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Journal of Educational Theory and Management

https://ojs.s-p.sg/index.php/jetm

Research on the Mechanical Analysis of Run-Up Speed in Pole Vaulting and the Application of Key Auxiliary Training Methods

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ARTICLE INFO

Article history
Received: 6 December 2024
Accepted: 16 December 2024
Published Online: 30 December 2024

Keywords:
Pole vault techniques
Run-up speed model
Training techniques

ABSTRACT

Analyzing from the perspective of physics mechanics, the pole vault is a project which transforms kinetic energy into elastic potential energy. The magnitude of kinetic energy depends on the vaulter's approaching speed, while the magnitude of elastic potential energy depends on height. Therefore, the run-up speed determines the vaulter's performance in pole vault to a certain extent. the horizontal speed of the pole-holding approach phase transitioning into vertical upward speed plays a crucial role in executing pole vault techniques, and the model of approaching speed establishes a theoretical foundation for vaulters to break through the pole limitation. In terms of specialized technical assistance in speed training, short-distance speed exercises are used in the approaching phase; in the swinging phase, gymnastic rings, single bar and suspension rope exercises are employed for suspension; in the stretch phase, trampoline exercises play a important role in rotation phase, etc.

1. Research Purpose and Significance

In the pole vault, run-up speed is not only the main factor for athletes to choose a high grip point and use a large poundage pole, but it is also an important driving force for the conversion of kinetic energy into potential energy after the human body leaves the ground. As the pole vault has evolved, speed has become a clear and distinctive characteristic of the event today.

It is hypothesized that under certain conditions, that is, the faster the run-up speed, jumping technique is reasonable, the more potential energy stored in the pole, when the pole deformation recovery, it can produce faster speed over the pole, pole pounds, athletes hold the pole higher, athletes are able to cross the crossbar higher. In the process of assisted descending of the pole, especially when approaching the horizontal position, the weight of the pole held in the left hand is greater, in order to balance the weight of the pole, the athlete will appear to hold the pole forward or backward, deceleration, and assisted running is not fluent.

In order to balance the weight of the pole, the athlete will lean forward or backward with the pole, decelerate, and have a poor run. When the balance of the pole cannot be maintained, the athlete will give up the pole insertion jump and run. The problem of changing poles is also a way for athletes to get to a high level of performance.

The faster the run-up speed, the higher the technical requirements for the pole insertion. How to complete the pole-planting technique in a fast running situation? How to surpass the breakthrough after changing poles and low-

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DOI: http://doi.org/10.12345/jetm.v8i4.21927

ering the load after poles? In view of the above problems, the theoretical model of the run-up mechanics has been established to realise the breakthrough of assisted running speed conversion in pole vault, to help the athletes improve their grip height and use higher-poundage poles, enhancing their technical level and overcoming psychological barriers.

2. Technical characteristics of the assisted running phase and analysis of assisted running mechanics

2.1 Technical points of assisting running and psychological requirements of pole changing

Pole vault is a sport that kinetic energy is converted into elastic potential energy. The size of kinetic energy depends on the running speed of the athlete, and the size of elastic potential energy depends on the height of the grip, we can understand why the performance of pole vault is determined by the running speed and the height of the grip.

Athletes with pole size and grip height, relatively speaking, athletes with high stature, large stride length, slow stride frequency, assisted running distance is slightly longer; athletes with short stature, small stride length, fast stride frequency and good explosive power, assisted running distance is slightly shorter. Excellent athletes tend to use 16-20 steps to assist the running distance. Running rhythm is, from the first step gradually accelerate, help to reach the highest speed, run to the full two-thirds of the time, the last few steps rely on running inertia, focusing on the insertion point jump. Running technique is characterized by high knee running style and high center of gravity. The pole change specialization is a reflection of the technical progress, manifested in the increase of the running distance and the improvement of the grip point. Bigger poles and higher grip points require more speed and specialized techniques. Therefore, coaches accurately assess and remind athletes of the timing of the pole change. Athletes should have a strong will to change rods, be brave and decisive, and overcome the psychological requirements.

2.2 The establishment of mechanical analysis model of running speed with pole holding

Correct pole technique to close to the torso with the help of the body force to reduce the weight of the arms of the pole, together as one forward movement, pole swing in the controllable range, the swing is too large will not improve the speed of the running aid, but will affect the speed of the running aid and rhythm.

