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FULL PAPER

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Hurdle technique analysis and application of the 110m hurdle based on human body motion mechanics

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ABSTRACT

Under the premise of the same hurdle velocity, based on human body motion mechanics, this study conducts force and motion analysis of the human body at three links: hurdle run transforms to crossing, soar and touchdown of the hurdle transforms to hurdle run. Besides, this study also analyses the impact of each link's responding time on the hurdle crossing velocity. With human body motion mechanics, such a natural science as a means of research, this study confirms the existing techniques and obtains the relevant factors to improve the hurdle velocity through theoretical analysis, in order to provide a theoretical basis for the 110m hurdler's techniques.

KEYWORDS

Momentum theorem;
Swing leg;
Velocity;
Stable center of gravity.

INTRODUCTION

China has won champions of the men's 110m hurdle in the Asian Games. For example, Li Tong created the Asian record of 13.25s in 1994; although this sport suffered certain landslide in the subsequent years, China's excellent hurdler Chen Yanhao reached a result of 13.37s in 2001; and year 2004 is an unusual year for China, as Liu Xiang reached the world record of 12.91s at the Athens Olympic Games, and in the subsequent IAAF Super Grand Prix of Lausanne he broke the world record for 13 years with a 12.88s result.

Hurdling mainly contains two parts: crossing hurdle and hurdle ran, and hurdle techniques links up the hurdle velocity between two adjacent hurdles. The rapid advance of Chinese athletes' performance is inseparable with the improvement of training techniques. Hurdle techniques analysis of predecessors is generally limited to the basis of comparison. For example, a research associate from Shanghai Institute of Sports Science, Master Xu Yicheng in the article "hurdle technique analysis of excellent men's hurdlers", compared the techniques of 8 excellent male athletes with two top athletes Liu Xiang and Chen Yanhao, in order to find out the direction for athletes to work on; a lecturer from Northwest Normal University, Master Deng Yunling in the article "monitoring methods and research means of special ability of Chinese excellent men's 110m hurdle athletes", based on the technical data of Chinese excellent male hurdlers as well as Liu Xiang and Chen Yanhao, transformed these data into indicators for and reached a conclusion by comparing these indicators.

Although the techniques of international forefront athletes are reasonable, that cannot be regarded as a

FULL PAPER

theoretical basis. By means of scientific means and correct analysis method, the hurdle techniques have been greatly improved. However, it is also possible to draw the same appropriate conclusions by analysis from other point of view, and even to develop the theory. The innovation of this paper leis in that this study abandons the methods of previous research in this regard and confirms the existing techniques with natural science of human body mechanical theory as a means of research. This study carries out a detailed analysis of the pros and cons of hurdle techniques of 110m hurdle at present by theoretical analysis.

ANALYSIS OF HURDLE TECHNIQUE LINKS

For a 110m athlete in the hurdling competition, velocity is the ultimate goal of every athlete. A quite obvious phenomenon is that the average hurdle crossing velocity is lower than the average hurdle velocity for the same athlete. Although the run distance between hurdles accounts for more than 70% in the whole movement distance, what constraints the hurdle movement is still the hurdle crossing velocity. The main reason is that the convergence between the hurdle crossing and hurdle run is the complex point of hurdle technique, which is also the key point of hurdle techniques.

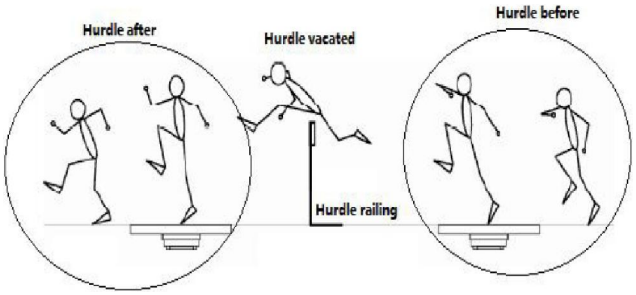

Figure 1 : Schematic diagram of hurdle technique links

Hurdle techniques are divided into three links as hurdle run transforms to crossing, soar and touchdown of the hurdle transforms to hurdle run; as can be seen from Figure 1, Hurdle before, Hurdle vacated and Hurdle after are respectively the simplified sketch map of the three links.

Hurdle before

The crossing link means the moment that the athlete receives the reaction forces from the ground. The outer force on the human body when crossing comes from the ground, and it is the reaction force of the kicking foot to the ground. Force analysis of the human body when crossing is shown in Figure 2.

