>17</td>
<td>137,2</td>
<td>5,87</td>
<td>15,0±1,48</td>
<td>Time trial on outdoor track</td>
</tr>
<tr>
<td>Billat et al. (2009)(^8)</td>
<td>8</td>
<td>129</td>
<td>6,20</td>
<td>16,9±1,9</td>
<td>Time trial on indoor track</td>
</tr>
<tr>
<td>Ditroilo et al. (2012)(^11)</td>
<td>72</td>
<td>134,6</td>
<td>6,73</td>
<td>13,6±1,1</td>
<td>Indoor Athletic Race</td>
</tr>
<tr>
<td>Present Studies (2012)</td>
<td>18</td>
<td>118,8</td>
<td>6,73</td>
<td>14,0±1,5</td>
<td>Race</td>
</tr>
</tbody>
</table>

**Figure 3: Trend of blood lactate concentration after an 800m as a function of the final time according to data reported in literature as shown in Table 3 (p=0.135) (The symbols refer to the following authors: L = LACOUR et al.\(^1\); PS = Present Study (2012); H = HILL\(^3\); T = THOMAS et al.\(^10\); D = DUFFIELD et al.\(^4\); Bi = BILLAT et al.\(^8\); Bo = BOSQUET et al.\(^7\); Di = DITROILO et al.\(^11\))**
As can be seen in Figure 4, the lactic power reduces significantly from the first section (start-300m), to the second section (300m – 600m) and the last section (600m – finish). As would be expected from this, the authors who evaluated the maximal kinetic oxygen consumption during an 800m race (DUFFIELD et al. and SPENCER & GASTIN) reported that oxygen consumption rises very quickly after the first ten seconds and provides the maximal contribution to the total expenditure during the final section of the race.

Conclusions

The 800m is a race in which the percentages of the energy contribution of the aerobic and anaerobic mechanisms are very close. The current availability, low cost and ease of use of equipment for blood lactate measurement allows coaches to know the blood lactate of their athletes after a race of 800m and consequently to direct the preparation more towards the aerobic or the anaerobic lactic mechanism as required. Moreover it can also allow coaches to control the changes caused by training.

For example, with an athlete who runs the 800m between 110 and 125 sec and has a low concentration of lactate compared to that indicated by the line in Figure 1 it might be that the glycolytic mechanism is the less effective of the two. The coach, therefore, should adjust the training programme to stimulate that mechanism.

Table 4: Energy expenditure in the 800m for performances from 105 sec to 120 sec (calculated with the RITTWEGER et al. formula), the contribution of the anaerobic lactic mechanism (calculated according to di PRAMPERO et al. formula) and the contribution of the anaerobic lactic mechanism as a percentage of the total energy expenditure

<table>
<thead>
<tr>
<th>Time over 800m (sec)</th>
<th>Total Energy Expenditure (mL·kg⁻¹)</th>
<th>Lactic Component (mL·kg⁻¹)</th>
<th>Lactic Component (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>110</td>
<td>169.1</td>
<td>42.15</td>
<td>24.9%</td>
</tr>
<tr>
<td>115</td>
<td>167.0</td>
<td>40.50</td>
<td>24.2%</td>
</tr>
<tr>
<td>120</td>
<td>165.1</td>
<td>36.60</td>
<td>22.2%</td>
</tr>
</tbody>
</table>
Conversely, for an athlete who comes from a 400m background and has a very high lactate concentration in relation to the average values, especially if his/her running technique does not result in a very high-energy expenditure, an improvement of the aerobic components may lead to a significant improvement of the performance.

The second example highlights the blood lactate data relating to the theoretical transition from 300m to 600m, which shows that, contrary to the feeling of athletes during the race, the production of energy during the 800m becomes less lactic and more aerobic as the race progresses. However, even a small increase in the concentration of lactate in the muscles significantly affects the feeling of fatigue and the efficiency of the muscles. Therefore, there is need to develop the ability to run with a correct technique, despite the increased concentration of lactate.

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REFERENCES


Coaching

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Report on the 5th European Pole Vault and High Jump Conference
Cologne, Germany
Introduction

The 5th edition of the European Pole Vault and High Jump Conference, hosted by the German Sport University Cologne, brought together a strong line-up of internationally recognised coaches, scientists, star athletes and a record 283 participants from 24 countries under the theme “Physical Preparation” from 16-18 March 2012.

Staged with support from the German athletics federation (DLV) and Nordic Sport, this edition of the biennial conference was the first event in the 2012 European Athletics Coaching Summit Series. Plenary sessions took place in the main lecture theatre of the university and the practical demonstration sessions were staged in the university’s large, fully equipped athletic hall.

Former German national pole vault champion Günther Lohre, who is currently a DLV vice president, welcomed the participants at the opening of the conference. In his speech, he emphasised the value of information exchange amongst coaches, scientists and athletes for the further development of performances in athletics and the need to build and strengthen international communities for this purpose. Mr Lohre was immediately followed by the holder of the German women’s outdoor high jump record (2.06m) and 2009 European indoor champion Ariane Friedrich, who gave an overview of her exciting career with all its ups and downs, including her achilles tendon rupture in late 2010, and insights into her training programme.

The main conference programme included a mixture of general experiences, lectures on event specific theory, practical presentations, guided observation sessions, roundtable discussions plus informal opportunities for the participants to interact directly with the speakers.

This report provides highlights of the presentations and other activities that took place during the four session of the conference.
presented by Schuldt and Strutz could be used by all jumpers. Starting with strength endurance without jumping or sprinting is a means to get fitter and lowers the danger of injuries to the legs and feet. A higher level of strength endurance is a good basis for improving the maximum power, which itself is a good platform for bounding and sprint training needed for improving specific speed and power. This means the athlete can do the technical work on a higher level. And to apply these different sets of training means one after the other gives different stimuli to the muscles, optimises adaptation and creates a good chance to improve performance.

Session II - Saturday Morning

In the day’s first presentation, entitled “Strength Training in the Long-term Training Process”, Klaus Wirth from the Institute of Sport Sciences at the J.W. Goethe University in Frankfurt, covered the importance of maximum power for the jumping events and speed power in general. Referring to several research reports, Dr Wirth showed the relevance of maximum power and weight lifting exercises, coach, who put her on a training programme that was derived directly from the philosophy of the successful German throwing school and contained four basic steps: 1) general conditioning, 2) maximum power, 3) specific power and 4) technique training. She concentrated on developing ever more strength and speed and then on using stiffer poles but no higher grip. At the same time, she lost more than 4kg of body weight. Sharing overall training structure, key microcycles and individual sessions, Strutz and Schuldt made it clear that being an outstanding technician, as Ms Strutz was before 2008, was an important prerequisite for their strategy. M. Strutz was not able to improve her pole vault results in 2010, but her basic body composition improved and she mostly got rid of her various injuries. In 2011, she returned to the international scene with great results, winning a silver medal at the IAAF World Championships in Athletics with a national record of 4.80m and became more consistent in competition (10 times 4.70m or higher).

In one of the four parallel workshops that followed, German national coach Wolfgang Killing suggested that the training philosophy presented by Schuldt and Strutz could be used by all jumpers. Starting with strength endurance without jumping or sprinting is a means to get fitter and lowers the danger of injuries to the legs and feet. A higher level of strength endurance is a good basis for improving the maximum power, which itself is a good platform for bounding and sprint training needed for improving specific speed and power. This means the athlete can do the technical work on a higher level. And to apply these different sets of training means one after the other gives different stimuli to the muscles, optimises adaptation and creates a good chance to improve performance.
including the deep-squat. He then explained the classic training schedule for developing power, starting with hypertrophic training (high number of repetitions, endurance power), changing to maximum weight training (1-3 repetitions with high loads, maximum power), then changing training again to a regime focused on reactive/specific power, bounding and technical work before the competition period.

The second presentation of the morning, entitled “Mechanisms of Adaptation of Muscle Cells/Fibres to (resistance-) Exercise - Implications for Training”, was given by Wilhelm Bloch, the head of the Institute of Cardiology and Sports Medicine at the German Sport University Cologne. Prof. Bloch gave a deep insight into mechanisms of adaptation of muscle cells/fibres to exercise and named some implications for training. He also explained that muscle plasticity is higher and faster than expected and thus offers good chances for optimising adaptations through training. Periodical changes of intensity and volume guarantee both hyperplasia and hypertrophia. As adaptation of muscle cells is very specific, even technical modifications alter the regulation of muscle structure and function.

Session III – Saturday Afternoon

As has been the case for the last three editions of the conference, the Saturday afternoon session saw the group divide into two parallel mini-conferences, one for high jump and one for pole vault. The high jump mini-conference, moderated by German national coach Wolfgang Killing, featured the following presentations and practical demonstrations:

The Norwegian Training Regime
Hanne Haugland (NOR)

Ms Haugland, the 1995 world high jump champion, said that there are different ways to success in the high jump, and that each athlete has to find out his/her own right way. She introduced the Norwegian high jump system using a model one-year plan. The main training contents are weight training (good technique, from light to heavy to fast), bounding and plyometric jumps, sprints (from 150m easy to short, high intensive sprints/hurdles) and technical jumps (short approach to long approach).

The British Training Regime
Fuzz Ahmed (GBR)

Mr Ahmed is the national event coach for high jump in Great Britain. He explained the major changes in UK athletics after London was awarded the 2012 Olympic Games in 2007. These included changes in the coaching structure, the people involved, coaches’ education programmes and in training design. He then gave an overview of the training structure for high jumpers in the Olympic season.

The German Training Regime
Brigitte Kurschilgen (GER)

Ms Kurschilgen is the national event coach for high jump in Germany and responsible for both men and women. She illustrated the very individual planning of the 2012 season for Germany’s top high jumpers and explained the specific challenge that came up with having the European Championships six weeks prior to the finals at the Olympic Games in London.

Practical Demonstration
Hanne Haugland (NOR) and Fuzz Ahmed (GBR)

In the second half of the afternoon’s programme, Ms Haugland and Mr Ahmed gave a very exciting practical coaching demonstration working with German junior high jumpers.

The pole vault mini-conference, moderated by German national coach Herbert Czingon, featured the following presentations and roundtable discussion:

My Training Philosophy
Damien Inocencio (FRA)

Mr Inocencio, himself a former pole vaulter with a best of 5.42m, was not a full-time coach when he, started working with Renaud Lavil- lenie (FRA) in August 2008. At that time, Mr
Lavillenie had already achieved a mark of 5.70m indoors, but failed to qualify for the Olympic Games in Beijing. Mr Inocencio very soon changed aspects of Mr Lavillenie’s approach and takeoff: the run-up was moved out from 16 to 20 strides and the take-off spot was moved out from around 4m to between 4.40m and 4.60m. This allowed Mr Lavillenie to take advantage of his speed better than before, use stronger poles with a higher grip and achieve a better bar clearance. He was able to improve to 5.80m, then 5.96m and finally 6.01m. The problem was that he was unstable in training and competition and only could only place third in the IAAF World Championships in Athletics in Berlin the same year, despite being the world performance leader at the time. Mr Inocencio explained the various refinements to the training programme and to his own philosophy that enabled Mr Lavillenie to improve further and eventually take gold in the IAAF World Indoor Championships the week before the conference. He said that expected even further improvements by Mr Lavillenie in the future, including a big performance at the Olympic Games in London.

Mr Schade, has been a biomechanics consultant to top German vaulters for over 15 years. In this role, he has compiled hundreds of individual energy analysis tests of high performance pole vaults. He said that we have to abandon the idea of a generalised model of “modern pole vault technique”. For instance, the concept of the “free take-off”, seen by many athletes and coaches all over the world as a key to top performances, is not supported by the available scientific data. Based on specific training tests with current German pole vaulters, Mr Schade suggests individualised strategies for the short-term and the long-term development of top results. Training programmes have to be considered for how they address aspects of technique specific to the individual vaulter. In particular, the level of the initial energy during technical training and competition very often shows to be a counter productive factor for technical improvement. Mr Schade suggested that, for some athletes,
a short-term reduction of approach speed applied in parallel to an improvement of the fast stretch-shortening cycle of the hip/legs and the arms/shoulders, respectively might be a productive approach.

**Long-Term Analysis of Velocity and Take-off Data in the Pole Vault**  
Bettina Perlt (GER)

Dr. Perlt, the head of the Pole Vault Department at the Institute Of Applied Training Sciences (IAT) in Leipzig, Germany, has collected thousands of individual data sets on vaulters. These show the importance of improved velocity data in combination with proper step rhythm and take-off spots for the successful individual long-term development. She also gave some insight into the computer based “MIS”-System with a structured compilation of velocity, stride length and video data, which she has been programming for more than six years and which is still growing, including data from different independent sources.
to ever more drop outs, even among previous medal winners in global junior competitions. The participants agreed, that the various pole manufacturers’ developments of improved poles has not helped to generate better performances yet. The cost of proper poles and pits remains very high in most areas of the world. Improved international cooperation is important to generate better utilisation of individual experience in the development of know-how of technique and training in the pole vault.