From the mechanics of the discussion. This running technique is described as 'accelerated' running. It is characterized by the fact that when lowering the bar in the run, the gravity of the bar in the hands changes, which counteracts the speed of the run. In order not to lose speed, the athlete can use a faster run to maintain the direction of the bar and balance the weight of the bar. The theoretical basis for this is based on Newton's second law of mechanics.

When the athlete is assisting in the run, (assuming this fastest speed is a steady speed) mechanics dictate that the force the athlete gives to the pole upward is constant and equal to the force of gravity of the pole. The forward force is variable. The magnitude of an object's acceleration is proportional to the force acting on it, inversely proportional to the mass of the object and proportional to the inverse of the object's mass, and the direction of acceleration is the same as the direction of the force exerted. If we say accelerate to a stable speed, this forward force can be no more, because maintain a uniform speed. It can be understood that the last few steps of the weight of the pole will have no effect on the speed of the athlete's assisted running, the athlete can be highly concentrated on the insertion of the hole jump, and more actively and effectively play the speed of the assisted running. This is a very important technical point in the process of assisted running, is the technical theory that the athlete can use larger poles. As shown in Figure 1 below: according to the model, there is only one downward force at rest.

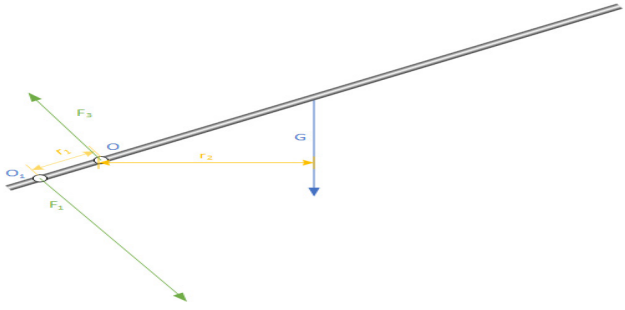

Figure 1. Mechanical analysis at rest

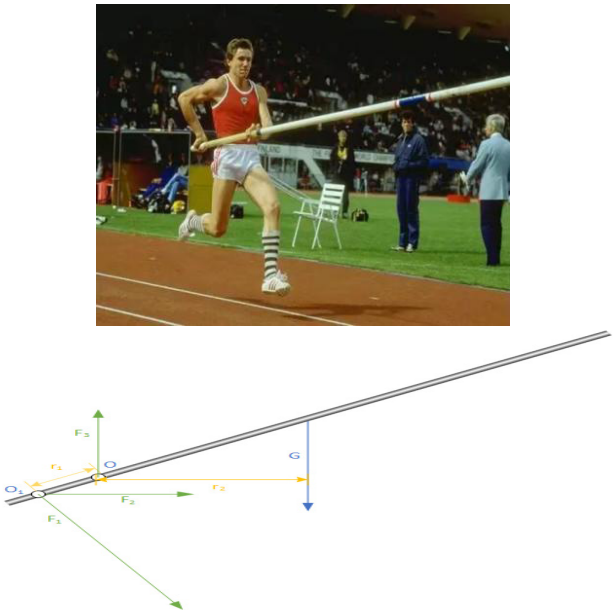

Figure 2. Mechanical analysis model of pole vault run-up

Figure 2: Analysis of the mechanical model during the run-up. During straight-line motion, as the athlete accelerates in the run-up, after the pole descends, the weight of the pole is the same as its weight when stationary. However, due to the pole's forward velocity, the force generated can exceed the weight of the pole, making it seem 'lighter'. As shown in Figure 2, the pole experiences both forward and downward forces, whereas when stationary, only the downward force is present. This demonstrates that weight, under the influence of velocity, can be decomposed into different forces.

The forces on the pole are shown above, G represents the force of gravity on the pole, and points O and O1 are the grip points of the athlete holding the pole. In the process of assisted running, the athlete's force on the pole can be decomposed into F1,F2,F3. F1,F3 is used to balance the pole's gravitational force G, and the force F2 accelerates the pole forward. According to Newton's second law formula

$$F2 = Ma$$

When the speed is increased to the highest, the acceleration a is 0, at this time F2 = 0, the athlete to pay the force to reach the minimum, that is, the feeling of lightening the pole.

