

Analysis of Technical Characteristics of Ren Mengqian, an Excellent Pole Vaulter

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Abstract

To advance the development of Chinese women's pole vaulting technique, three-dimensional photogrammetry and video analysis methods were utilized to conduct kinematic analysis on the technique employed by Ren Mengqian, an outstanding female pole vaulter in China, during the 2019 National Indoor Track and Field Championships finals from an energy transfer perspective. The findings indicate that during the energy acquisition stage, Ren Mengqian executed a reasonable jumping action with appropriate jumping angle and timing that met technical requirements. However, during the energy storage stage, her bow rod had suboptimal effects in her fourth trial jump while insufficient bending of the rod occurred in her fifth trial jump which affected pole energy storage. In terms of energy release stage, Ren Mengqian maximized elastic potential energy through stretching but required acceleration for maximum vertical speed.

Keywords: Pole vault; Ren Mengqian; Energy transfer; Technical characteristics.

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INTRODUCTION

Pole vaulting is a competitive sport in which athletes gain kinetic energy through running and jumping, and convert kinetic energy into elastic potential energy and human gravity potential energy. From the perspective of energy transfer, the complete action of pole vault can be divided into energy acquisition stage, energy storage stage and energy release stage. In this study, the technical performance of Ren Mengqian at the 2019 National Indoor Track and Field Championships was analyzed from the perspective of energy transfer by

using 3D photogrammetry, video analysis and other research methods, in order to promote the optimization of technical movements of pole-vaulters.

RESEARCH OBJECT AND METHOD

1. Research Objects

The author takes Ren Mengqian's 5 attempts in the women's pole vault competition in the 2019 National Indoor Track and Field Championship Finals as the research object. Table 1 shows the five attempts of Ren Mengqian.

Table 1: List of Ren Mengqian's jumps

Skip time	Maximum height of center of mass /m
4.15m (1)	4.45
4.15m (2)	4.12
4.15m (3)	4.52
4.50m (1)	4.62
4.50m (2)	4.64

2. Research Methods

(1) Documentary method

Using "pole vaulting" as the key word, the author searched 285 literatures on CNKI, and selected 43 literatures with reference value for the research.

(2) Three-dimensional photogrammetry

Venue: Indoor Track and Field Hall of Zhejiang Sports Vocational and Technical College, the shooting time is March 19-20, 2019.

Camera equipment: Two SONY (HDR-FX1000E) cameras, shooting at 25 frames per second.

Position setting: The two cameras are respectively placed on the stands on both sides of the competition venue, the main optical axis Angle is about 120°, the camera height is about 5 meters, and the radial PEAK frame is used to calibrate the movement space before the competition.

(3) Video analysis method

In order to obtain motion feature data, two SONY (HDR-FX1000E) cameras were used in this study to simultaneously shoot the last two steps of the athletes' run-up and the process of jumping to the push rod at fixed point and fixed focus. The two cameras were respectively placed in the opposite stand of the competition venue (FIG. 3). The height of the cameras was about 5m, the Angle between the main optical axes of the two cameras was about 120°, and the shooting frequency was 25 frames/SEC. In the later stage, the digitalization of sports technology adopts the German SIMI Motion8.0 motion analysis system to analyze the technical videos of athletes, and the analysis frequency is 50Hz/ SEC. In order to obtain human body index data, In this study, 15 human link markers (head, left shoulder, right shoulder, left elbow, right elbow, left hand, right hand, left hip, right hip, left knee, right knee, left ankle, right ankle, left toe, right toe) were established in the analytical system. 8Hz low-pass filtering was applied to the original position data to smooth the node data, and DLT method was used to calculate the spatial coordinates.

(4) Data analysis

The author used SPSS 17.0 and PYTHON software for statistical analysis and processing of the original data.

(5) Definition of technical indicators

The amount of pole bending: indicates the degree of pole bending, that is, the amount of rod string shortening.

Swing speed: The maximum linear speed of the ankle joint during the swing (unit m/s).

Body Angle: The Angle between the trunk link and the horizontal plane (i.e. the XY plane).

Extension deviation Angle: the Angle between the trunk link and the coronal plane (i.e. the YZ plane).

Suspension link: the moment when the jumping foot is off the ground to the moment when the body forms the maximum back arch (the maximum hip Angle of the jumping leg).

Swing link: the moment when the body forms the maximum back arch to the moment when the pole is bent to the maximum.

Body link: maximum bending moment of pole to minimum hip Angle moment of take-off leg.

Stretching stage: the minimum hip Angle of the jumping leg to the moment of the hand pushing rod.

RESULTS AND ANALYSIS

1. Characteristics of energy acquisition stage

The energy acquisition stage refers to the stage from the pole run-up to the jump off the ground, including the run-up and jump two technical links.

(1) The last 2 step length and pace characteristics of the run-up

In the last two steps of the run-up process, the hole insertion needs to be completed, and the athletes generally adopt the "chasing rod" running method to speed up the pace, in order to reduce the influence of the falling rod on the run-up speed.