Session IV – Sunday Morning

Adaptation of Tendons to Training Loads
Gert-Peter Brüggemann (GER)

Prof. Brüggemann is the head of the Institute of Biomechanics and Orthopaedics at the German Sport University Cologne. He said that the adaptation of tendons to training loads has been subject to a series of studies. After explaining the mechanisms of storing and recoiling energy in the muscle-tendon-unit, he presented findings relevant for the training of jumpers: 1) Tendons have the potential to adapt in both volume and material properties, 2) tendons’ response to training is later than that of muscle, 3) tendons of pre-pubescent children have the potential to adapt, 4) tendon adaptation increases the potential of transfer force (load), 5) tendon adaptation increases the potential to store elastic energy and to enable the CE to work at a higher force potential; 6) tendon material properties play an important role in athletic performance.

Summary and Outlook
Herbert Czingon and Wolfgang Killing (GER)

The conference was concluded with a presentation that covered the views of participating athletes, coaches and national coaches. Key words highlighted included: 1) crisis, 2) decision point, 3) responsibility, 4) analysis and 5) hard work. A focus of the discussion was on the first day’s presentation about the application of the training used for throwers to the jumping events.

Additional Points

The available Powerpoint presentations are available for download at: http://www.polevault-symposium.de in the “news” section.

I would like to thank the German Sport University Cologne, the student volunteers and everyone else involved in the conference for their valuable contributions to its success. Special thanks to Herbert Czingon and Wolfgang Killing for both their work and their contribution to this report.

I would also like to acknowledge the generous support of our sponsors Nordic Sport, the German Athletic Federation (DLV) and European Athletics.

Finally, I would like to inform the readers of this report that the 7th edition of the European Pole Vault Conference will take place in Cologne in 2014.

Reported by Wolfgang Ritzdorf

Wolfgang Ritzdorf is the Director of the IAAF World High Jump Centre and a lecturer at the German Sport University in Cologne.

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Development

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The CD Performance Progression Tool
by Steven Hollings, Patria Hume and Will Hopkins
The CD Performance Progression Tool

by Stephen Hollings, Patria Hume and Will Hopkins

ABSTRACT

In 1997 two of the authors created a method to compare performance progression in track and field athletics using tables, published in booklet form, plotting the progressions of 390 successful athletes. Such a tool is useful for coaches and high-performance support programme managers as it gives a basis for determining if an athlete is on a course that will lead to world-class results or if adjustments to the athlete's preparation and targets are required. However, at the time the original work was published certain limitations were identified. The methodology was subsequently adopted by both UK Athletics (in 2006) and Athletics New Zealand (in 2009) to produce a series of "performance funnels" to monitor both their elite and developing athletes. In the process, the two organisations addressed some but not all of the identified weaknesses. This article outlines how a revised method was developed using a database of 168,000 performances from more than 2,000 athletes. The new method has been turned into a computer-based tool available on a CD. The article explains the use of the tool and provides interpretations of data from example athletes.

AUTHORS

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

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

Will Hopkins is Professor of Exercise Science at the Sports Performance Research Institute New Zealand at AUT University, Auckland, New Zealand.

Introduction

In the selection of athletes for high-level training and support, many athletics programmes have taken into consideration the rate at which performance improves once an athlete is accepted into a programme. Unless required levels of progress are maintained, the ultimate objective of the athlete’s membership of the programme is unlikely to be attained. Athletes who do not meet progressive goals are usually excluded from the programme. If it is the desire of a national athletics federation to develop a cost effective
programme for groups of developing athletes there is the need to establish and implement an effective performance monitoring system that informs the athlete of what is required at each stage of the development pathway. The establishment of an ultimate performance goal, yearly progression performance goals and a rate of progression that reflect the unique characteristics of each event are required for each athlete. If the developing athlete is to achieve a high level of success, a good start is to base the goals on the performances achieved by older successful athletes in the same event, when they were at the same stage of development.

HOLLINGS, HUME & TREWIN (1991) developed a method to monitor performance progression and published a booklet Successful Athletes: Role of Performance Progression that tabled and plotted the performance progression of 390 successful athletes across 36 track and field events. Competition results were obtained from a variety of sources and included the athlete's life-time best performance and yearly best performance. The selected athletes all ranked in the world all-time top 50 athletes for their event.

When describing the methodology used to generate the performance progression, a number of limitations of the original method were noted:

- only taking into consideration the athlete's single best performance in any one year;
- the small cohort of athletes used in the construction of the performance progressions for each event;
- the arbitrary selection of athletes that were used in the analysis (i.e., only recently retired athletes were used);
- the age of the athlete at the time of achieving their year best performance was rounded down to the full year of age;
- discarding performances that were achieved indoors, wind aided, or at altitude;
- discarding performances in all throwing events that were achieved prior to the age of 18;
- discarding data for the men's javelin throw prior to 1988, as a new specification for the javelin was introduced in that year;
- not including data for the women's hammer throw, women's pole vault, women's 3000m Steeplechase, and women's 5000m as data were not extensive enough due to the relatively recent introduction of these events at the time.

Subsequently, UK Athletics (in 2006) and Athletics New Zealand (in 2009) adopted the original methodology to produce a series of “performance funnels” to monitor both their elite and developing athletes. These performance funnels addressed a few of the limitations identified, including the use of performances of a greater number of athletes for each event and the use of data for events not included in the earlier work. However, the other limitations we had identified were not addressed.

The aim of the current study was therefore to develop a revised method to calculate the performance progression of successful athletes addressing the limitations identified in the previous work.

Method

A total of 168,576 competition performances by 2,017 athletes across 19 men's and 19 women's track and field events published at tilastopaja.org were used in the construction of performance trajectories. All known published career competition performances for 1,026 male and 991 female track and field athletes who finished in the top 16 (track events and combined events) or top 12 (field events) of their event at an Olympic Games or an IAAF World Championships between 2000 and 2009 was used for the construction of individual performance trajectories. All known performances for each athlete throughout his/her career were used, rather than using the single best performance in any one year, which was the approach taken in previous work. Where athletes were subsequently disqualified from the competition (for whatever reason), the performance was discarded. All data for athletes suspended for a doping violation were also discarded. The exact age of the athlete on the
An individual performance trajectory for each athlete was generated using the mixed linear model procedure (Proc Mixed) in the Statistical Analysis System (Version 9.2, SAS Institute, Cary, NC). The performance trajectory for each athlete was constructed by plotting each competition performance against the age of the athlete on the day of the competition. A polynomial/quadratic trajectory was drawn through all of the data points (see Figure 1). Athletes and their trajectory were grouped into three categories; athletes who were medallists (1st – 3rd); finalists (4th – 8th); finished in 9th -16th place in a track event or combined event or 9th – 12th place in a field event, at a World Athletics Championships or an Olympic Games between 2000 and 2009. Each of the trajectories in the respective categories were then colour coded, medallists – red; finalists – blue; 9th to 12th or 9th to 16th – mauve (see Figure 2). Vertical dashed lines on the figures indicate the mean ± 1SD for the mean peak age of athletes in the event. The solid black vertical line on the y axis indicates the variance in all of the trajectories for athletes in that event.

A CD containing all the performance trajectories for each of the 38 track-and-field events was produced. The programme was built using the compiler Visual Studio© in C# language and using Microsoft Excel© to store data and to display the graphs. The programme works with all Microsoft Excel© versions but has been based around Microsoft Excel 2007©.

How to Use the CD Performance Progression Tool

The CD performance progression tool allows the user to plot an athlete’s competition performances onto a chart to see (a) how an athlete is progressing over any period of time, and (b)
compared to individual athletes who have been successful on the world stage. A unique feature of the progression trajectories is that if the cursor is placed on any performance trajectory, the name of the athlete will appear. New performance data for any developing athlete can be entered and a unique performance trajectory will be generated for this athlete. Developing athletes can then compare their performance progression trajectory with athletes who have already progressed to be successful.

Interpretation of Example Athletes

A unique feature of the performance progression CD is its ability to be able to plot an athlete's performance trajectory alongside the trajectories of established successful athletes and then the athlete and their coach can make interpretations in light of the way the trajectory is progressing or otherwise. The trajectories are particularly useful for assessing the progress of young developing athletes, giving a guide to the resources that may be required for them to progress. Figures 3-8

Another characteristic of the current work is that each athlete has a unique performance trajectory. On looking at progression trajectories (see Figure 2) for any event it can be seen that athletes progress at very different rates throughout their athletics careers. One of the limitations of previous work was that mean values of performance at a specific age by all athletes in the event was used, and the “mean value athlete” was used as the benchmark progression. The current approach allows for each athlete’s individual progression to be compared to individual athletes who have been successful on the world stage. A unique feature of the progression trajectories is that if the cursor is placed on any performance trajectory, the name of the athlete will appear. New performance data for any developing athlete can be entered and a unique performance trajectory will be generated for this athlete. Developing athletes can then compare their performance progression trajectory with athletes who have already progressed to be successful.

Figure 2: Performance trajectories for 62 male 200m athletes
provide examples of the individual trajectories of an athlete, superimposed on the chart showing the performance trajectories of successful athletes in the same event.

Young athletes progressing towards possible senior success or otherwise

Athlete A (Figure 3) started competing young, at the age of 14.6 yrs, and is progressing well according to the steep trajectory slope. At age 18 yrs, she has already reached the level of other athletes who were achieving similar results at the same age and went on to be successful senior athletes. She has lots of time to get to the top of her event and an improvement of 1-2m each year over the next 4-5 years should see her in senior level final or medal contention. Her competition results have been consistent as shown by the tight yearly performance clusters.

In contrast, Athlete B (Figure 4) has shown inconsistent performances throughout her short career and appears to have plateaued. To get back on course she needs to be throwing consistently in the 51-52m range at each competition over the next two to three years. It is accepted that the discus throw event is prone to changing weather conditions (particularly the direction of the wind), but this athlete has to achieve greater consistency if she is to make progress.

Athlete C (Figure 5), started young, at 14 years, and over the first two years made good progress to move into a performance zone that would give her encouragement to be a very successful high jumper. However, since her jump of 1.82m she has steadily declined in her performance results resulting in the undesirable inverse u-shaped trajectory. Both the athlete and her coach need to assess the reasons for this sharp decline.

Athlete D (Figure 6) is a young athlete who has very recently made a substantial improvement in his performances. Although he showed some promise in the very early part of his career and had results that confirmed this promise, the performances in the following years showed that he was slipping behind in...
Figure 4: Women’s Discus Throw Performance Progression – Athlete B

Figure 5: Women’s high jump performance progression – Athlete C
The performance trajectory charts have the ability to show a decline in performance of an athlete after they have reached their peak. By showing this decline, the athlete and their coach can then make decisions about their future, or address the issues that may be causing this decline.

**Athlete past their peak**

Athlete F (Figure 8) had a successful career in the 200m culminating in a top 16 finish at an IAAF World Championships in Athletics at the age of 23 years. Her performance trajectory up to that point is illustrated with the additional dark dashed black line. However, since that point, due possibly to injury or a change in social circumstances, she has been unable to maintain or build on those performances. The wide range in her performances in the years following her peak are also predictive that she has reached her peak and that it will be extremely difficult for her to regain her status as an elite athlete. This athlete reached her peak before the mean age of that of her peers.

**Latecomers**

Athlete E (Figure 7) started as late, as a 21 year old, and has made excellent progress over three years to have performances that would place him in the elite zone. He also changed coaches and has had two seasons of international-level competition, which may account for a change in his status as an international class athlete. However, he needs to have more performances consistently in the 3:38-3:39 range over the next couple of seasons if he is to retain that status. Further, he is approaching the mean age of peak performance in the event, although his late entry into the sport may delay reaching his age of peak performance.
The CD Performance Progression Tool

Figure 7: Men’s 1500m performance progression – Athlete E

Figure 8: Women’s 200m performance progression – Athlete F
Conclusion

The CD-based performance progression tool is a computer-based system rather than in booklet form, which allows users to plot their own data interactively. The revised method to calculate the performance progression of successful athletes addressed the limitations outlined in our previous work, and provides the user with a visual display of how their progression compares directly with current and past elite athletes as well as the ability to be able to plot every known performance, rather than the single best performance of the year. The accuracy of the model suggests it would be possible to use the model to make statements about the individual’s future progression with good precision.

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REFERENCES


UK Performance Funnels can be viewed at: http://www.uka.org.uk/world-class/performance-funnels/

NZ Performance Funnels can be viewed at: http://performance.athletics.org.nz/index.php/carding/performance-planning
The following articles included in this bibliography deserve particular attention:

An overview of the high jump is presented by Schiffer (2009). The aspects and topics dealt with in this article include the history of the high jump, the elements of the Fosbury flop technique, as well as several components of the basic training of the high jump (e.g., horizontal jumps, sprinting and specific strength).

A very specific aspect of the flop technique, namely the biomechanics of a high jumper’s rotation on take-off and bar clearance, is dealt with by Reid (2009). Reid focuses on the knee and arm action during take-off and bar clearance and states that there is a significant difference in the “reaction” of the knee drive whether the jumper uses an inside arm position on take-off or an outside arm position. If an athlete uses an outside arm thrust across the body, the knee opposite will twist away from the bar. If an athlete uses an inside arm thrust or a double arm thrust vertically, the inside knee can be driven more in a straight vertical direction, providing the maximal amount of thrust in line with the parabolic path the jumper is travelling. Coaches have to decide which arm action, and resulting knee drive positioning, is best for each of their athletes. In any case it is important for the jumper to keep his or her arms vertical, inside the imaginary lines of the body cylinder on take-off.