In the process of lowering the pole, so that the combined force of F1 and F2 is F, there is a moment calculation formula

$$F * r1 = G * r2$$

The force arm r2 increases, while r1 remains unchanged, so F must increase, and at this time the athlete feels that the pole becomes heavier. The reason why the previously mentioned assisted running technique is used by most good athletes is that the method is based on the mechanics above. According to this mechanical principle, the athlete in the process of assisted running to increase the speed of assisted running, break through the psychological barriers, on the basis of the theory to establish confidence, the athlete to replace the larger pole, can be based on this method to solve the concerns of changing the pole, to improve the level of athleticism. Can also be based on this theoretical basis, athletes in the absence of insertion holes on the runway for running practice with poles, only when the forward thrust, athletes can hold the poles to assist running speed to the limit.

2.3 Training methods for assisted running speed improvement

It is very difficult for athletes to break through the speed of assisted running with a pole. Technical action speed is built on the basis of technical proficiency and having solid basic skills. The last few steps of pole lifting, pole insertion speed awareness is formed in the early stages of training repeated training and continuous accumulation, the last few steps are completed in the state of automation. Therefore, the breakthrough in technical speed, to strengthen the basic pole vaulting technique accumulation and repeated, to strengthen the body's memory to achieve the automation of technical movements, so that there can be changes in the speed of movement and improve.

It has been proved in practice that the special speed of pole vaulting is dominated by short-distance pole-vaulting. For example, 20 meters of pole running between rows, 40 meters, 60 meters of pole speed training. In addition, the use of uphill pole-carrying running, timing running, also has obvious practical effects.

3. Technical Points of Pole Vaulting Stage

3.1 Pole vaulting technique and timing

Currently, the starting point of the world's best pole vaulters is mostly below the projection point of the grip point, which reduces the loss of momentum during the jump. If the take-off point is too far, it is disadvantageous to the advantage of run-up speed. There are two types of take-off directions: jumping forward and upward, and slightly forward and upward. The difference between the two lies in the take-off angle.

The timing of the pole planting take-off, as mentioned above, occurs during the last two steps of the run-up. When the pole is parallel to the ground, the second-to-last step prepares for the upward take-off, while the final step generates a noticeable explosive push-off from the ground. The higher the take-off center of gravity, the higher the pole is raised. The left arm should not be bent, as any bending

DOI: http://doi.org/10.12345/jetm.v8i4.21927

would reduce the energy transferred to the pole. To maximize the bending of the pole and store more potential energy, the athlete should use arm strength and the force connecting the shoulders and chest to support the pole forward and upward. This helps form an arch-like position with the body, increasing the swing speed of the body.

Top pole vaulters around the world place great emphasis on the technique of transitioning from the run-up to the swing of the body on the pole during take-off, because the better the technique is mastered during this phase, the more potential energy the pole can gain from the run-up, leading to a higher jump. Therefore, during each training period, great effort should be devoted to improving take-off technique and increasing the automation of the take-off movement.

3.2 Jumping angle and pole vaulting technique training methods

The jumping angle of pole vaulters is also affected by the height of the athlete's grip, the height of the athlete and the hardness of the pole. While focusing on the jumping angle, it is also important to consider the risks associated with a small jumping angle. When the athlete's jump angle is small, it needs fast running speed and stick insertion technique to match, when the speed is not enough, it will affect the forwardness of the stick, and the pursuit of the athlete's jump angle is risky for the athlete. Therefore, the jumping angle has reference significance, but it should be built on the good running speed and pole insertion technique.

Pole vaulting technique is the core of the complete technique, no matter what level of athletes you are at, special technique imitation throughout the sports career, which is successful experience sharing tips. Mimicry exercises: in situ top bar exercises, marching bar lifts, three-step marching insertion bar lifts, barbell lifts, and short-range insertion bar jumps. The final transition is to the specialized technique practice for conversion and mastery. The two should be carried out alternately to assist the athletes to master the special techniques to improve the level of special techniques.

4. Technical Points of Hanging and Pendulum Stage

4.1 Technical points of the hanging and pendulum stage

After the human body left the ground into the hanging and pendulum stage, this time need to pay attention to two points, the first point, the eyes do not look at the crossbar, consciously do the back to the inverted movement; the second point of attention, the right hand sticking to the pubic symphysis joint cited, the shoulder downward pressure is also to promote the leg in the direction of stretching, close to the direction of the pole extension, with the help of the pole's direction of the rebound force of the body turn.

This kind of action with the nature of gymnastics, for beginners and intermediate athletes this technical link is not important, with the athletes mastered gymnastics technical skills have a lot to do. It is related to the gymnastic skills mastered.