The last two steps of Ren Mengqian showed the characteristics of "big and small", which accelerated the step frequency by shortening the step length, and met the technical requirements of pole vaulting.

The run-up is the main way for athletes to gain kinetic energy, and maintaining the accelerated rhythm in the run-up is the key to improving performance. The change trend of Ren Mengqian's run-up speed in the last two steps is inconsistent with the world's high-level athletes and their previous performance, and there is a phenomenon of deceleration.

Skip time	Step size /m			Pace (m/s)		
	Reverse two steps	Backward step	Difference value	Reverse two steps	Backward step	Difference value
4.15m (1)	1.98	1.94	0.04	8.46	8.22	0.24
4.15m (2)	2.01	2.00	0.01	8.35	8.15	0.20
4.15m (3)	2.03	2.01	0.02	8.40	8.20	0.20
4.50m (1)	2.01	1.93	0.08	8.32	8.15	0.17
4.50m (2)	2.11	1.98	0.13	8.35	8.19	0.16

(2) Take-off speed change, take-off Angle and take-off time characteristics

Take-off horizontal speed loss (V_x loss) can be used as an index to evaluate the take-off effect of athletes. The average rate of horizontal speed loss of the world high-level female pole vaulters is $19.48 \pm 4.97\%$. The loss

rate of Ren Mengqian's first trial jump is higher than that of the world's high-level athletes, and the loss rate of the rest of the trial jumps is lower than that of the world's high-level athletes (see Table 3), which indicates that Ren Mengqian's technical movements in the jumping link are reasonable.

There is a significant negative correlation between jump Angle and athletic performance. In a certain range, the smaller the jump Angle, the better the athletic performance. The average starting Angle of Asian elite female pole vaulters is 19.86°. It can be seen from Table 3 that the takeoff Angle of Ren Mengqian's 5 trial jumps is reasonable.

The jump time reflects the speed of the jump, and the faster the jump, the better the effect. The starting time of pole vaulters is 0.12 ~ 0.15s. Ren Mengqian's takeoff time is stable at 0.12s, and the completion of the takeoff action is good.

Skip time	Vx loss (m/s)	Vx loss rate (%)	Takeoff Angle (°)	Jump time (s)	Pendulum velocity (m/s)
4.15m (1)	1.67	21.08	19.91	0.12	13.05
4.15m (2)	1.29	16.77	17.48	0.12	12.81
4.15m (3)	1.19	15.43	17.68	0.12	13.24
4.50m (1)	1.38	17.97	18.83	0.10	13.17
4.50m (2)	1.26	16.44	20.05	0.12	13.11

(3) Characteristics of energy storage stage

The energy storage stage refers to the beginning of the bending of the pole to the maximum bending of the pole. In this stage, the dynamic energy is mainly converted into elastic potential energy by overhanging and swinging body.

The amount of pole bending of the world high-level female pole vaulters accounts for 14.41% of the total amount of pole bending in the jumping link, 36.67% in the hanging link and 49.15% in the swinging link. The amount of Ren Mengqian bending in each link showed "take-off < overhang < The characteristics of "pendulum" conform to the characteristics of energy utilization. This further shows that the centrifugal force ($F=mr\omega^2$) generated by the pendulum is the main power source of the rod bending.

To enhance the strength of the bending rod, we must try to increase the rotation radius and speed up the angular speed. However, there is usually a restrictive relationship between the radius of rotation and the acceleration of the angular speed, which requires the athlete to accelerate the angular speed without shortening the radius of rotation too much. From the relationship between angular velocity and linear velocity ($v=r\omega$), it can be seen that when the rotational radius r is constant, the greater the linear velocity v is, the greater the angular velocity ω is.

Studies have shown that the swing speed of the world's high-level female pole vaulters is 12.41 ± 0.51 m/s, and the swing speed of the 2015 World Championship champion Silva Alisre is 13.78m/s (Xie Huisong *et al.*, 2015; Li Xinxin *et al.*, 2014). The maximum swing speed of Ren Mengqian's 5 trial jumps was 13.24m/s, which had a certain gap with the world's top athletes. In the future training, it can strengthen the core strength training and speed up the swing speed.

(4) Characteristics of energy release stage

The energy release stage refers to the stage from the maximum bending moment to the overhand pushing

moment. In this stage, the elastic potential energy of the pole is transformed into the gravity potential energy of the human body through stretching, including three technical links: mass body, stretching and pushing the pole.

2. Analysis of stretching velocity characteristics

Stretching is the main part of human body to use the elastic potential energy of pole, and its effect directly affects the lifting height of athletes. The research shows that the increase of the vertical speed of the world high-level female pole vaulters in the stretch is 0.72 ± 0.22 m/s. Table 4 shows that Ren Mengqian's vertical speed increase is higher than the average level of high-level female athletes in the world, indicating that Ren Mengqian can make full use of the elastic potential energy of the pole in the stretch link. In terms of extended vertical speed, the 2015 World Championship women's pole vaulting champion Silva Allisre's extended vertical speed reached 4.71m/s, Bubka's extended vertical speed reached 5.60m/s when she passed 6.01m, and there is a big gap between Ren Mengqian's maximum extended vertical speed and the world's top athletes.