Jesse’s article “Weight training for high jumpers” (2008) is interesting both from the point of view of history and from the point of view of training science. First published in the 1970s, it examines the change that took place in the high jump at the end of the sixties. At that time Russian athletes and coaches transformed the high jump from a “spring” event to a “power” event. They reduced jump practice, increased weight training, and employed jump-technique simulation drills. The Americans, however, cautiously protected the “natural spring” and concentrated on bar clearance technique. Against this background, Jesse suggests that greater emphasis be placed on strength development for the leg biceps (hamstrings), a higher level of strength in the rotational muscles of the mid-section, and greater strength in the soleus muscles of the calf. He seriously questions the practice of many jumpers who incorporate in their weight training programmes such exercises as heavy cleans, bench presses, snatches and clean and jerks, all of which require a massive expenditure of energy. According to Jesse, the use of weightlifting exercises that have little or no relationship to the skills of an event for which the athlete is training is a waste of time that could be put to much better use. Weight training exercises should be based on the skills of the event taking into consideration the muscular movements involved in carrying out the skills.

Bisetto (2008) points out that although the dominant high jump technique when Jesse wrote his article was the straddle, Jesse’s
Killyéni (2011) recollects the Hungarian high jumper István Somodi, who was an outstanding figure of Hungarian athletics before the First World War. Somodi was the first Hungarian high jumper to develop a personal technique that was noticed at international level as well as at home. His style and technique are acknowledged as being the forerunners of the flop technique utilised by Dick Fosbury in 1968. Somodi’s most outstanding international success was the 1908 Olympics, where he won the silver medal. His success had an impact on athletics and the high jump in Hungary, since it created a new school of thought, while at the same time influencing local sporting life.

This bibliography has been compiled 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.

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thoughts and research discussions still have some relevance to today’s flop high jumpers. For example, Jesse’s reference to the fact that the Russians have been reducing jump practice, increasing weight training and employing jump stimulation drills can be applied to flop jumpers. According to Bisetto, many young athletes spend far too much time on just practicing the flop and not enough emphasis on conditioning and technique related drills.

The straddle is also dealt with in the appendix to Tidow’s analysis of the flop high jump (2007). Here, Tidow asks whether the straddle deserves to be extinct. He arrives at the conclusion that even today the straddle would theoretically be a genuine alternative to the power flop for some athletes. According to Tidow, the primary causes of the disappearance of the straddle may be that the flop can be learned much more quickly than the straddle and makes significantly less demands on the athlete’s physical and motor prerequisites. The flop can be taught even during childhood, i.e. at the favourable learning age, and makes early successes possible. Furthermore, if the flop is taught at an early age, it is not necessary for the athlete to learn a further high jumping technique at a later time, which may be very energy and time consuming. A further important factor contributing to the ‘extinction’ of the straddle is the fact that this technique generally puts a higher load on the body and therefore can lead, for example, to knee joint injuries.

Historical aspects of the high jump are dealt with by McNab and Killyéni. McNab (2006) outlines the development of the high jump as a competitive sport. He provides details on early reference to the sport and the change in technique over the years beginning with the Scottish Highland Games in the 19th century to the modern-day Fosbury flop. In his article “Raising the Bar”, McNab (2012) looks even further into the past. He cites several personalities engaged in the sport in its early years like the German physical educationist Guts Muths, and English jumper John Ireland in the 18th and 19th centuries.
New Studies in Athletics

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

Bibliography

AG Wettkampfsystem Kinderleichtathletik
Weit- & Hochspringen, Mehrfach- und Stabspringen [Jumping for distance and height, multiple jumping, and jumping using a pole]
Leichtathletiktraining, Münster (Germany), 22, (2011), 9/10, pp. 22-35

The new concept for the jumping events for children between six and eleven years provided by the German Athletics Federation is divided into four fields of movement: “From `jumping far’ to the ‘long jump,” “From ‘jumping high’ to the ‘high jump’, “From ‘multi-jumping’ to the ‘triple jump’, and „From ‘pole jumping’ to the ‘pole vault’“. Within competitive athletics for children, the Fosbury flop, which is the preferred jumping style in youth athletics, is carefully prepared and presented in a motivating way. The requirement profile for the 10- and 11-year-old children initially includes the scissors jump with the focus being on the take-off extension, the use of the swinging leg, and the bilateral take-off. The scissors jump is prepared by jumps for height and distance from a straight and frontal run-up into the long-jump pit.

Antekolovic, L.; Blazevic, I.; Mejovsek, M.; Coh, M. Longitudinal follow-up of kinematic parameters in the high jump – A case study
New Studies in Athletics, Aachen (Germany), 21, (2006), 4, pp. 27-37, 112, 114

The aim of this study was to evaluate the high jump technique of a single subject by determining the influence of kinematic parameters, tracking the changes to the recorded values with changes to the height of the jump and comparing the recorded values with those of other elite high jumpers. The subject of the study was Blanka Vlasic, the Croatian women’s record holder. Over a three-year period, her technique development was followed using data on 25 parameters acquired from jumps ranging from 1.80m to 2.00m. The values obtained for Vlasic are, for the most part, within the ranges documented for other world-class women high jumpers. Certain parameters for Vlasic changed with the height of the jump, influenced by improvements in her technique and important motor abilities. The authors found that systematic follow-up of the studied kinematic parameters enabled Vlasic to have a fast and rational technique learning process.

Bidder, T.
High jump sequence
Athletics Weekly, Farnham (Surrey), 61, (25 May 2006), 21, pp. 31-33

The focus of the article is on high jumping and includes training advice for elite jumpers in winter months and in the competition phase, conditioning requirements and a frame by frame explanation of jumper Susan Moncrieff’s technique.

Bisetto, S.
Weight training for high jump
Modern Athlete and Coach, Ashmore City (Austr.), 46, (2008), 2, pp. 20-21

This article is a reply to the article „Weight training for high jumpers” by John P. Jesse in Modern Athlete and Coach 1/2008 (pp. 20-24). The author points out that Jesse’s article was written almost forty years ago and although the dominant high jump technique of the time was the straddle, Jesse’s thoughts and research discussions still have some relevance to today’s flop high jumper. For example, Jesse’s reference to the fact that the Russians have been reducing actual jump practice, increasing weight training and employing jump stimulation drills can be applied to flop jumpers. The author adds that many young athletes spend far too much time on just practicing the flop and not enough emphasis on conditioning and technique related drills.

Blažević, I.; Antekolović, L.; Mejovšek, M.
Variability of high jump kinematic parameters in longitudinal follow-up
Kinesiology, Zagreb, 38, (2006), 1, pp. 63-71

The aim of this research was to determine the basic kinematic parameters of the high jump as well as the impact of changes in kinematic parameters on the height of the jump, and finally to determine the variability of kinematic parameters in longitudinal research. By means of kinematic analysis, 25 kinematic parameters were acquired for seven
new studies in athletics · no. 3.2012

The article discusses the effects of high jump training and competition on immune system function and blood cells of track-and-field athletes in South China Normal University in Guangdong, China. Ten male high jumpers underwent medical examinations at the beginning and end of training and after competition during the eight-week training and competition period. The findings showed that although training leads to a decline of the athletes’ body function it does not affect the immune function of B-lymphocytes.

Coh, M.
Biomechanical characteristics of take off action in high jump – a case study


This study aimed to establish the kinematic and dynamic parameters of the take-off action that generate the greatest efficiency in high jump. A biomechanical analysis was conducted using two synchronized cameras operating at a frequency of 50 Hz (SONY DVCAM DRS-300PK) and one high-speed camera with a 500 Hz frequency (MIKROTRON MOTION BLITZ CUBE ECO-1). The area of the last two strides of the run-up and take-off phases was defined with two Calibration Cubes measuring 1 x 1 x 2 metres. The kinematic parameters were established using the 3-D computer application APAS (Ariel Performance Analysis System). The 15-segment model of the body was digitized and defined by 18 reference points. Numerical data were smoothed with a 16-level digital filter. The dynamic parameters were established using a force plate (Kistler 9287) which was fastened at the take-off zone. The horizontal (x), vertical (y) and lateral (z) components of the ground reaction forces were measured. The signal sampling frequency was 1000 Hz. It was established that the most important kinematic parameters of the high jump include the horizontal velocity of the jumper’s CM at the beginning of the take-off phase and the vertical velocity of the jumper’s CM at the end of the take-off phase, equalling 4.33m/s. The efficiency of the take-off is related to the vertical ground reaction force which features two maximums. The jumper developed the first maximum of the vertical ground reaction force during the eccentric phase of the take-off, equalling 4213 N, whereas the second maximum was recorded in the concentric phase, measured at 4091 N. The lateral ground reaction

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Chun-hua Cai; Guo-qiang Xiao.
The effects of high jump on immune system function and blood cell of track and field athletes in university

Journal of Beijing Sport University, Beijing (China), 32, (2009), 4, p. 67

The article discusses the effects of high jump training and competition on immune system function and blood cells of track-and-field athletes in South China Normal University in Guangdong, China. Ten male high jumpers underwent medical examinations at the beginning and end of training and after competition during the eight-week training and competition period. The findings showed that although training leads to a decline of the athletes’ body function it does not affect the immune function of B-lymphocytes.
force equaled 3053 N and was manifested in an extreme loading on the ankle joint of the jumper's take-off leg in the take-off action.

Coh, M.; Supej, M. Biomechanical model of the take-off action in the high jump – A case study

*New Studies in Athletics, Aachen (Germany), 23, (2008), 4, pp. 63-73*

The article presents a case study that examines the key dynamic and kinematic parameters of take-off action in the high jump. A single elite athlete with a personal best performance of 2.31 meters was studied using a direct measurement method for the dynamic parameters and a synchronised three-dimensional video system for the kinematic parameters. The results of the study show that the jumper produced the highest ground reaction force in the eccentric phase of the take-off.


The paper presented in this article aimed to examine the effectiveness of differential learning in the high jump and in the area of coordination as compared with the “traditional” method of learning. The subjects were 16-year-old school pupils.

Fern, E. High jump training

*Modern Athlete and Coach, Ashmore City (Austr.), 49, (2011), 1, pp. 31-34*

The author reports what he has observed when watching high jumpers training in Germany. From his observations he derives conclusions regarding the high-jump run-up. He particularly focuses on the use of hurdles for teaching the correct run-up. When training the high-jump run-up using hurdles the following goals should be aimed at: 1. The high jumper should run tall, lift his or her knees and put down his or her feet actively. 2. He or she should think about having his or her knee going past the leg on the ground as soon as his or her foot touches the ground. 3. He or she should really work the outside leg on the approach. He or she should put it down, pick it up and grab fort he next step. He or she should drive off the penultimate step, bring his or her heel to his or her butt and drive his or her knee up. 4. He or she should gently increase his or her running speed as he or she moves through the approach. 5. He or she should lean when going through the curve. He or she should lean from the ankles, not the waist. The body should be kept tall and tight through the core. 6. There should be no interruptions, braking, and no sinking movements during the run-up. The next to last step does not have to hit heel first, because this slows the jumper down. This step should be rather run over into the take-off position. The lean-back at touchdown should happen naturally.

Frommel, H. Ökonomischer und pragmatischer Sportunterricht : zum Thema Flop (Einführung) in einer 7. Klasse des Gymnasiums [Economic and pragmatic physical education using the example of the Fosbury flop in 7th grade of grammar school]

*Lehrhilfen für den Sportunterricht, Schorndorf (Germany), 60, (2011), 11, pp. 21-25*

The author presents a 45 minute physical education lesson dealing with the introduction of the Fosbury flop for 12- to 13-year old pupils.

Frosio, I.; Sibella, F.; Botton, C.; Borghese, A.; Girlanda, M. Quantitative analysis of high jump styles


The purpose of this study was to investigate the relationship between the kinematics and dynamics in elite high jumpers. The analysis was based on an accurate anthropometrical model of the body and on the kinematic data obtained through optical motion measurement during an indoor training session. Based on angular momentum measurement suggestions for improving movement efficiency are provided. The analysis of the kinematic coordination and of the
inter-trial variability suggests that athletes should focus more on either the kinematics or the dynamics. Based on the data obtained, the authors arrive at the conclusion that the angular momentum and the kinematic variability do not appear to be correlated.

Glad, B.
The IAAF World High Jump Centre
New Studies in Athletics, Aachen (Germany), 24, (2009), 3, pp. 35-42
The article offers information on the International Association of Athletics Federations (IAAF) World High Jump Centre (WHJC) in Cologne, Germany. It mentions that WHJC was founded in November 2007 to support talented athletes who miss quality facilities and other services that would improve their ability to become world-class high jump performers. It states that some of the athletes who train in WHJC include Eike Onnen. An interview with WHJC Director Wolfgang Ritzdorf is also presented.

Hui-ju Pan; Xiao-hu Li; Xu-jiang Mao; Wen-hai Shi
A kinematic analysis on buffering technique in taking-off process of Chinese elite high jumper Huang Haiqiang
Journal of Beijing Sport University, Beijing (China), 32, (2009), 2, p. 115
The article presents a study which examines the kinematics underlying the buffering technique in the take-off process of Chinese elite high jumper Huang Haiqiang. The study was carried out using two cameras to film the athlete’s activities. The activities were analyzed using SMI software from Germany. The results show that buffering is lighter with a 13.24 inches knee angle at maximum buffering time. The authors also state that there is a disparity in Y velocities of the jump leg at take-off.

