Kinematical Analysis on the Throwing Discus Technique of Distinguished Throwing Athlete, Nu Ermaimaiti

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Abstract. It is difficult for many researchers to analyze the technique of throwing discus by some reasonable means because of the fast and complicated process. The paper uses the three-dimensional video analysis technique to obtain the relevant kinematic parameters of each stage and obtains the kinematic characteristics of the excellent Chinese athletes at the present stage. Then, the paper analyzes the advantages and disadvantages of the athletes at all stages, and provides a reasonable theoretical basis for diagnosing the technical movements of the China excellent athletes.

Keywords: discus technology, kinematic parameters, kinematic characteristics

1. INTRODUCTION

In recent years, the performance of China's outstanding discus athletes is wandering between 50-60 meters basically and has a certain gap with the world's top athletes' performance. In this paper, we did field shooting to throwing discus technology of Nu Ermaimaiti in 2016 National throwing champion in the competition and use three-dimensional video analysis method to draw the various aspects of the kinematic parameters and kinematics characteristics. Then we compare these parameters with the relevant kinematic parameters of the world's outstanding athletes to put forward some theoretical basis and improve the scientific level of sports training.
2. RESEARCH OBJECT AND METHOD

2.1 Research Object
Nu Ermaimaiti was born in 1982, height 192cm, weight 90kg, the athlete of XINJIANG Sport Bureau in China. He won the champion of 2016 National Throwing Competition. The best score of this competition is the third throw in finals, 58.10 meters.

2.2 Research Method
Three-dimensional camera analysis method: We use two Nissan JVC GC-PX10AC high-speed cameras (50 frames / second) to do the simultaneously shoot of 2016 National Throwing Competition. The two cameras were placed on the front and rear sides of the throwing circle, respectively. These two cameras have axis angle of 90°, shooting frequency of 50Hz. We use high-titanium 3-D Signal TEC V1.0C three-dimensional video analysis software to analyze the technical action and choose Matsui Hideyoshi’s human model (21 joints, 16 links). The original data is smoothed by a low-pass filter with a cutoff frequency of 8 Hz.

3. RESULT AND DISCUSSION

3.1 Analysis of Stage When Athlete Rotates with Two Foots
This stage starts from the maximum time in first lap to the right foot off the ground moment. Its main task is to move from the quiescent state of the discus to the throwing direction, through the rear throwing arm until the pendulum maximum time. Now, the pulling angle of athletes is biggest. Pulling angle directly affects the size of the extent of the torsion shaft shoulder and hip axis. This action is the key beyond a good instrument, i.e., the larger the twist angle of the shoulder of the hip, the full extent of body twisting.

If we want to get the best pedal to the initial speed, we must increase the degree of tightening the shoulder. The degree of rotation of the shoulder depends mainly on the size of the pulling angle. From Table 1, we can see that at the maximum time of the pre-pendulum, the pulling angle of MAIMAITI is 205°. The average pulling angle of foreign outstanding athletes is 216.4° which is bigger than national athletes, resulting in insufficient degree of hip (reverse angle of 38.5°, the average angle of foreign athletes is 42°). Cannot forming a good move beyond the device is not conducive to maintain the follow-up rotation of the hip speed always greater than the shoulder speed posture. There was a significant positive correlation between the size of the angle and the angle of the hip cuff. At the maximum time of the pendulum, the angle of the left pedal is 29.6°. While pedal angle of the foreign outstanding athletes is about 38°. This angle contrasts prove against the idea that the athlete's shoulder-hip twist is not sufficient, indicating that MAIMAITI’s shoulder hip flexibility is weak.
3.2 Analysis of Stage When Athlete Rotates with Left Foot:

This stage is from the right foot off the ground to the left foot off the ground moment. The body in the rotation process need to smoothly rotate forward the right leg. The right leg need to rotate under low level like a buckle when swing to the throwing cycle and combine with left leg pedal phase. The left arm cooperates to control the direction and maintain the body balance. Its key role is to form a good overtaking equipment and improve the level of speed, so that athletes get greater momentum.

As shown in Table 2, in the right foot off the ground moment, the left shoulder speed 4.25 m/s, right shoulder speed 2.68 m/s, left hip speed 1.18 m/s, right hip speed 2.38 m/s. Shoulder speed is significantly greater than the hip speed, indicating that the left shoulder drives the beginning of the main direction to rotate the right shoulder. At this stage, the rotation of the lower limbs mainly relies on the right hip to drive the left hip. And in the left foot off the ground moment, the shoulder speed decreased significantly, while the hip axis speed increased significantly, indicating that MAIMAITI finish this stage beyond the instrument posture task in a high level.