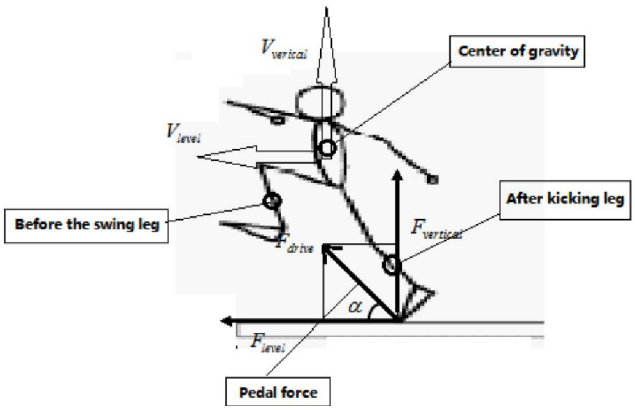

Figure 2 : Force analysis at crossing moment

According to momentum theorem:

$$\begin{cases} F_{level} \bullet t = m(V_{level} - V_{0level}) \\ F_{vertical} \bullet t = m(V_{vertical} - V_{0vertical}) \\ F_{level} = F_{drive}\cos\alpha \\ F_{vertical} = F_{drive}\sin\alpha \end{cases} \Rightarrow \begin{cases} V_{level} = \dfrac{F_{drive}\cos\alpha \bullet t}{m} + V_{0level} \\ V_{vertical} = \dfrac{F_{drive}\sin\alpha \bullet t}{m} + V_{0vertical} \end{cases} \quad (1)$$

In formula (1): F_{drive} expresses the force of the ground to the body center of gravity via the back kicking leg and its angel is α ; $F_{level}, F_{vertical}$ respectively mean the average components of the back kicking force in the horizontal direction and a vertical direction; m indicates the human body mass; $V_{level}, V_{vertical}$ respectively mean the velocity (vector) of the body center of gravity in the horizontal direction and vertical direction when the athlete crosses the hurdle; t means the action time of the ground to the human body; $V_{0level}, V_{0vertical}$ respectively mean the velocity (plus or minus) of the body center of gravity in the horizontal direction and vertical direction before crossing.

Judging from formula (1),are in positive proportion with,is in negative proportion with the angle,is in positive proportion with the angel.

Hurdle vacated

The hurdle vacated link refers to the whole process that the athlete takes off the ground. The human body suffers from the air resistance as well as gravity and internal forces of the body. In order to cross the hurdle railing, the motion state of the human body should meet the following equation:

Figure 3 shows the force analysis of the hurdle vacated link:

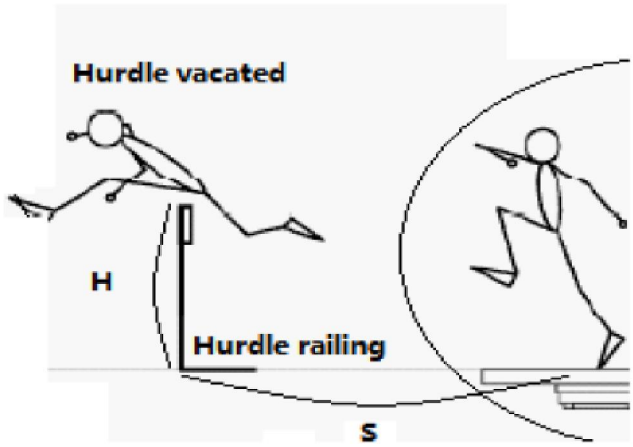

Figure 3 : Sketch map of hurdle vacated link

According to momentum theorem:

$$\begin{cases} s = V_{level} \bullet t_1 + \int_0^{t_1} \int_0^t a_{//}(\tau) d\tau dt \\ h \le V_{vertical} \bullet t_1 - \dfrac{1}{2} g t_1^2 + \int_0^{t_1} \int_0^t a_{\perp}(\tau) d\tau dt \end{cases} \quad (2)$$

In formula (2): *s* means the horizontal distance between the body center of gravity and the hurdle railing; t_1 means the time of the athlete from off the ground to crossing the railing; g means the value of the gravitational acceleration; $a_{\perp}(\tau), a_{//}(\tau)$ respectively means the vertical acceleration and the horizontal acceleration generated by the athlete's internal forces at any moment (vector, plus or minus, instantaneous value); *h* means the minimum value that the center of human body needs to increase.

Judging from formula (2):when $a_{//}(\tau)$ is positive and continually increases, the generated horizontal distance within the same time increases with it, and vice versa; when $a_{\perp}(\tau)$ is positive and continually increases, the generated vertical distance within the same time increases with it, and vice versa.