Hunneshagen, C.
„Coaches’ Eye” Technical analysis and fault finding as an internet application for coaching high jump
According to psychologists and educators, humans learn most effectively, when they can grasp information via more than one sense and when they can test the information in practice during the learning process. This article describes an online multimedia learning platform designed to use this approach to supplement coach education systems. The author outlines the process of developing the application, including the identification of a universal technical model and creation of a catalogue of questions. This is followed by a description of the application, which includes sections for 1) technical analysis, 2) fault-finding and correction and 3) a library of drills. Each section is illustrated with screen shots from the program. The article concludes with a discussion of the uses of the application and the next steps in the project. The project described in this article was the overall winner in the 2006 European Athletics Science Awards.

Isolehto, J.; Virmavirta, M.; Kyröläinen, H.; Kom, P.
Biomechanical analysis of the high jump at the 2005 IAAF World Championships in Athletics
New Studies in Athletics, Aachen (Germany), 22, (2007), 2, pp. 17-27
The purposes of this study were to determine how the maximum height of the jumper’s centre of mass (CM) during the flight phase of the high jump is dependent on the kinematic variables of the take-off and to update current knowledge about the development and performance of the Fosbury flop technique. The best jumps of the finalists at the 2005 IAAF World Championships in Athletics were filmed and analyzed. The authors confirm earlier findings that the vertical velocity and height of the CM at the end of the take-off phase determine the height of the flight. The most important factor related to vertical velocity at the moment the take-off foot loses contact with the ground is the CM position when the foot touches down for the take-off. CM height at this point is related more to arm technique than physique. The difference due to arm action can be 8 cm if the jumper is 2 m tall.

Jesse, J. P.
Weight training for high jumpers
Modern Athlete and Coach, Ashmore City (Austr.), 46 (2008), 1, pp. 20-24
At the end of the 1960s, Russian athletes and coaches transformed the high jump from a „spring” event to a „power” event. They reduced
actual jump practice, increased weight training, and employed jump-technique simulation drills. The Americans, however, cautiously protected the „natural spring“ and concentrated on bar clearance technique. Against this background, the author suggests that greater emphasis be placed on strength development for the leg biceps (hamstrings), a higher level of strength in the rotational muscles of the midsection, and greater strength in the soleus muscles of the calf. The author seriously questions the practice of many jumpers incorporating in their weight training programs such exercises as heavy cleans, bench presses, snatchers and clean and jerks, all of which require a massive expenditure of energy. The writer has maintained for many years that use of weightlifting exercises that have little or no relationship to the skills of an event for which the athlete is training is a waste of time that could be put to much better use. Weight training exercises should be based on the skills of the event taking into consideration the muscular movements involved in carrying out the skills.

Katzenbogner, H.  
*Damit der Hochsprung kein „Flop“ wird* [Teaching the Fosbury flop successfully]  
*Leichtathletiktraining, Münster (Germany), 21*, (2010), 1, pp. 12-19  
The Fosbury flop can be successfully learned by children 10 years old and older. The objectives of the lesson presented by the author to introduce the flop technique are: 1. Run-up and take-off training on a circular path using different jumping rhythms (bounding run, single-leg hops); 2. pop-up jumps and rotational jumps on a soft surface; 3. flop exercises from standing position (learning the flight phase); 4. landing in sitting position and on the back from a run-up; 5. flop technique from five run-up steps.

Katzenbogner, H.  
*Hochspringen wie Walery Brumel* [Jumping high like Valeriy Brumel]  
*Leichtathletiktraining, Münster (Germany), 20*, (2009), 9, pp. 32-39  
In this lesson for pupils from the age of 10 onwards the straddle technique of high jumping is introduced. By learning this technique, the children can expand their jumping experiences.

Katzenbogner, H.  
*Von Tierspielen zum Rollsprung: Bei der Vorbereitung auf den Hochsprung helfen Steige- und Rollsprünge* [From animal games to the roll jump: pop-up and roll jumps are helpful when preparing the high jump]  
*Leichtathletiktraining, Münster (Germany), 20*, (2009), 4, pp. 14-23  
The high jump should already be prepared during childhood by jumping onto and over various obstacles. Even simple techniques, such as the squat, roll, and scissors jump, are suitable to give the children a feeling for the high jump. The secure and fluent combination of run-up and take-off as well as the skillful clearing of obstacles are the basis of competition technique. Against this background, the author presents an athletics lesson with the following objectives: 1. Introduction to the technique of the pop-up and roll jump; 2. jumps with changes of direction and turns; 3. jumps from straight and oblique run-ups; 4. making the children aware of the take-off and swinging leg; 5. improvement of the orientation, differentiation, and balancing abilities.

Kaufhold, M.-A.  
*Der Speed-Flop im Sportunterricht – ein Webcam-unterstütztes Unterrichtsvorhaben zum Hoch-Springen* [The speed flop in school physical education classes – a webcam-supported high-jump teaching project]  
*Lehrhilfen für den Sportunterricht, Schorndorf (Germany), 58*, (2009), 7, pp. 7-9  
The author shows that the teaching of the speed flop in school physical education classes can be facilitated through video analysis using a webcam.

Keil, J.-G.  
*‘Now is now!’ Eine Einstellung, die Stefan Holm 2004 zum Olympiasieg führte* [‘Now is now!’ An attitude that led Stefan Holm to the Olympic victory in 2004]  
*Leichtathletiktraining, Münster (Germany), 21*, (2010), 5, pp. 33-38  
Sweden’s Stefan Holm was one of the best high jumpers in the world. He was four times indoor world champion and won the gold medal at the Olympic Games in Athens in 2004. When he finished his career in 2008, he had cleared 2.30 m 132 times with a personal best of 2.37 m. In this paper, an overview of Stefan Holm’s performance and career development is given. His career was based on the following seven principles: 1. „Don’t
care about things that you can’t change!” 2. “Everyone makes mistakes, but you should make the same mistake only once!” 3. “Always look a little beyond the bar!” 4 “Victories must be learned!”
5 “Expect the unexpected!” 6 “Never be too sure that you will win!” 7 “In competition only the moment counts!” The article also deals with typical training contents used by Stefan Holm (jumps over the bar, hurdle jumps, horizontal jumps).

Keil, J.-G.
Zwei Hochsprung-Talente auf dem Vormarsch [Two talented high jumpers making their way]
Leichtathletiktraining, Münster (Germany), 22, (2011), 2/3, pp. 26-35

On the basis of photo sequences, the high-jump technique of the two German junior high jumpers Mateusz Przybylko and Melina Brenner is analyzed. In 2010, Mateusz Przybylko was both German Youth and German Junior Champion and increased his personal best to 2.16 m. He was the only German high jumper who took part in the 2010 U-20 World Championships in Moncton, where he cleared 2.10 m. Melina Brenner improved her personal best to 1.85 m in January 2011. In 2010, the 17-year-old high jumper represented Germany at the first Youth Olympic Games in Singapore, where she was second in the B final. The photo sequences show Mateusz Przybylko jumping over 2.06 and Melina Brenner during a jump over 1.82 m. The home coach of both athletes, Hans-Jörg Thomaskamp, presents additional information on the abilities and techniques as well as the training of both high jumpers.

Killing, W.
Kajsa Bergquist – Königin der Lüfte [Kajsa Bergquist – Queen of the air]
Leichtathletiktraining, Münster (Germany), 17, (2006), 4, pp. 16-21

In February 2006, the Swedish high jumper Kajsa Bergquist achieved a new indoor world record of 2.08 m. The author comments on this jump on the basis of a picture sequence. The most important technical criteria of the jump are: 1. The very powerful stride, 2. the extremely high approach speed, 3. a clearly visible inward lean when running the curve, 4. an extraordinary vertical jumping power, 5. an enormous upward drive which results in a very high rise which is unique for women, 6. a fast rotation of the body around the bar.

Killing, W.
Zweimal Bronze für Deutschlands Höhenjäger: In Berlin gewannen zwei von drei deutschen Startern eine Medaille [Two bronze medals for German high jumpers: In Berlin two of three German high jumpers won a medal]
Leichtathletiktraining, Münster (Germany), 20, (2009), 10+11, pp. 26-35

No. 95: High Jump
After a more or less detailed introductory overview of the historical development of the German high jump, the international level in the high jump, the development of the German World Cup candidates, the qualifications for the 2009 World Cup and the performances in the finals, the author analyzes the techniques of the medalists from Berlin in their respective best attempts. Using biomechanical analyses, the technique of the following athletes is dealt with in detail: Women – 1. Blanka Vlasic (1st place with 2.04 m), Anna Chicherova (2nd place with 2.02 m), Ariane Friedrich (3rd place with 2.02 m), Men – 1. Jaroslav Rybakov (1st place with 2.32 m), Kyriakos Ioannou (2nd place with 2.32 m), Sylvester Bednarek (3rd place with 2.32 m), Paul Spank (3rd place with 2.32 m). In addition, the 1.87-m jump of German high jumper Meike Kröger is analyzed (11th place). The warming-up of Ariane Friedrich and Blanka Vlasic before the World Cup final in Berlin is also described. Finally, the author discusses the further performance prospects of the German high jumpers.

Killing, W.; Baarck, K.
Die Hochsprungtechnik der Allrounderinnen [The high-jump technique of heptathletes]
Leichtathletiktraining, Münster (Germany), 20, (2009), 8, pp. 16-23

Based on photo sequences, the authors analyze the high-jump technique of the currently best German heptathletes, Jennifer Oeser (PB: 1.86m), Carolin Schäfer (PB: 1.78m), and Deborah Brodersen (PB: 1.80m). The respective home coaches of the three athletes give an insight into their athletes’ training.

Killing, W.; Fredebold-Onnen, A.
Eike Onnen und die magischen 2,30 Meter [Eike Onnen and the magical 2.30 metres]
Leichtathletiktraining, Münster (Germany), 18, (2007), 5, pp. 4-12

The authors show three typical training weeks from the autumn and winter season 2006/2007 of the German 2.30m high jumper Eike Onnen and comment on picture sequences of his 2.30m and 2.26m jumps. The article also includes a biomechanical comparison between Eike Onnen and the world-class high jumper Sokolowskij. This comparison shows that Sokolowskij’s run-up velocity is higher and that his lifting path is longer. This leads to a higher rising velocity and to a significantly higher flight height. These results can also be interpreted as an indication of Eike Onnen’s possible reserves.

Killing, W.; Jeschke, E.
Mit Macht nach oben [Upwards powerfully]
Leichtathletiktraining, Münster (Germany), 19, (2008), 6, pp. 18-27

The author gives an insight into the training of the German high jumper Kimberley Jeß, who holds the German record for 14-year-olds (1.83m). Kimberley Jeß is a very versatile athlete who competes a lot in her special event (more than 30 high-jump competitions per year). The main focus of her training is on sprint, jumping strength, and jumping technique. Apart from athletics, Kimberley takes part in two ballet sessions per week. Using a picture sequence, the author analyses Kimberley’s high-jump technique and arrives at the conclusion that her technique is good and stable. Kimberley’s primary goals for the future should be a higher run-up speed and a take-off farther away from the bar. A positive side effect of a take-off at greater distance from the bar would be a more marked rise from the inward lean and a better rotation around the bar.

Killyéni, A.
István Somodi – High jumper, innovator of Hungarian athletics and role model of the all-round sportsman in the first decades of the twentieth century

István Somodi was an outstanding figure of Hungarian athletics before the First World War. His life and his all-round sporting career are unique in the history of Hungarian athletics, and an analysis of them provides an opportunity to learn about the life, the opportunities for improvement and the importance of the national and international successes of a talented athlete from the countryside. Somodi was the first Hungarian high jumper to develop a personal technique that was noticed at international level as well as at home. His style and technique are acknowledged as being the forerunners of the flop technique utilized by Dick Fosbury in 1968. Somodi’s most outstanding international success
was the 1908 Olympics, where he won the silver medal. His success had an impact on athletics and the high jump in Hungary, since it created a new school of thought, while at the same time influencing local sporting life. As a result, a sports ground of European standard was inaugurated in Cluj in 1911. The value of Somodi’s achievements was heightened by the fact that as an athlete from the countryside, and who lived far from the capital, he rarely had the chance to take part in major competitions in the capital city or in Central Europe. He valued his studies more than his sporting successes, and although a great career was awaiting him in the Hungarian capital city of Budapest, he remained in his home town in the hard times after the First World War, and for decades worked hard training talented local athletes.

Koszewski, D.
Im „Blindflug“ zu Medaillen: Biomechanische und methodische Überlegungen zum Hochsprung [Winning medals „flying blind“: biomechanical and methodological reflections on the high jump]

The high jump is one of the most popular events in children’s and youths’ athletics. Particularly, the flop technique can be easily learned. The main characteristics of the flop technique are the bar clearance in the back layout position and the curved run-up which is much faster than the run-up of the straddle jump. The athlete takes off from the leg that is farther away from the bar. The action of the swinging leg, which is slightly flexed, is very dynamic. Generally, the flop high jump should be trained as a complete movement. With beginners, the special focus should be on the run-up-take-off complex.

Kurschilgen, B.
Mit hohem Tempo hoch hinaus! [High into the air with high speed]
Leichtathletiktraining, Münster (Germany), 19, (2008), 4, pp. 12-17

The author analyses the technique of the German top-level high jumper Ariane Friedrich using a picture sequence of her 2.01m jump at the 2008 German Indoor Championships. The focus of the analysis is on the run-up, the preparation for take-off, the take-off, the rise, and the bar clearance. The author identifies the following factors as the causes of Ariane Friedrich’s success: 1. A low body weight in spite of a steady strength level and a much higher run-up velocity than in the previous years, 2. a stabilised level of reactive strength abilities, 3. a high degree of will power, consistency and mental power on the basis of a stable and optimal training environment.