By reviewing the relevant literature, we understand that the linear oscillation of swinging legs when the left foot single support rotation phase tends to reduce the speed loss of the discs in the pre-rotation, which is beneficial to reduce the time of the vacating stage and improve the stability of the body's gravity center, so that discs get a better starting speed. MAIMAITI spend 0.34 s on right foot from the ground moment to the left foot off the ground, while foreign outstanding athletes at this stage have the average time in 0.2 s or so. This shows that MAIMAITI takes method of making the right leg rotate around the left side of the support leg in large radius arc, increasing the distance of the swing radius, resulting in the rotation of the angular acceleration smaller, so that the acceleration distance becomes shorter, vacated distance longer. This will affect the finisher's final shot speed.

### Table 1. Relevant kinetic parameters with pairs of feet support.

| Athlete                    | Pulling Angle (°) | Shoulder Twist Angle (°) | Stomp Angle (°) |
|---------------------------|-------------------|--------------------------|-----------------|
| Nu Ermaimaiti             | 205               | 38.5                     | 29.6            |
| Foreign Outstanding Athletes | 216.4             | 42                       | 38              |

### Table 2. Nu Ermaimaiti’s Relevant kinetic parameters with left foot support.

| Moment | Speed of Left Shoulder(m/s) | Speed of Right Shoulder(m/s) | Speed of Left Hip(m/s) | Speed of Right Hip(m/s) |
|--------|-----------------------------|-----------------------------|------------------------|-------------------------|
| T2     | 4.25                        | 2.68                        | 1.18                   | 2.38                    |
| T3     | 2.42                        | 3.20                        | 3.32                   | 3.12                    |
3.3 Analysis of Vacated Stage

This stage is between the left foot off the ground moment and the right foot moment. The left leg of the athlete should be moved forward to the right leg. From \( I = mr^2 \) and \( M = Ia \) formula we know that reducing the radius of rotation of the lower limbs help to reduce the moment of inertia of the lower limbs and increase the rotational angular velocity. The left leg swings down quickly to avoid the center of gravity moving forward. At the same time, the athlete may reach the formation of hip - waist - shoulder arm - discus twisted close to the state, which reserve more elastic potential energy for the last two support stage to achieve the purpose of quick shot.

As can be seen from Table 3, at the left foot off the ground moment Nu Ermaimaiti has a pulling angle of 182.2°, twist angle of 15°. And at the right foot reaching ground moment, his pull angle is 196.5°, twist angle is 76.2°. Foreign outstanding athletes have the twist angle of 75°, indicating that in the vacated stage Nu Ermaimaiti has ability to keep beyond the instrument posture which is conducive to reducing the body in the horizontal direction of the speed loss and store more elastic potential energy for the next stage. At the left foot and the right foot to the ground moment, Nu Ermaimaiti’s discus speed were 7.72 m / s and 6.52m / s, decreased by 1.2m / s, indicating a gap with foreign outstanding athletes’ 0.83 M / s at this stage. One should minimize the loss of discus speed while maintaining the last full force. And the speed of gravity center in the vacated phase should be a slight decline, Nu Ermaimaiti’s speed of gravity center showed a slight upward trend in this stage, extending the time and cannot achieve a better momentum of transmission.

| Moment | Speed of Discus(m/s) | Speed of Gravity Center(m/s) | Pulling Angle (°) | Shoulder Twist Angle (°) |
|--------|----------------------|----------------------------|------------------|--------------------------|
| T3     | 7.72                 | 2.32                       | 182.2            | 15.0                     |
| T4     | 6.52                 | 2.35                       | 196.5            | 76.2                     |

3.4 Analysis of Transitional Stage

This stage is from the right foot reaching ground moment to the left foot reaching ground moment and is an important part of the action. The right leg falls near the center of the throwing circle. The toes are inclined 45° in the opposite direction of the throwing direction. The left leg tends to swing linearly and quickly. The positive rotation of the lower limbs reduces the time spent in this stage, so that the hip shaft further beyond the shoulder and the formation of discus - throwing arm - shoulder - waist - hip again tighten the posture, storing as much elastic energy for the final work.