3. Feature analysis of mass Angle and extension deviation Angle

The results show that there is a significant negative correlation between team Angle and stretch deviation Angle ($r=-0.784$, $P < 0.01$). The larger the team Angle is, the smaller the stretch deviation Angle is. There was a significant negative correlation between the extension deviation Angle and the height obtained in the extension section ($r=-0.644$, $P < 0.05$). The smaller the extension deviation Angle, the higher the height obtained in the extension section. This shows that the larger the mass Angle and the smaller the extension deviation Angle, the better to obtain a higher height under the condition of the same extension speed. The extension deviation Angle of the world's high-level female pole vaulters is 30.48 ± 4.40 °, but Ren Mengqian's extension deviation Angle is larger, which affects her extension height.

Skip time	Vertical velocity of extension (m/s)			Body Angle	Deflection Angle
	Initial velocity of extension	Maximum value	Increment		
4.15m (1)	2.79	3.56	0.77	1.10	33.65
4.15m (2)	2.75	3.56	0.81	8.70	30.56
4.15m (3)	2.70	3.42	0.72	14.01	32.36
4.50m (1)	2.51	3.41	0.90	12.16	38.36
4.50m (2)	2.61	3.43	0.82	8.75	39.27

(4) Kinematics analysis of the last 2 step speed and step length in the run-up stage

The average difference of the last two steps of the Chinese elite female pole vaulters is 0.05m, showing the characteristics of "big - small" gait. In other words, China's excellent female pole vaulters in the final stage of the run-up to shorten the step length and speed up the technical characteristics, which is conducive to the run-up and jump of the positive connection. Among them, Sun Sinan had the biggest change in step size, which was 0.13m; Song Tingting, Yang Yang and Chen Qiaoling had the smallest change of step length, which was 0.02 m. The difference between the last two steps of China's excellent female pole vaulters is between 0.02 m and 0.13 m. The research shows that the difference of the last two steps of the pole vaulter run-up is within the range of 10cm ~ 20cm, and the penultimate step is 5% ~ 15% shorter than the penultimate step is the athlete's performance of actively accelerating the jump. If we take this as the standard, only Ren Mengqian and Sun Sinan among the outstanding female pole vaulters in China are within this range, and the step difference of other athletes is less than this standard. The change in step length is caused by the athlete preparing to take off from the hole. The greater the difference, it indicates that the athlete is fully prepared for the hole jump in the final stage of the run-up. Of course, the change of the athlete's step length is related to its form, technical level and speed ability, and the difference of step length is not fixed, it will change with the athlete's competitive state and the change of the competition environment. According to the correlation between the kinematic indexes of pole vaulters' pole-holding run-up and take-off techniques, the speed of the penultimate 1 and 2 steps in the last stage of the run-up has a certain correlation with their athletic performance, while the step length and step difference of the penultimate 1 and 2 steps have no significant correlation with their athletic performance.

CONCLUSION

1. In the energy acquisition stage, the change trend of Ren Mengqian's last two run-up speed was inconsistent with the performance of high-level athletes in the world, and the technical movements of the jump were reasonable and the jump time met the technical requirements.
2. In the energy storage stage, Ren Mengqian's fourth trial jump was not complete enough, and the bow rod effect was not ideal; The fifth test jump has short hanging time and small bending amount, which affects the energy storage effect.

There is a certain gap between the swing speed of the test jump and that of the world high-level athletes.

3. In the energy release stage, there is a big gap between Ren Mengqian's maximum vertical stretching speed and that of high-level athletes in the world.
4. The length of the last two steps of the run-up of China's excellent female pole vaulters presents a "large-small" rhythm pattern, which is conducive to the connection between the run-up and the jump, but the absolute speed level is relatively poor, and the run-up speed of the pole vaulter has a high correlation with its athletic performance. Therefore, we should strengthen the training of the absolute speed ability of the excellent female pole vaulters in our country, and improve their ability to hold the pole.
5. China's excellent female pole vaulters are equipped with more reasonable horizontal and vertical speed at the moment of take-off from the ground, and the jumping Angle is larger than that of the world's outstanding athletes. Therefore, in the future, we should pay attention to the athletes' instant horizontal speed and vertical speed, and with the improvement of the athletes' competitive level, the formation of suitable for the athletes' actual lifting Angle, so as to improve sports performance.
6. Most of China's excellent female pole vaulters use the way of inserting the hole and then jumping, which does not meet the current jumping mode of the world's excellent pole vaulters. In the future, we should strengthen the training of athletes' jumping technique and master the key points of "free jumping" technique.
7. The starting point of China's excellent female pole vaulters is not just below the projection point of the overhand grip point, which is easy to cause the loss of horizontal speed to increase, which is not conducive to the play of subsequent movement technology. Therefore, in the future training, attention should be paid to the accuracy of the height of the overhand grip point and the appropriate position of the jumping point, so that the athletes' jumping point is located directly below the projection point of the overhand grip point as far as possible.

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