Laffaye, G.
Fosbury flop: predicting performance with a three-variable model

The goal of this study is to (a) find the most predictive anthropometric factors, (b) check the predictability of a new jumping motor test, and (c) predict Fosbury-flop (FFP) performance by using a multi-regression analysis. The participants of this study were 49 girls (age 13.6 ± 0.48 years; height = 1.61 ± 0.07 m) and 68 boys (age 13.6 ± 0.47 years; height = 1.64 ± 0.10 m). We measured the height, the sitting height), the highest position touched by the hand in a standing position (HEIGHTARM), the highest position touched by the hand during a running 1-leg vertical jump with a semi-restricted curved run-up (HMAX), and the best performance in the FFP. We then calculated the leg length (LEGLNGTH), the skelic index (ratio of legs length to the abdomen length, SKEL), the vertical performance (VP, difference between HMAX and HEIGHTARM). The ability level was deducted from the difference between (LEGLNGTH + VP) and FFP. Pearson correlation coefficients were calculated, and a multiple-regression analysis technique was applied to find the most predictive model (p < 0.05). The FFP was correlated with standing height (HEIGHT; r = 0.398; p < 0.05), HMAX (r = 0.707; p < 0.0005), ABILITY (r = 0.391; p < 0.005) but not with SKEL (r = 0.161; p = 0.01). The best multiple-regression model included HEIGHT, HMAX, and ABILITY with a high level of prediction (r2 = 0.94). In conclusion, the FFP performance can be predicted with equation: FFP = -0.618 HEIGHT + 0.898 HMAX + 0.669 ABILITY − 0.08. This equation is quite similar for both sexes, showing that 13-year-old girls and boys use the same method to jump high, which implies that the way to increase coordination or lower limb strength during training can be the same for junior boys and girls in high jump.
Li Lin; Bi Hai-Bo; Hou Ming-Xin
The relationship between high jump athletes' self-control ability and performance
Journal of Beijing Sport University, Beijing (China), 30, (2007), 10, p. 1412
The article explores the relationship between high jump athletes' self-control ability and performance. Results show that there is significant positive correlation between the scores for preparation, operation, the feedback and performance. Generally speaking, when the skill level is improved, the self-control ability is greatly enhanced.

Lima, J. C.; Marin, D. P.; Barquilha, G.; Da Silva, L. O.; Puggina, E. F.; Pithon-Curi, T. C.; Hirabarai, S. M.
Acute effects of drop jump potentiation protocol on sprint and counter movement vertical jump performance
Human Movement, Wroclaw (Poland), 12, (2011), 4, pp. 324-330
Purpose: Muscle post-activation potentiation (PAP) is a mechanism by which power twitch is increased after previous conditioning contractions. In this study, we determined the time-dependent effect of a loaded drop-jump protocol on sprint time and countermovement jump height in well-trained athletes. Methods: Ten athletes randomly performed the control and experimental protocols on two different days. As a pre-test, the athletes performed the vertical jump and 50 m sprint test for preload measurements. Then, the experimental or control protocol was randomly applied, where the control protocol was composed of the athletes remaining at rest for 10 min. In the experimental protocol, the athletes performed two sets of 5 drop jumps (0.75 m), with a 15 s interval between the jumps and a 3 min rest after each set. Then the vertical jump and 50 m sprint tests were performed again 5, 10, and 15 min after the protocol. Results: The experimental condition (drop jump potentiation protocol) increased performance in the vertical jump by 6% after 15 min (p < 0.01) and in the sprint by 2.4% and 2.7% after 10 and 15 min, respectively (p < 0.05). Conclusions: These findings suggest that the drop jump potentiation protocol increases countermovement vertical jump and sprint performance in high-performance athletes at different times, suggesting that PAP induction depends not only on the design of the protocol, but also on the effect of time and the type of exercise involved.

Martins, S.; Carvalho, J.; Conceição, F.
Insights of take-off of ground reactions force in high jump
The article presents a study that examines the high-jump (HJ) take-off technique using force plate data and defines the take-off the ground reaction force (GRF) profiles as function of technical and conditional characteristics of different athletes. It highlights the significant role of take-off on HJ performance where it exhibits an increased complexity due to the curvilinear approach-run pathway. Results of the study suggest that GRF can be used to perform technical evaluation.

Masters, A.
High jump training: method for marking run-up curves
Modern Athlete and Coach, Ashmore City (Austr.), 48, (2010), 3, pp. 11-12
The article focuses on the method used for making a curve for a high jumper’s run. It mentions that the information provided was based on detailed measurements of the run-ups of 8 of the best male high jumpers and 7 of the best female high jumpers in the world. Several diagrams are also offered depicting the method and the measurements for marking average curves for men and women.

McEwen, F.
High jump: Teaching the Fosbury flop
Modern Athlete and Coach, Ashmore City (Austr.), 45 (2007), 4, pp. 10-14
The critical factor in the high jump is how fast and how powerful is the athlete at take-off. This in turn determines the optimal take-off time for any individual. Those with high reactive capacity will have shorter take-off times than those with less reactive capacity and more strength. Take-off time is strongly influenced by the athlete’s preparation for take-off and by the action of the free elements (arms and legs). Over-preparation for take-off will lengthen the take-off time as will the use of long arms and lead leg swings. The athlete must adopt a movement pattern which will set up optimal take-off conditions. That is, the preparation for take-off and the style of free element swing must be tailored to the individual ath-
lete. These requirements, in turn, will determine the speed of the athlete’s approach run. In short, the speed of the approach run is determined by the athlete’s take-off characteristics rather than the reverse, i.e., the speed of the approach run determines the athlete’s reactive activities at take-off. The consequence is obvious: Athletes must work to improve their reactive capacity if they want to use a shorter take-off time and/or quicker approach speeds. Hence, the development of reactive capacity must be a central element of high-jump training from their earliest introduction to the event.

McNab, T.  
Scots to Fosbury: the technical evolution of the high jump  
The author outlines the development of the high jump as a competitive sport. He provides details on early reference to the sport and the change in technique over the years. Beginning with the Scottish Highland Games in the 19th century, techniques have evolved to the modern-day Fosbury flop.

McNab, T.  
Raising the bar  
Athletics Weekly, Farnham (Surrey), (1 May 2012), pp. 24-25  
The article discusses the developments in the sport of high jump. It cites several personalities engaged in the sport in its early years like European physical educationists like Guts Muths, and English jumper John Ireland in the 18th and 19th centuries. It presents several outstanding athletes in the sport, including Thomas Anderson, Donald Dinnie and Scottish American James Goldie.

Melfort, J.  
Le saut en hauteur feminin. Mélanie: de la préparation à la finale [Women’s high jump: pre-competition preparation of Melanie Skotnik]  
Coach Jimmy Melfort gives an account of how he helped prepare French high jumper Mélanie Skotnik between her arrival at the 11th IAAF World Championships in Athletics (Osaka, 2007) and her performance in the finals.

Mühlbach, T.  
Bausteine für das richtige Floppen [Modules for the correct flop technique]  
Leichtathletiktraining, Münster (Germany), 18, (2007), 8, pp. 20-27  
For young athletes, the flop high jump is an extremely attractive jumping style, because the basic form of this jumping style can be learned very fast even by 12-14 year-old children. Against this background, the author presents a methodical sequence including six steps: 1. Pop-up jump from a straight run-up; 2. curve run and pop-up jump; 3. five-stride curve run with scissors jump; 4. landing position and bar clearance; 5. flop jump from a five-stride run-up; 6. flop jump from a seven-stride run-up.

Paish, W.  
Teaching the high jump  
Athletics Weekly, Farnham (Surrey), (1 October 2008), p. 29  
The article focuses on teaching beginners the skills needed for high jumping in Great Britain. The author believes that the essential first experience for the novice high jumper must be the running straight jump. The technical emphasis in training must be the planting of the take-off foot, together with the vigorous extension of the take-off leg.

Parker, R.  
Soaring high  
Athletics Weekly, Farnham (Surrey), (2 September 2012), pp. 40-41  
The article discusses some pointers in high jump run-up and take-off. It elaborates on how high jumpers can execute a correct and continuously accelerated run-up and vertical take-off. It also offer information on the serious problems of jumpers using a „J“ curve in their run-up and a sharp curve closer to their take-off. The author underscores the role of speed, alignment and rhythm of the final three strides in a successful high jump.

Pfitzner, M.  
Tausche Fosbury-Flop gegen Schersprung. Wie können Oberstufenschüler ihre Leistung im Hochsprung verbessern? Welche Faktoren entscheiden über die gesprungene Höhe? [I’ll exchange the Fos-
bury flop for the scissors jump. How can upper-grade students improve their high-jump performance? Which factor are responsible for the height cleared?]

Sportpädagogik, Seele (Germany), 33, (2009), 3+4, pp. 40-43

The focus of the teaching project described in this article was “individual performance” with the goal of improving the students’ high-jump performance. First of all, the students were asked to use the “mind-mapping process” to identify the following performance-relevant factors of the high-jump performance: body height, strength, jumping ability, speed, body weight, and technical skills. Then the students were asked to determine teaching emphases (i.e., jumping exercises) in accordance with the assessment of their performance. In doing so, they learned that “technical skills”, jumping strength, and body height have the greatest impact on improving their high-jumping performance.

Reid, P.
High jump mechanics: A coach’s technical check list (For slow motion viewing of competition jumps)

Modern Athlete and Coach, Ashmore City (Austr.), 48, (2010), 1, pp. 19-20

The article discusses coaching techniques for proper execution of high jump by an athlete. It says that it is important for the coach and the jumper to review the technique used during an event to be able to correct mistakes during the practice. It suggests that filming the movement of the jumper can help identify on what technique a jumper needs to work on.

Reid, P.
High jump technique: the biomechanics of a high jumper’s rotation on take-off and bar clearance

Modern Athlete and Coach, Ashmore City (Austr.), 47, (2009), 4, pp. 20-23

In the mid 1960’s, American Dick Fosbury and Canadian Debbie Brill were the first athletes to use the back layout technique of high jumping successfully in international competition. Called the “Fosbury Flop” or the “Brill bend”, the technique was used by both athletes in their respective 1968 Olympic Trials. Dick Fosbury’s gold medal in the 1968 Olympic Games in Mexico City ensured his name was forever ensconced with the event. Brill did not qualify for the Canadian Olympic team that year, but would go on to be selected to compete at the next four Olympic Games. Because of the success of Dick Fosbury at the 1968 Olympics his technique was immediately studied by some of the world’s outstanding high jump researchers/coaches in the decade that followed. Initially many studies discussed the rotational aspects of jumping high in the most efficient manner. Authors who studied Fosbury’s technique noted the unique arm action of Fosbury, his use of the inside knee drive, and his controlled head position as he passed over the bar. Authors who studied Brill’s technique noted in more detail the fact that she twisted her knee away from the bar on take-off. Many coaches assumed the twisting of the knee was required to rotate the jumper onto their back (rotating around the longitudinal axis). Few realized Brill’s style was quite unique. She used her outside arm thrust across her face as she tried to drive it vertically, which caused the reaction of the opposite (inside) knee twisting away from the bar. Since Fosbury hardly used his arms on take-off at all, or as he cleared the bar, many instructional articles assumed that twisting the knee away from the bar was important in rotating the jumper on take-off. What was overlooked at the time was the fact that rotation is initiated by the shoulders and position of the arms (action) with the “direction” of the driving knee of the free leg, reacting for the most part, to the arm action used (outside arm, inside arm, double arm, etc.). Coaches/researchers did not initially notice the variation in arm use on take-off (inside single arm, outside single arm, double arm vertical thrust, dropping the arms to the hips). There is a significant difference in the “reaction” of the knee drive whether the jumper uses an inside arm position on take-off or an outside arm position. If an athlete uses an outside arm thrust across the body, the knee opposite will twist away from the bar. If an athlete uses an inside arm thrust or a double arm thrust vertically, the inside knee can be driven more in a straight vertical direction, providing the maximal amount of thrust in line with the parabolic path the jumper is travelling. Coaches have to decide which arm action, and resulting knee drive positioning, is best for each of their athletes. In any case it is important for the jumper to keep his or her arms within the body cylinder.
Any “action” of reaching in of the arms will result in two “reactions” that can have a negative impact on the jump. Reaching in can pull the athlete toward the bar prematurely, which reduces the time the jumper has to travel vertically to arrive on top of the bar and secondly reaching in with the inside arm will result in the reaction of the knee twisting away from the bar, compromising the ability to drive the knee, vertically. It is therefore preferable if the athlete keeps his or her arms vertical, inside the imaginary lines of the body cylinder on take-off.

Ritzdorf, W. 
Approaches to technique and technical training in the high jump
New Studies in Athletics, Aachen (Germany), 24, (2009), 3, pp. 31-34
The coach’s approach to technique and technical preparation are critical for his/her athlete’s success. All coaches face this challenge, regardless of the athlete’s level of ability or performance. The author starts with a discussion of the importance of understanding the technical model in his event. He then describes the key elements of the approach he has developed while working with athletes who are normally quite talented but may be underdeveloped from a training or technical point of view. It includes two strategies for technique development: a) checking whether the athlete’s personal style contributes or hinders the achievement of key technical elements and b) developing the athlete’s technical model based on an assessment of his/her reactive strength, which is the most important factor affecting the take-off in the high jump. He then gives a brief description of the four elements of the technical preparation program he uses: a) development of general qualities; b) development of specific qualities; c) development of specific skills, and d) technical training.