4.2 Utilizing the pole rebound technique in the pendulum phase

How does the human body utilize the energy stored through the pole-bouncing? That is to shorten the radius of rotation of the human pole that is to increase the curvature of the pole. The curvature of the pole is not a goal to be pursued, the pole curvature is large, excessive bending which is dangerous for athletes, but also requires strong control ability, if the pole curvature is too large, it means that the athlete's upward rebound time is extended, and athletes need to be enough body control ability, if the athlete has completed the pendulum stretch, the pole is not yet bouncing straight, but also the phenomenon of touching off the crossbar. Not every rebound speed is exactly the same to, practice has proved that the human body only with the pole rebound speed is the same, in order to help the elasticity of the pole. Therefore, the swing radius and swing speed should be matched appropriately to maximize the use of pole elasticity.

4.3 Exercise method of hanging pendulum stretching stage

In order for athletes to better complete the technical aspects of the pendulum, different gymnastics techniques correspond to different pendulum phases.

In the basic training stage, the ground push bar turn imitation, the vault three-step bent bar pendulum turn, and the short-range pendulum technical exercises play an important role.

After jumping off the ground, important auxiliary exercises, bar big loop exercises. Its force is similar to the structure of athletes' swinging body force after jumping off the ground, and it is a good auxiliary exercise to train athletes to establish the speed of swinging body. The second one is the bar pendulum and other pendulum pendulum exercises. The bar pendulum exercise, the rope pendulum pendulum exercise, the ring pendulum pendulum exercise, these exercises are closer to the pendulum stretching phase technique. As a stretching stage, they are good auxiliary exercises. Third, trampoline exercises. Trampoline exercises are close to the stretching phase of

 DOI: http://doi.org/10.12345/jetm.v8i4.21927

the pendulum with the straight pendulum under the body. This exercise is a good auxiliary exercise for the athlete to complete the inverted pendulum turn over the pole.

5. Technical Points of Turning, Crossing Pole and Landing

5.1 Technical Points of the Turning and Crossing Stage

Turning body is the end of stretching, forming an inverted posture facing the crossbar. The theory is that this link is an inertial force process, the human body's center of gravity trajectory has been determined, therefore, when the technical aspects of running, insertion points, swinging the body is not mastered, in the pole will be manifested. Ideal over-pole posture is an inverted position on the pole, the lead and turn is should not make any pause, and will be in the position of both hands directly downward push the pole, increase the upward momentum, help to increase the height of the leap.

In the course of practice, according to the technical and technological links, with which the special close to the auxiliary exercise method is most effective. Seemingly auxiliary exercises, but can prompt athletes to jump higher. In the stage of technical maturity should also be repeated over the pole jump to improve the specialized technology.

6. Conclusions and Suggestions

6.1 Conclusion

The complete technique of modern pole vaulting is characterized by speed and gymnastic exercises for the sport. The running technique is assisted by high knee assisted running with a large stride, high center of gravity, swing leg glaring off the ground and then positively folding the front pendulum, and the running technique of driving the front pendulum with hip force. Based on the analysis of the results of the study, the following conclusions were drawn:

(1) Assisted running speed is a key factor in using a large poundage pole and improving the grip point.

(2) According to the decomposition of forces, accelerating the running aid speed reduces the pole load after lowering the pole. Reduce speed loss.

(3) A reasonable way to utilize the elasticity of the pole is that the speed of the athlete's pendulum needs to be consistent with the speed of the pole bounce.

6.2 Suggestions

(1) Running with intensity and holding the bar for short distances can improve the athlete's specialized assisted running speed.

(2) The bar big loop exercise's play a positive role in pendulum speed during the pendulum phase.

(3) Enhance the pendulum practice of multiple pendulums to improve the special control ability in the pendulum phase.

(4) Trampoline exercises have a positive effect on improving athletes' sense of rotation and aerial orientation.

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Qin Xia, female, born in January 1979, from Chengdu city. Graduated from the Graduate School of Beijing Sport University, majoring in Physical Education and Training.

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4. Since August 2008, has been working in the Department of Physical Education at Renmin University of China. During her tenure, she has published more than 10 articles on track and field training, and participated in 3 research projects, one of which she served as the corresponding author. She also authored a monograph titled *Guidelines for Beginner Pole Vault Training*, which will be published in July 2024.

DOI: http://doi.org/10.12345/jetm.v8i4.21927