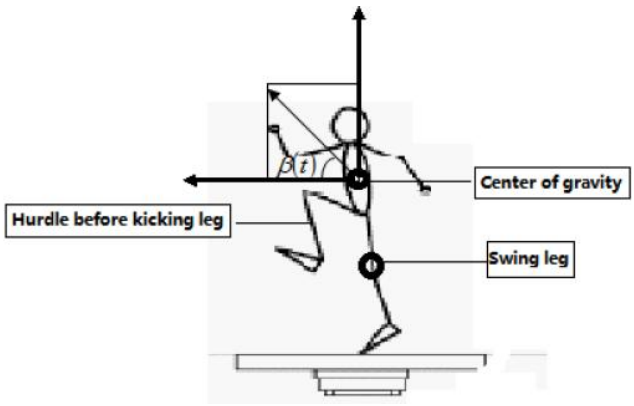

Figure 4 : Force sketch map when the swing leg off the hurdle and touchdown

Hurdle after link analysis

Off-hurdle and touchdown refers to that the body center of gravity vacates to the highest level and begins to fall down until the moment that the swing leg's touchdown. Force analysis of the swing leg's off-hurdle and touchdown is shown as Figure 4:

According to momentum theorem:

$$\begin{cases} \int_0^t F_{Rf}(t)\cos\beta(t)dt = m(V'_{//\,final} - V_{//\,final}) \\ \int_0^t F_{Rf}(t)\sin\beta(t)dt = m(V'_{\perp final} - V_{\perp final}) \\ V_{//\,final} = V_{level} + \int_0^T a_{//}(\tau)d\tau \\ V_{\perp final} = V_{vertical} - g \bullet T + \int_0^T a_{\perp}(\tau)d\tau \end{cases}$$

$$\Downarrow \quad \Downarrow$$

$$\begin{cases} V'_{//\,final} = \dfrac{\int_0^t F_{Rf}(t)\cos\beta(t)dt}{m} + V_{level} + \int_0^T a_{//}(\tau)d\tau \\ V'_{\perp final} = \dfrac{\int_0^t F_{Rf}(t)\sin\beta(t)dt}{m} + V_{vertical} - g \bullet T + \int_0^T a_{\perp}(\tau)d\tau \end{cases} \quad (3)$$

In formula (3): $F_{Rf}(t)$ indicates the instantaneous force of ground on the body center of gravity, wherein $\beta(t)$ means the force direction; $V'_{//\,final}, V'_{\perp final}$ respectively means the horizontal velocity and the vertical velocity of the human body when the foot touchdown and off the ground (vector); $V_{//\,final}, V_{\perp final}$ respectively means the horizontal velocity and the vertical velocity of the human body when the foot just touches the ground and does not suffer force (vector); *T* means the period of time from finishing crossing to the beginning of touchdown (without force).

Judging from formula (3): $V'_{//\,final}$ decreases when $\beta(t)$ increases, and vice versa; $V'_{\perp final}$ **increases when** $\beta(t)$ increases, and vice versa;are both in the same change rate as.

RESULTS ANALYSIS

Comparative analysis of the results from hurdle before link

For hurdler, the back kicking leg's landing and be-

FULL PAPER

ing kicking state, is the beginning of the hurdle action. Good crossing determines the pros and cons of crossing effect.

Crossing and inter-attack railing action directly determines the hurdle crossing velocity. And the specific reflection of hurdle crossing velocity is the value of V_{level}; the hurdle crossing velocity increases when the crossing angle decreases; the hurdle crossing velocity increases when the reaction force of the ground to the back kicking leg increases.

When crossing hurdle, hurdlers must reasonably select the before hurdle distance, as the before hurdle distance determines the size of the crossing angle. Theoretically, the crossing angle decreases with the increase of the distance, and as a result the hurdle crossing velocity increases. However, the velocity in the vertical direction will decrease, thus the lifting distance of the center of gravity is very limited. Therefore, when choosing crossing distance, not only to control the lifting distance of the body center to cross the hurdle is needed, but also to decrease the angle and increase the horizontal crossing velocity is necessary.

In the hurdle crossing process, according to the relationship between action and reaction based on Newton's Third Law, the greater the force of back kicking leg to the ground, the reaction force will be greater that the kicking leg receives from the ground. On the basis of momentum theorem, a conclusion can be reached that the instantaneous momentum received by the center of the human body increases if the back kicking leg's kicking velocity increases, i.e. $\sqrt{V^2_{0level} + V^2_{0vertical}}$ in 2.1 increases.