Rosenfelder, W. 
Einführung des Hochsprungs. Zwei Doppe lstunden in Schule und Verein [Introducing the high jump: two double lessons for school and club] 
Sportpraxis, Wiebelsheim (Germany), 50, (2009), 6, pp. 11-16
The focus of the high-jump teaching lessons presented in this article is on: 1. High-jump variations – scissors jumps; 2. the Fosbury flop – improvement of the flight phase.

Schiffer, J. 
The high jump
New Studies in Athletics, Aachen (Germany), 24, (2009), 3, pp. 9-22
The article presents an overview of the main aspects and other topics related to high jump. It says that the first recorded competition for high jump in modern times has taken place in Scotland during the 19th century. It discusses the elements of the Fosbury Flop technique which include the approach, take-off and bar clearance. Several components for the basic training of high jump are also mentioned including horizontal jumps, sprinting and specific strength.

Schwender, U. 
Der Weg zum Flop [Teaching the Fosbury flop] 
Lehrhilfen für den Sportunterricht, Schorndorf (Germany), 61, (2012), 2, pp. 13-14, Lit.
In teaching the high jump, the focus has traditionally always been on the run-up and take-off part of the jump. On the other hand, the clearing of the bar has often been neglected. Against this background, the author describes the method of teaching the flop according to Dick Fosbury with the emphasis on correct bar clearance.

Semenov, V.G.; Smoljanov, V.A. 
Specifika prisposobitel'nych perestroek dvigatel'nogo apparata prygunov v vysotu s razbega v processe stanovlenija sportivnogo masterstva [Specificity of the adjustment of the motor apparatus of top-performance high jumpers] 
Teorija i praktika fizičeskoi kul'tury, Moscow, (2010), 12, pp. 15-17
According to the authors, the examination of the content and nature of the adjustment of the force relations between the muscle groups on the basis of the working segments of the lower extremities of high jumpers in various training stages is of a high topical interest. In their tensometric investigations to identify the maximal isometric muscle tension of the thigh extensor, the lower-leg extensor and the foot flexor in 70 high jumpers of different performance ability, they arrive at the conclusion that, firstly, the force potential of the extensors and its relationship to athletic performance is the adaptation process that is influenced by the intramuscular coordination acquired in the course
of special strength training; and that, secondly, the level of strength development of the various muscle groups of the extensors of the lower limbs and their contribution to high-jump performance must be systematically monitored and should be used as an objective basis for the specification of the tasks and the choice of the structural means of special strength training.

Theodorou, A.; Skordilis, E.
Consequences of the new competition rules for the high jump at the European Team Championships
New Studies in Athletics, Aachen (Germany), 24, (2009), 3, pp. 23-30

In 2009, European Athletics replaced the European Cup with the European Team Championships. The new event featured innovative technical rule changes in many events including the pole vault and high jump, where each competitor was entitled to a maximum of four aggregate fouls throughout the competition. The purpose of this study was to examine the effects of the new rules on performance in the high jump. Data on performances in the top leagues (n=48; 24 males and 24 females) were obtained from both the 2008 European Cup and the 2009 European Team Championships. Nine dependent variables were examined using a statistical analysis package. The authors found the new rules had not affected the results but, in the case of male jumpers, several performance parameters including mean height and the number of successful attempts had improved. They suggest a psychological effect of the rules was to make the jumpers more focused on their technique. On the other hand, the overall performance of the women jumpers seems to have deteriorated. The number of attempts taken and the mean mark achieved were lower and there were more failed efforts in 2009 compared to 2008. A possible explanation is that the psychological effect led to the jumpers taking too few attempts and failing more often.

Visnes, H.; Bahr, R.
Jumping ability and change of jumping ability as a risk factor for developing jumper’s knee? Data from the patellar tendinopathy cohort 2006-2010

Background: Previous studies on high level athletes has shown that players with jumper’s knee jumps as high and perhaps even higher than the symptom-free athletes. The reason for this difference is unknown, and we know little about when this difference occurs. Objective: Assess the Jumping ability and change of this ability as a risk factor for developing jumper’s knee. Design: Prospective cohort study. Participants: Elite volleyball players at junior high school (Top Volley Norway) at Sand, Norway. Method: Standardised jumping on the power platform (Bosco test). Standing jump (SJ) and countermovement jump (CMJ) were tested at baseline and then
twice a year. The jumper’s knee diagnosis was based on a standardised clinical examination. Results: A total of 113 symptom-free students were included, with a mean observation time of 1.8 years. 19 of these developed jumper’s knee (16 boys and three girls). The three symptomatic women these were excluded in the analysis. The groups were equal at baseline; asymptomatic athletes had SJ of mean 27.5 cm and CMJ at 35.0 cm, while the jumper’s knee group had SJ at 28.0 cm (p=0.67 vs asymptomatic) and CMJ (37.2 cm (p=0.10). Jumping ability changed in both groups. For the asymptomatic it was SJ: 5.5 cm (95% CI 1.9 to 9.1) for and CMJ: 6.0 cm (4.1-7.9) while the corresponding results in jumper’s knee group was SJ: 3.7 cm (-1.8 to 9.3) (ANOVA, p=0.003) and CMJ: 4.5 cm (0.3 to 8.8) (ANOVA, p=0.001). Conclusion: There is no difference at baseline between the men who developed jumper’s knee with those who remained asymptomatic. Those who remained asymptomatic, however, increased their jumping ability more than those who developed a finding that conflict with data from previous cross-sectional studies.

Wang Ling-Fei
Kinetics analysis of characteristics of the last two run-up steps and taking off speed of Chinese excellent woman Fosbury flop high-jump athletes
Journal of Shenyang Institute of Physical Education, Shenyang (China), 27, (2008), 1, pp. 89-90
In this article, the characteristics of the last two run-up steps and taking-off speed of Chinese women flop high jumpers are discussed. The author points out that the amortization action of the jumpers studied during the last two steps is not very marked and that the speed of the swinging action of the leg swing at the take-off is low. Furthermore, there is a very pronounced fluctuation of the height of the body’s centre of gravity in most of the athletes.

Wensor, D.
Teach kids scissors high jump in 30 minutes
Modern Athlete and Coach, Ashmore City (Austr.), 48, (2010), 2, pp. 6-8
The article presents an outline of the process that the author used in teaching young athletes a scissors high jump technique. It provides an overview of the 30 minute working model which aims to teach the basic, safe, working model technique within the period of thirty to forty minutes as well as its steps and activities involved. It notes that awarding points or labels according to the height jumped offers additional fun and competitive element of the game.

Zhong-Ge Zhou
A study on pre-competition special strength training of elite man high jumper
Journal of Beijing Sport University, Beijing (China), 32, (2009), 1, p. 126
The article presents a study which examines the special strength training of Zhang Shufeng before the 10th National Games in 2005. In the study, the characteristics of Zhang Shufeng’s training stages and load control were investigated. Moreover, mathematical statistics and logical analysis serve as reference to the strength training of male high jumpers.

Žilinskiené, N.; Radziukynas, D.
Geriausiu pasaulio šuolininkiu i aukšti rezultatu kaitų bendrų dėsningumai ir individuolūs ypatumai [Constant patterns and individual Characteristics of the change of results of female world-class high jumpers]
The preparation of female high jumpers consists of preparatory, main and specialized preparation, as well as stages of achieving and maintaining high sport results. The complete process encompass the period of 15-20 years and lasts from the age of 12-13 up to 30-31. Developing, impact of sport training contributes along with the natural biological and physical pubescence of female athletes. Aim of research was to determine general consistent patterns and individual peculiarities of the elite female high jumpers of the World and Lithuania during their complete sports career. Subjects of research: The elite female high jumpers of the World and Lithuania (n=13). Methods of research: Analysis of literature, analysis of documents (all data has been collected from www.iaaf.com and sports diaries), mathematical statistics (mean, standard error, standard deviation, statistical significance of mean differences according to Student criterion). Results of research: The average height of
the elite female high jumpers of the World and Lithuania (n=13) is 1.81 ± 0.02 m, their average weight is 61.83 ± 1.41 kg and their body mass index is 18.77 ± 0.20. The best average sport results 2.03 ± 0.01 m have been achieved at the age of 25.92 ± 0.94. It takes from 10-11 years to achieve international level sport results. The female high jumpers jump on average 22.25 ± 2.43 cm over their height. Taller athletes, whose height varies from 1.86 in up to 1.93 m, jump by 16-17 cm lower as compared to those whose height is 1.69-1.79 m. The female high jumpers’ height has no impact on their sports results. The results of the study show that the sport results of the World’s best female high jumpers at certain preparation stages do not improve evenly. The uneven increase of results was determined by the initial preparation stage (12-17 years old) going up from 1.40 ± 0.06 m up to 1.84 ± 0.02 m (p < 0.001). During the special preparation stage (18-21 year old) the sport results increase rapidly and start improving from 1.84 ± 0.02 m up to 1.94 ± 0.03 m (p < 0.001). The development during the stage of high sport results (22-26 years old) is slower, yet results improve from 1.95 ± 0.02 in till 2.01 ± 0.02 m (p < 0.001). During the stage of maintaining high sport results (27-32 years old) the rate of development of sport results is kept stable fluctuating between 1.99 ± 0.02 m and 2.01 ± 0.01 in (p < 0.05). During the whole sport career the results improve by 44.69 ± 6 cm on average. These findings show that the development of the individual sport results during the annual training cycle is wave-like, i.e. every two or three competitions they increase, but then decrease again.
Wikipedia defines a dictionary as “a collection of words in one or more specific languages, often listed alphabetically, with usage information, definitions, etymologies, phonetics, pronunciations, and other information; or a book of words in one language with their equivalents in another, also known as a lexicon.”

Considering this definition, the title of the new book by Peter Matthews – a well-known track and field commentator for the BBC, ITV and the IAAF, who has already published several reference books on athletics and sports in general (e.g., The Guinness Book of Track & Field Athletics, 1982, The All-Time Greats of British and Irish Sport, 1995, and The Guinness Encyclopedia of International Sports Records and Results, 3. ed. 1993) – is misleading.

The Historical Dictionary of Track and Field contains more than 500 cross-referenced entries on key figures, places, competitions, and governing bodies within the sport. It does not include any technical athletics terms, their definitions or translations into other languages. Therefore it is not really a dictionary but rather an encyclopedia, about which Wikipedia says: “Encyclopedia entries are longer and more detailed than those in most dictionaries. Generally speaking, unlike dictionary entries, which focus on linguistic information about words, encyclopedia articles focus on factual information to cover the thing or concept for which the article name stands.”

Although Matthews’ reference book also includes information about the different athletics events, championships, and associations, the vast majority of the entries is about athletes. That is why it could even be called a “biographical encyclopedia”, or at least an encyclopedia with a focus on biographical information.

However, oddly missing is any information about the criteria underlying the selection of the athletes in the article section of the dictionary. If one looks, for example, at the men’s

Of the 26 Olympic champions in the men’s 400 metres only six are included: Bill Carr (1932), Lee Evans (1968), Alberto Juantorena (1976), Michael Johnson (1996/2000), and Jeremy Wariner (2004).

Other Olympic champions one looks for in vain are (in alphabetical order): Dieter Baumann (5000 m, 1992), Hartwig Gauder (50km Walk, 1980), Heike Henkel (women’s High Jump, 1992), Willi Holdorf (Decathlon, 1964), Kelly Holmes (women’s 800m and 1500m, 2004), Steve Hooker (Pole Vault, 2008), Bernd Kannenberg (50km Walk, 1972), Dietmar Mögenburg (High Jump, 1984), Barbora Spotáková (women’s Javelin, 2008), Pekka Vasala (1500m, 1972), Klaus Wolfermann (Javelin, 1972), David Wottle (800m, 1972).

This list of Olympic champions not honoured with an article could be extended. Neither does Matthews’ book include famous coaches who had great influence on the development of athletics, as, for example, Franz Stampfl, Percy Cerrutty, or Arthur Lydiard.

To be honest, no special dictionary can really include everything and it is very easy to criticise any work for being incomplete. However, there should be strictly defined criteria for the selection of entries and the readers should be informed about them. Otherwise one could get the impression that the entries have been selected arbitrarily.

The Historical Dictionary of Track and Field not only deals with athletes and events of the more recent period but it also traces the origins and especially the early days of amateur and professional competition on an international level. Information is also provided on major sporting nations, not only the top ones, but also those that are particularly strong in one aspect or another (e.g., Cameroon, Mozambique, Sudan) and some that have not achieved much in the way of titles but are still broadening the field (e.g. Cyprus, Ghana, Senegal).

However, even the lack of success can be a reason for being included in Matthews’ book. This applies, for example, to Pakistan. The very short article about this country includes the following information: “… it is perhaps surprising that no Olympic or World Championships medals have been won for such a large country. Indeed, no athlete from Pakistan has even made a global final.”

Although the bulk of the information on sports, nations, and athletes can be found in the article section, which also includes extensive cross-references to facilitate the rapid and efficient location of information, a lot of further information can be found in the “Chronology” section (pp. xvii-xxix). The chronology covers several millennia, the focus, however, being on the past century and a half.

In the introduction of Matthews’ book, an overall view of track and field is given concentrating on:

- the Olympic Games and the International Association of Athletics Federations
- the Programme of Men’s Events
- Women’s Athletics
- Worldwide Competition
- Amateurism
- Records
- Marathon Running
- the Running Boom
- the African Running Phenomenon
- International Competition
- Indoor Athletics
- Athletics Today.
Useful information can also be obtained from the appendices of the book covering

- The Presidents of the IAAF (Appendix A)
- The winners of the Olympic Games (Appendix B)
- The venues and winners of the World Championships (Appendix C) and World Indoor Championships (Appendix D)
- The winners of the World Cross-Country Championships (Appendix E) and World Road Racing Championships (Appendix F)
- The IAAF World Athletes of the Year (Appendix G)
- World Records (Appendix H).

Readers who are interested in further information should have a look at the bibliography, which includes useful sources in the introduction and under the following headings:

- General Histories
- Bibliographies
- Greek and Roman Athletics
- Marathon
- National Histories
- Olympic Games
- Pedestrianism
- Running
- Statistics
- Biographies and Autobiographies
- Technique and Coaching
- Doping

- Websites
- International Organizations
- National Websites
- Other Recommended Websites for Statistics and Results.

In summary, Peter Matthews’ *Historical Dictionary of Track and Field* can be criticised for not disclosing the criteria underlying the selection process of entries and for giving the impression of having been compiled with a certain degree of arbitrariness. Nevertheless, the book is a source of information worthwhile looking at, and for people who want to get a broad overview of what track-and-field athletics is about, it may even be a recommendable, though rather expensive first information source.

*Reviewed by Jürgen Schiffer*

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**Peter Matthews**  
**Historical Dictionary of Track and Field**  
The databases of the Institute for Applied Training Science (IAT, Leipzig, Germany) on the internet: http://www.iat.uni-leipzig.de

Task and Structure of IAT

The Institute for Applied Training Science ("Institut für Angewandte Trainingswissenschaft – IAT") was founded in 1992 and is the central research institute for German top-level performance sport. The task of the researchers working at IAT is the process-accompanying training and competition research for German performance sport with the goal of identifying and utilising the performance potential of German elite athletes.

Figure 1: IAT entry page
IAT supports about 1,000 athletes and their coaches from 17 summer and six winter sports. The basis of this cooperation is long-term agreements with 19 top-level sport federations. In cooperation with its partners, IAT ensures the scientifically based counselling of coaches and enables the innovative control of training within coach-counsellor networks. IAT provides scientifically based training recommendations as well as sports-medical health and therapy recommendations. In addition to this, IAT develops measuring and information systems and passes the information and knowledge on to sport practitioners.

IAT is a part of the Scientific Network System for Performance Sport and cooperates with the Institute for the Research and Development of Sports Equipment (FES), the Coaches Academy in Cologne as well as with the German Olympic Training Centres, the Federal Institute of Sport Science (BISp) and the sport-science institutes at German universities.

IAT consists of seven departments
1. Department for Endurance Sports
2. Department for Strength and Technical Sports
3. Department for Technical and Tactical Sports
4. Department for Sports Medicine
5. “MINT” (Mathematics, Informatics, Sciences, Technology)
6. Department for Performance Sport of Young Athletes

### IAT Databases

The IAT databases are run by the Department for Sports Information and Communication. In the databases information about sport and training science is provided.

The following databases are available by clicking first the “Service” button on the top left of the entry page and then the “Datenbanken” button.

#### Archive of Performance Sports

For this database, more than 2,500 articles from the German-language magazine *Leistungssport* (“Performance Sport”) have been digitised and are now searchable. So far, about 500 of these articles have been released by the authors and database users can access them in full-text format. This database is a joint venture with the German Olympic Sports Confederation (DOSB) and Philippka publishers.

#### SPONET database

SPONET is a training-specific search engine that was developed by IAT especially for sports scientists, coaches and athletes. Every month about 250 new internet sources are evaluated and analyzed for professionals.
ViFa Sport

IAT is one of the five producers of the Virtual Library (ViFa) of Sport Science. ViFa Sport is a comfortable-to-use, centralized portal for sport-science information on the Internet. It includes both print media and electronic information resources of sport-science relevance. All resources made available through ViFa Sport are indexed and in most cases direct access is possible. (The ViFa Sport database will be dealt with in more detail in future issues of NSA.)

SPOWIS database

SPOWIS is a sports literature database that includes 120,000 literature documents on sport science and applied training science published before 1996. This makes SPOWIS the second-largest publicly accessible sport-science database in the world (behind SPOLIT, see NSA 3+4/2011). The main focus of SPOWIS is on results of sport-science research in the former GDR.
Sportbox
This database includes books about sport science and sport technique published in German speaking countries. The focus of the database is on kinesiology and exercise science, physical education, medicine, history, psychology and sociology. Sportbox is operated jointly with almost 250 German publishers and is edited by WVM publishers in Oepfershausen/Rhön (Thuringia, Germany). Currently, Sportbox includes almost 2,500 titles.

TUPL database
For this database, all articles published in the German-language magazine Theorie und Praxis Leistungssport (“Theory and Practice of Performance Sports”) and its successor Training und Wettkampf (“Training and Competition”) have been digitized. This means that about 3,500 articles are now searchable and viewable in full-text format.

Competition Results database
This freely accessible database includes all results at Olympic Games (since 1896), World and European Championships (since 2001) in all sports that are currently part of the Olympic Games. Currently, more than 121,000 individual results are available.

Figure 5: Overview of current competition results and competitions that will take place in the near future
Most databases produced and provided by IAT may be of interest for track-and-field coaches and athletes. It should also be considered that three of the IAT databases have a German-language focus (Archive of Performance Sports, Sportbox, TUPL). However, the other databases are of international character.

Reviewed by Jürgen Schiffer
Preparación Directa para la Competencia en el Salto en Alto de Élite

por Piotr Bora

Un momento para enfocarse en la puesta a punto para la principal competencia del año, por ejemplo, el Campeonato Europeo, el Campeonato Mundial o los Juegos Olímpicos, es un elemento clave de la actual teoría de entrenamiento y se lo conoce como Preparación Directa para la Competencia. El entrenamiento adecuado en este periodo puede tener un impacto positivo en los resultados alcanzados. Sin embargo, un entrenamiento inadecuado, por ej. excesivo entrenamiento puede conducir a resultados decepcionantes. Por lo tanto, es muy importante para el entrenador planificar adecuadas cargas de entrenamiento y seleccionar ejercicios apropiados y otros contenidos de entrenamiento en este periodo. Además, el programa debe ser individualizado para el atleta y condicionado a las demandas del esquema de competencias y al punto de implementación del plan anual de entrenamiento. El autor, entrenador nacional de saltos en Polonia, destaca los principios para la planificación de la Preparación Directa para la Competencia y proporciona entrenamientos típicos para los saltadores alto de élite basados en bibliografía relevante y sus experiencias personales.

Análisis Biomecánico en 3D de la Técnica de Salto en Alto de Mujeres

por Vassilios Panoutsakopoulos y Iraklis A. Kollias

El propósito del presente estudio fue investigar la cinemática tridimensional de la técnica contemporánea de salto en alto durante la competencia y comparar los resultados con las conclusiones de pruebas anteriores de nivel de élite. Se utilizaron como muestras las participantes de la prueba de salto en alto mujeres del Encuentro Atlético Europeo Premium “Thessaloniki 2009”. Se grabaron los saltos utilizando tres cámaras fijas de video digital, operadas a una frecuencia de muestreo de 50 campos/segundo. Se extrajeron los parámetros cinemáticos de los dos últimos pasos, el despegue y el pasaje de la varilla mediante análisis cinemático vía software. Los resultados indicaron que los parámetros cinemáticos de la carrera de aproximación (es decir, velocidad horizontal, largo de zancada, ángulo de zancada, altura del centro de masa del cuerpo) fueron similares a aquéllos descriptos en el pasado. Sin embargo, se observó una escasa transformación de velocidad horizontal de aproximación a velocidad vertical en el despegue ya que se pudo ver una mayor desaceleración de los miembros balanceantes en el momento del despegue. También se percibieron considerables inclinaciones hacia atrás en el despegue, amplios ángulos de despegue e ineficientes pasajes de la varilla. Los autores recomiendan considerar brindar a los atletas estudiados un mayor énfasis en los elementos técnicos de la fase de despegue y de pasaje de la varilla.
Resúmenes

Producción de Energía en los 800 Metros
por Enrico Arcelli, Amos Bianchi, Jennifer Tebaldini, Matteo Bonato y Antonio La Torre

Comprender los mecanismos de energía aeróbica y anaeróbica en los 800m puede tener importantes consecuencias prácticas para los entrenadores que intentan planificar y dirigir correctamente el entrenamiento del atleta. Este conocimiento es particularmente útil en este momento que se cuenta con equipamiento de bajo costo y fácil de utilizar para medir la concentración de lactato en sangre luego de una competencia o en el entrenamiento. El propósito de este estudio fue examinar la contribución del mecanismo de lactato anaeróbico desde el punto de vista del gasto total de energía y del gasto de energía en diferentes etapas de los 800m. Se midió la concentración de lactato en sangre en 18 atletas hombres al final de la carrera y luego de aprontes de 300m y 600m al mismo ritmo de carrera. La información confirma resultados anteriores respecto de que la concentración de lactato en sangre al final de los 800m tiende a disminuir con el incremento del tiempo de carrera. También se descubrió que la contribución del mecanismo de lactato anaeróbico hace pico desde la salida hasta los 300m, disminuye entre los 300m y 600m y se encuentra en su mínimo al final de una carrera de 800m. Las conclusiones incluyen consejos generales para trabajar con los atletas con los típicos perfiles de fortalezas-debilidades para los dos mecanismos estudiados.

CD - Herramienta de Progresión de Rendimiento
Por Stephen Hollings, Patria Hume y Will Hopkins

En 1997 dos de los autores crearon un método para comparar la progresión de rendimiento en el atletismo de pista y campo utilizando tablas, publicadas en formato de cuadernillos describiendo las progresiones de 390 atletas exitosos. Tal herramienta es útil para los entrenadores y directores de programas de apoyo de alto rendimiento ya que brinda las bases para determinar si un atleta se encuentra en el camino que lo conducirá a resultados de clase mundial o si son necesarios algunos ajustes a la preparación u objetivos del atleta. Sin embargo, en el momento de la publicación del trabajo original se identificaron ciertas limitaciones. La metodología fue posteriormente adoptada por UK Athletics (en 2006) y Athletics New Zealand (en 2009) para producir una serie de "embudos de rendimiento" para monitorear tanto a los atletas de élite como aquellos en desarrollo. En el proceso, las dos organizaciones atendieron algunas pero no todas las debilidades identificadas. Este artículo destaca de qué manera se desarrolló un método revisado utilizando una base de datos de 168,576 desempeños de 2.017 atletas. El nuevo método se ha convertido en una herramienta basada en computadora en formato de CD. El artículo explica el uso de la herramienta y proporciona interpretaciones de la información a partir de los atletas seleccionados.
La Préparation directe pour la compétition dans le saut en hauteur de haut niveau
par Piotr Bora

La période au cours de laquelle un athlète travaille pour atteindre le summum de sa forme à temps pour la compétition principale de son année sportive (tels que les Championnats d’Europe, les Championnats du monde, les Jeux olympiques…), appelée "Préparation directe pour la compétition", forme une composante clé des théories actuelles sur l’entraînement. Si un entraînement approprié au cours de cette période peut avoir un impact positif sur les résultats de l’athlète, un entraînement inadapté - trop ardu par exemple - peut, a contrario, déboucher sur des résultats décevants. Il est donc crucial de prévoir, pour cette période si importante, des charges d’entraînement appropriées, de pair avec des exercices et autres éléments de la préparation bien pensés. En outre, chaque athlète devrait bénéficier d’un programme conçu sur mesure, en fonction des exigences de son calendrier de compétitions et de l’état d’avancement de son planning d’entraînement annuel. L’auteur de l’étude, un entraîneur national pour les épreuves de saut en Pologne, expose les principes de la planification de la Préparation directe pour la compétition, détaillant notamment des séries de séances d’entraînement types adaptées aux sauteurs en hauteur du plus haut niveau. L'auteur base son exposé tant sur des articles et publications pertinents que sur sa propre expérience.