To sum up: to increase back kicking leg's kicking velocity and reasonably select the crossing angle can increase the hurdle crossing velocity.

Comparative analysis of the results from hurdle vacated link

In this article, the whole process that the hurdler is off the ground is regarded as hurdle vacated link. In the hurdle vacated link, the human body receives only an external force, gravity, except for air resistance. If the human body has no movement, the hurdle vacated link is just a projectile motion. However, the hurdle athletes can increase the hurdle crossing velocity by adopting a series of aerial posture and movement. The study will analyze the impact on hurdle crossing velocity from two aspects: adjustment of the gravity height and the limbs movement.

Position change of the athlete's center of gravity requires time and energy, so by adjusting the position of the center of gravity in the vacated process to keep basically stable, the physical consumption can be reduced. Maintaining the gravity center hold high when crossing and pressing the gravity center forward and downward can add to a dynamic rotation moment. Increasing the horizontal velocity can raise the crossing velocity. Athletes should have the awareness to adjust the position of the gravity center in advance when off the hurdle, in order to form a hurdle run posture as fast as possible after hurdling.

As the hurdling velocity is mainly reflected as a horizontal velocity, generally athletes' hurdle velocity is higher than the horizontal velocity of hurdle crossing. As a result, it is very necessary to end the hurdle vacated link as soon as possible and enter the hurdle run link. To end the hurdle vacated link quickly, on the one hand, it needs to increase the horizontal velocity of hurdle crossing; on the other hand, it needs to reduce the hurdle distance. In the hurdle vacated process, the back kicking leg outreaches and the thigh pulls the leg forward. With the active downward pressing of swing leg, this contributes to form a shear twist action for the benefit of moving on. Thus, the horizontal velocity in the hurdle vacated process increases and the hurdle crossing time reduces. When the gravity center passes the up side of the railing, athletes should press the swing leg downward actively and adjust the original motion track. Landing ahead and reducing the back hurdle distance also have the effect of reducing the hurdle crossing time.

To sum up: the movement of the human body gravity in the hurdle vacated process should try to keep straight and in gentle fluctuations, which will help save energy and improve the conversion of horizontal velocity; the gravity position when crossing the hurdle should be as forward as possible and form a dynamic rotation moment with the body fulcrum, to increase the hurdle crossing velocity; after passing the hurdle, the torso should keep slightly backwards and the swing leg should press downward actively. Under the premise of a small amount of loss of horizontal velocity, it can reduce the

hurdle crossing time.

Comparative analysis of the results from hurdle after link

After athletes' crossing, the swing leg continues to run, and the purpose is to reduce the loss of horizontal velocity, to form the first posture for hurdle run and maintain the body balanced. Mechanical theoretical analysis of the technical movements from these three aspects is conducted in 2.3 as follows.

The swing leg and the ground form an angle with the off-hurdle and touchdown of the swing leg. Thus, the center of gravity of the human body is behind the fulcrum in the horizontal direction, which helps to form a backward rotation moment in the opposite direction of the horizontal velocity of the center of human body gravity. This will generate resistance to the athlete's advancing and thus reduce the hurdle run velocity after landing. The resistance moment can produce a backward acceleration and decrease the value of and. Therefore, to reduce the acceleration, it is necessary to reduce the distance between the supporting point and the center of body gravity as the swing leg landing. The effect of reducing the resistance acceleration can be achieved by reducing the level arm of the resistance moment. Besides, move the human center of gravity to the front of the fulcrum as fast as possible, in order to convert the resistance moment to dynamic moment and accelerate the hurdle velocity.

With hurdlers' landing, the swing plays the role of forward kicking as well as supporting. The non-uniform downward press of the swing leg will generate the acceleration in the opposite direction, and thus produce resistance hindering the body forward. When the reaction force received by the swing leg from the ground gradually strengthens and exceeds the human body's own acceleration, the dynamics pushing the human body forward is generated. This process is in accordance with the momentum theorem in formula (3), meaning that the accumulation of force with time changes the velocity. In order to overcome the former resistance and fast increase the latter velocity, the foot of athlete when landing should possess a relative backward velocity to the center of human body gravity. This velocity generates the instantaneous impulsion and increases the action force of the ground to the swing leg. Increase the force that conducted to the center of human body gravity rapidly. Although the reduced resistance is not much, the dynamics increases and can contribute to the conversion of landing to hurdle run acceleration.

With the touchdown and supporting of athlete's swing leg, the position of the gravity center of human body should convert to the position for hurdle run directly in the descend process, which can get rid of the process of descent and ascend again. This is because through the useless up and down process, the human body wastes physical energy. Besides, the athlete wastes also time in the conversion of hurdle run.