Une analyse biomécanique 3D de la technique de saut en hauteur féminin
par Vassilios Panoutsakopoulos et Iraklis A. Kollias

L’objectif de cette étude était d’examiner la cinétique tridimensionnelle de la technique actuelle du saut en hauteur dans les compétitions de haut niveau et d’en comparer les résultats avec ceux issus de compétitions précédentes de même niveau. Les analyses ont porté sur les athlètes prenant part au concours de saut en hauteur féminin de Thessaloniki 2009, une compétition de catégorie Premium de l’Association européenne d’athlétisme. Chaque essai a été enregistré à l’aide de trois caméras vidéo numériques fixes, opérant à une fréquence d’échantillonnage de 50 trames/seconde. Les paramètres cinétiques des deux dernières foulées de la prise d’élan, de l’impulsion, ainsi que du franchissement de la barre, ont ensuite été extraits à l’aide d’un logiciel d’analyses. Les résultats indiquent que les paramètres cinétiques mesurés lors des phases d’approche (c’est-à-dire vitesse horizontale, amplitude des foulées, angles des foulées, hauteur du centre de masse du corps) étaient similaires aux résultats relevés dans le passé. Toutefois, on a pu relever une mauvaise transition de la vitesse d’approche horizontale en vitesse verticale de décollage, avec une décelération plus importante des segments libres au moment de l’impulsion. Il a également été relevé une propension des athlètes à se pencher vers l’arrière de manière excessive au moment du décollage, ainsi que des angles latéraux d’impulsion élevés et des esquives de la barre inefficaces. Les auteurs recommandent que les athlètes concernées accordent plus d’importance aux éléments clés de la phase d’impulsion finale et de celle de l’esquive de la barre.
La production d’énergie sur 800m
par Enrico Arcelli, Amos Bianchi, Jennifer Tebaldini, Matteo Bonato et Antonio La Torre

Bien comprendre les mécanismes énergétiques, aérobie et anaérobie, dans l’épreuve du 800m peut avoir des conséquences pratiques importantes pour tout entraîneur désireux de planifier et gérer au mieux l’entraînement d’un athlète. Ces connaissances revêtent d’autant plus d’importance qu’il existe maintenant des instruments, à la fois peu coûteux et faciles à utiliser, qui mesurent la concentration de lactate sanguin au terme d’une compétition ou d’une séance d’entraînement. L’objectif de cette étude était d’examiner la contribution du mécanisme de lactate anaérobie, avec une analyse de la dépense énergétique totale et de la dépense mesurée à différents stades d’une course de 800m. Les concentrations du lactate sanguin de 18 coureurs masculins ont ainsi été mesurées au terme d’une course, ainsi qu’après des distances de 300m et de 600m parcourues à la même allure que celle de la course. Les données recueillies confirment les éléments déjà constatés, à savoir que la concentration en lactate sanguin à la fin d’un 800m tend à diminuer à mesure que le temps final augmente. Il a également été constaté que la contribution du mécanisme de lactate anaérobie atteint son niveau maximal entre le départ et les 300m, décroissant entre 300m et 600m pour atteindre son niveau le plus bas à l’arrivée aux 800m. Les conclusions offrent des conseils d’ordre général pour travailler avec des athlètes présentant des profils de force-faiblesses typiques pour les deux mécanismes étudiés.

L’Outil d’observation de la progression des performances disponible sur CD
par Stephen Hollings, Patria Hume et Will Hopkins

En 1997, deux des auteurs de cette étude avaient formulé une méthode comparant la progression des performances en athlétisme à l’aide de tableaux, publiés sous forme de livret, traçant les courbes de progression de 390 athlètes de haut niveau. Un tel outil est utile pour les entraîneurs et les spécialistes chargés de gérer les programmes de soutien de compétiteurs de haut niveau, car il fournit une base permettant de déterminer si un athlète est en bonne voie pour réaliser des résultats du plus haut niveau mondial, ou si des ajustements à sa préparation et aux objectifs visés sont requis. On notera cependant qu’à l’époque de la publication des recherches originales, certaines limites du système avaient été identifiées. La méthodologie a par la suite été adoptée par les fédérations nationales d’athlétisme britannique (en 2006) et néo-zélandaise (en 2009) afin de produire une série “d’entonnoirs des performances” pour tracer les performances des athlètes de l’élite, mais aussi des espoirs. Au cours de ces processus, les deux organismes concernés se sont attachés à résoudre quelques-uns, mais pas l’ensemble, des points faibles identifiés. Cet article décrit comment une méthode révisée a été développée à l’aide d’une base de données regroupant 168 576 performances établies par 2017 athlètes. Cette nouvelle méthode existe désormais sous forme d’un outil informatisé, disponible sur CD. L’article explique comment se servir de l’outil et fournit des interprétations des données pour un certain nombre d’athlètes.
Аннотация

Непосредственная подготовка к соревнованию у элитных прыгунов в высоту

Петр Бора

Время, выбранное для специальной подготовки к основному соревнованию года, например, к чемпионату Европы, мира или Олимпийским играм, является ключевым элементом существующей теории тренировки и известно под названием непосредственной подготовки к соревнованию. Должная тренировка в этот период может иметь положительное влияние на выполненные результаты. Однако, неправильная, то есть, чрезмерная, тренировка может привести к разочаровывающим результатам. Поэтому очень важно для тренера планировать соответствующую тренировочную нагрузку и выбирать соответствующие упражнения и другие тренировочные средства на этот период. Более того, программа должна быть индивидуализирована под спортсмена и обусловлена требованиями расписания соревнований и той степенью, до которой был выполнен ежегодный план тренировки. Автор статьи, тренер сборной команды по прыжковым видам Польши, выделяет принципы планирования непосредственной подготовки к соревнованию и приводит типичную нагрузку для элитных прыгунов в высоту на основании соответствующей литературы и своего личного опыта.

3D Биомеханический анализ техники прыжка в высоту у женщин

Вассилиос Паноцакопулос и Иралис А. Коллиас

Цель данного исследования заключается в том, чтобы изучить трехразмерную кинематику современной техники прыжка в высоту во время соревнования и сравнить полученные результаты с теми, которые получены на предыдущих соревнованиях элитного уровня. Для исследования использовались результаты спортсменок – прыгуний в высоту европейского соревнования Премиум класса «Салоники 2009». Прыжки фиксировались с помощью трех стационарных цифровых видео камер, работающих с выборочной частотой 50 разрядов/сек. Кинематические параметры последних двух шагов и преодоление планки были выделены с использованием кинематического анализа и программы математического обеспечения. Результаты указывают на то, что кинематические параметры разбега (то есть, горизонтальная скорость, длина шага, угол шага, высота центра массы тела) были похожи на те, которые выявлялись в прошлом. Однако, наблюдалась плохая трансформация горизонтальной скорости разбега в вертикальную скорость отталкивания, так как в момент отталкивания можно было видеть снижение ускорения маховых конечностей. Также отмечались значительный наклон назад при отталкивании, большой угол отталкивания и не эффективное преодоление планки. Авторы рекомендуют, чтобы спортсмены придавали больше внимания основным элементам техники во время фазы отталкивания и преодоления планки.
Производство энергии в беге на 800 метров
Энрико Арселли, Амос Бианчи, Дженифер Тебальдини, Маттео Бонато и Антонио Ля Торре

Понимание механизмов аэробной и анаэробной энергии в беге на 800 м может иметь важные практические последствия для тренеров, пытающихся правильно планировать и руководить тренировкой спортсмена. Эти знания особенно полезны сейчас, когда имеется недорогой, легкий в использовании инвентарь для измерения концентрации лактата в крови после соревнования или тренировки. Цель этого исследования заключалась в том, чтобы изучить вклад механизма анаэробного лактата с точки зрения общего расхода энергии и расхода энергии на разных этапах бега на 800 м. Концентрация лактата в крови измерялась у 18 спортсменов (мужчин) в конце после соревнования и после бега на время по дистанции 300 и 600 м с соревновательным темпом. Данные подтверждают ранние результаты того, что концентрация лактата в крови после бега на 800 м имеет тенденцию снижаться при увеличении времени соревнования. Также было обнаружено, что вклад механизма анаэробного лактата доходит до своего пика на старте бега на 300 м, падает между 300 и 600 м и доходит до своего минимума в конце соревнования по бегу на 800 м. Выводы включают общие консультации по работе со спортсменами с типичными сильными и слабыми сторонами двух изучаемых механизмов.

Прогрессия результата (на CD)
Степен Холлинс, Патрия Хьюм и Вил Хопкинс

В 1997 году два автора создали метод для сравнения прогрессии результата в легкой атлетике с использованием таблиц, опубликованных в виде буклета на основании изучения прогрессии результата у 390 успешных спортсменов. Такой механизм полезен для тренеров и менеджеров, которые занимаются программой высших достижений, так как он дает основу для размышлений о том, вступил ли какой-то определенный спортсмен на дорогу, которая приведет его к результатам мирового класса, или требуется корректировка тренировочной программы спортсмена и задач, которые он должен выполнять. Однако, когда был опубликован первый вариант этой работы, были выявлены некоторые ограничения. Методология была последовательно утверждена Федерацией легкой атлетики Великобритании (в 2006 году) и Федерацией легкой атлетики Новой Зеландии (в 2009 году) с целью создания серии «каналов результата» для контроля за элитными и развивающимися спортсменами. В процессе двух организаций обратили внимание на некоторые, но не на все выявленные слабые стороны. Эта статья подчеркивает, как совершенствовался пересмотренный метод с использованием базы данных 168,576 результатов, принадлежащих 2,017 спортсменам. Новый метод был переработан в компьютеризированное пособие, имеющееся в наличии на диске. Эта статья разъясняет использование этого механизма и дает интерпретацию данных участвовавших в исследовании спортсменов.
لا يوجد النص العربي يمكن قراءته بشكل طبيعي.
م 800 تقيساسم يف قفطاخلا جاتنإ
yroto lO 8w6 wO yW d8 wI yW 8o yW 8W 4k d8 wI lO 8w6
摘要

精英跳高运动员的直接比赛准备

皮奥特·博拉

集中致力于为年度主要比赛，如欧洲锦标赛、世界锦标赛或奥运会，而减量上强度的阶段，是当今训练理论的一个关键因素，被人们称为直接比赛准备。这个阶段的适宜训练对于比赛成绩会产生积极的影响。但是，不适宜的训练，如过度训练会导致令人失望的结果。因此在这个阶段，教练员制定出适宜的训练负荷计划、选择适宜的练习和训练内容是非常重要的。而且训练计划应该根据运动员、比赛日程要求，以及执行年度训练计划的程度等具体情况，实现个性化。作者是波兰跳跃项目国家级教练员，概括了制定直接比赛准备计划的各项原则，并且根据有关文献和他的个人经验，提供了精英跳高运动员的典型训练手段。

女子跳高技术的三维生物力学分析

瓦希利奥斯·帕诺特萨克普洛斯, 伊拉克里斯·A·克里亚斯 皮奥特·博拉

本研究的目的是调查目前比赛跳高技术的三维运动学情况，并且与以往对于高水平比赛技术的研究结果进行比较。研究人员将参加欧洲田径“西萨朗尼基”奖励赛中的女子跳高运动员作为样本。使用三台固定数字摄像机，以每秒50格画面的频率记录运动员的每次试跳。采用专门软件对于最后两步助跑、起跳和过杆的运动学参数进行运动学分析。研究结果显示，助跑（如水平速度、步长、步的角度和身体质心高度）情况与以往的研究报告结果相似。但是，通过研究观察到，在起跳即刻肢体摆动减速较大，水平速度向垂直速度的转化情况不良。本研究还观察到，起跳时运动员身体后仰过多、起跳角度过小、过杆动作效率低。作者们建议，接受研究的运动员们应该更加重视起跳和过杆阶段的关键技术因素。
800米跑的能量产生

恩里克 · 阿塞利, 阿莫斯 · 比安吉, 詹尼弗 · 特巴蒂尼, 马迪奥 · 伯纳多, 安东尼奥 · 拉 · 托尔

对于致力于制定正确的训练计划和管理运动员训练过程的教练员们来说，理解800米跑的有氧和无氧供能机制，会对于他们的训练实践效果产生重要影响。目前，在比赛后和训练中测量血乳酸浓度的器材使用成本低而且便捷，使这门知识尤其有用。本研究的目的是从800米跑总能量消耗和分段能量消耗的观点出发，考察无氧乳酸供能机制的贡献。分别在800米比赛结束时，以及在比赛速度下300米、600米计时跑后，测量18名男运动员的血乳酸浓度。数据证实了较早前的研究结果，在800米跑结束时，随着比赛时间的增加，血乳酸浓度趋于下降。研究还发现，无氧乳酸供能机制的贡献从起跑至300米赛段达到最高、300米至600米赛段有所下降、在800米赛跑结束时降至最低。研究结论包括对于在这两个机制研究中，所发现存在着典型弱点的运动员们提出的一般建议。

成绩进展CD工具

斯蒂芬 · 霍林斯, 帕特里亚 · 胡姆, 威尔 · 霍普金斯

在1997年，有两位作者采用出版手册的方式，创造了一种在田径运动中使用各种表格，描绘390名成功运动员成绩进展和进行比较的方法。这种工具对于教练员们和高水平运动成绩支持计划的管理者们是有用的，它提供了一个基础，来帮助确定一名运动员是否处于通往创造世界级成绩的进程中，或是否需要对于这名运动员的训练准备和各个目标予以调整。但在当初原作出版时，发现了一些特定的局限。这种方法随后被乌克兰（2006年）和新西兰（2009年）田径协会所采用，产生了一系列的“成绩筛查漏斗”，来监控他们的精英和处于发展中的运动员们。在这个过程中，两个组织也提出了一些问题，但又不是全部所发现的弱点。本文概括了，根据来自2017名运动员168576项成绩的数据库，而开发出的一个修正方法。这种新方法已经转化成一个可在电脑上使用的CD工具。本文说明了这种工具的使用方法，并提供了对于来自运动员示例数据的解释。
London Olympic Review

including:

- Everybody’s Games
  by Helmut Digel

- Muscle Damage and Fatigue in the Marathon
  by Juan Del Coso, Juan José Salinero, Javier Abián Vicen, Cristian González-Millán, Sergio Grande, Pablo Vega and Benito Pérez-González