In summary, with the athlete's landing and the swing leg's touchdown, the gravity center of human body should rapidly move to the front of the fulcrum of the rigid human body structure, in order to reduce the action time of resistance moment and the loss of horizontal velocity; the swing leg should have a relative backward velocity to the gravity center of the human body when landing, which can generate instantaneous impulsion to the ground; thus the reaction force of the ground to the human body increases, as well as the dynamic time and the horizontal velocity; the athlete will directly turn into hurdle running after landing, so reasonable control of the descent velocity of the gravity center of human body can reduce the action time of ground on human body and the hurdle crossing time.

CONCLUSIONS

Hurdle athletes should focus on the learning of theoretical knowledge in the training process. And the improvement of techniques and perfection of movements should be confirmed form the scientific principles, in order to improve the 110m hurdle. The reflection of hurdle crossing velocity leis in the increasing of crossing horizontal velocity and the decreasing of the crossing distance; adjusting the center of body gravity before crossing to a high position helps to reduce the rising time of the gravity center and to reduce the crossing angle; under the premise of reasonable control of the front railing distance, increase the front railing distance as possible, to reduce the crossing angle; the increasing of back kicking leg's velocity when crossing contributes to increase the reaction force from the ground; the increase of action force of ground to the gravity center

FULL PAPER

of human body and the decrease of crossing angle both helps to increase the horizontal velocity when crossing; keep the motion of the gravity center of human body in the vacated hurdle process as straight as possible, or in slightly fluctuations, which can save the physical energy consumption and promote the conversion of horizontal velocity; the position of gravity center when crossing should be at front and form a dynamic rotation moment with the body fulcrum, in order to increase the hurdle crossing velocity; after passing the railing, the torso should be slightly backwards and the swing leg should actively downward press. Under the premise of a small amount of loss of horizontal velocity, reduce the after hurdle distance, in order to reduce crossing time; with the athlete's landing and swing leg's touchdown, the gravity center of human body should rapidly move to the front of the fulcrum of rigid human body structure, to reduce the action time of resistance moment and the horizontal velocity loss; this study confirms the theoretical basis for experiential techniques and restores the situation of all hurdle links based on rational use of natural scientific theory.

REFERENCES

[1] Bing Zhang,Hui Yue; Bio-mechanical Mathematical Model Analysis for Race Walking Technique. International Journal of Applied Mathematics and Statistics, **40(14)**, 469-476 **(2013)**.

[2] Bing Zhang,Yan Feng; The Special Quality Evaluation of the Triple Jump and the Differential Equation Model of Long Jump Mechanics Based on Gray Correlation Analysis. International Journal of Applied Mathematics and Statistics, **40(10)**, 136-143 **(2013)**.

[3] Cai Cui; Application of Mathematical Model for Simulation of 100-Meter Race. International Journal of Applied Mathematics and Statistics, **42(12)**, 309-316 **(2013)**.

[4] Chungen Lu, Ziqiang Liu; 110m hurdle technical characteristics of Shi Dong-peng. Shandong Sports Science & Technology, **30(1)**, 41- 43 **(2008)**.

[5] Haibin Wang, Shuye Yang; An Analysis of Hurdle Performance Prediction Based On Mechanical Analysis and Gray Prediction Model. International Journal of Applied Mathematics and Statistics, **39(9)**, 243-250 **(2013)**.

[6] Hongwei Yang; Evaluation Model of Physical Fitness of Young Tennis Athletes Based On AHP-TOPSIS Comprehensive Evaluation. International Journal of Applied Mathematics and Statistics, **39(9)**, 188-195 **(2013)**.

[7] Weishou Zhang, Lihua Wang, Xiaofeng Xu; Grouping study of the whole course velocity change for excellent male 110m athletes in China. Journal of Shandong sports institute, **23(5)**, 101-103 **(2007)**.

[8] Yi Liu; The Establishment of Hierarchical Model for Basketball Defensive Quality. International Journal of Applied Mathematics and Statistics, **44(14)**, 245-252 **(2013)**.

[9] Yong Fan; Statistical Analysis Based On Gray System Theory Basketball Team Scores Its Technical Indicators Associated. International Journal of Applied Mathematics and Statistics, **44(14)**, 185-192 **(2013)**.

[10] Zuojun Tan; Fuzzy Data Envelopment Analysis and Neural Network Evaluation Mathematical Applications Model Which Based On Martial Arts Competition. International Journal of Applied Mathematics and Statistics, **44(14)**, 37-44 **(2013)**.