According to Table 4, we can see that at the time of the left foot touching the ground, the twist angle of Nu Ermaimaiti is 42.3° and the pulling angle is 156.7°. While foreign outstanding athletes have the twist angle around 45.3°, pulling angle of about 135°. This shows that at this stage Nu Ermaimaiti rotates the upper body appropriately and move the shoulder behind the hip
axis as far as possible by moving back the rear throwing arm, completing the attitude beyond the device. In the moment of right foot touching the ground, his left hip speed is 5.82m / s, right hip speed is 1.72m / s. In order to reduce the time spent in the transition phase, one should use the move straight method to make left side of the swing legs land quickly. This leads to a significant increase in the left hip speed above the right hip speed. When his left foot lands, his left shoulder speed is 5.82m / s, right shoulder speed is 3.15m / s, left and right shoulder speed difference is 2.67m / s, lower than the difference of foreign outstanding athletes. This shows that though Nu Ermaimaiti tighten the upper body reasonably, his outbreak of the waist and abdomen is poor, resulting in that the left shoulder cannot be quickly promoted to the best level and drive the right shoulder homeopathic acceleration, which will affect the finisher last shot speed.

**TABLE 4.** Nu Ermaimaiti’s Relevant kinetic parameters at transitional stage.

| Moment | Shoulder Twist Angle (°) | Pulling Angle (°) | Shoulder Speed(m/s) Left | Shoulder Speed(m/s) Right | Hip Speed(m/s) Left | Hip Speed(m/s) Right |
|--------|--------------------------|-------------------|--------------------------|----------------------------|--------------------|---------------------|
| T4     | 76.2                     | 196.5             | 2.52                     | 2.85                       | 3.82               | 1.72                |
| T5     | 42.3                     | 156.7             | 5.82                     | 3.15                       | 2.32               | 2.16                |

**3.5 Analysis of Final Stage**

This stage is between the left foot landing moment to the discus shot moment and is the last shot of the discus accelerated stage. Athletes place the arm after the rear of the body through the shoulders thrown tightly and fully use leg waist’s turning ability. Throwing arm in no hurry to speed up, instead, turned back to shoulder after finishing the rotation of foot homeopathically. Finally, the last shoulder moves beyond the hip axis to complete the entire technical action.

Discus shot is the most important factor in determining the final score. But the athletes sometimes ignore the shot angle and shot height and other factors, which make it difficult to improve performance. From Table 5 we can get the figure that at the shot moment, Nu Ermaimaiti has the shot height of 1.81m, shot angle of 34.1°. Bajar's shot height is 1.65m, shot angle is 36°. By reviewing the relevant literature, we found that the shot height increased from 1.50m to 1.80m, the results can rise 0.4m. And shot height and height were positively correlated. Shot height is generally 90% of the height. Nu Ermaimaiti’s height is 1.92m, so the shot height is around 1.72m. In this game, Nu Ermaimaiti’s shot height is higher than 1.72m, which is mainly related to the use of jump shot throwing technology. His shot angle is between 33° and 37°, in the reasonable range. In the final moment, Nu Ermaimaiti’s shot speed is 23.72m / s, while Bajar’s shot speed is 25.6m / s, a difference of 1.88m / s. His score worse than the bargain 8.84m, indicating that in the last shot moment Nu Ermaimaiti’s outbreak power is not enough. The main reason is
that he did not completely in the last stage of the upper limb twisted force on the instrument and doesn’t play out the physical storage of the elastic reasonably, resulting in low shot speed.

| Nu Ermaimaiti | 23.72 | 1.81 | 34.1 | 58.10 |
| Bajar | 25.6 | 1.65 | 36 | 66.94 |

4. CONCLUSION AND SUGGESTION

1. At stage with two feet support, Nu Ermaimaiti’s shoulder hip twist level is lower than the level of foreign outstanding athletes, resulting in the transition phase cannot form a good beyond the device action. Athletes should strengthen the flexible quality of the shoulder and waist through practice.

2. At stage with left feet support, Nu Ermaimaiti uses a right leg around the left side of the support leg from top to bottom radius of the arc swing way. It will increase the vacating phase and the transition phase of the time. So, the athlete should be appropriate to reduce the rotation radius in the rotation. By reducing the moment of inertia to increase the rotation of the angular velocity, thereby improving the efficiency of action.

3. At vacated stage, Nu Ermaimaiti’s ability to stay beyond the device is stronger. But due to vacant time slightly leading to too large discus speed loss. This is mainly due to the lack of control of the speed of gravity center. If you can enhance the speed of the lower limbs in the transition stage and form a more substantial posture beyond the instrument, you can make up for its lack, and then improve the rotation technology.

4. At transition stage, Nu Ermaimaiti can be very good to complete the hip axis beyond the shoulder of the action posture. But at the left-foot-land moment his left and right shoulder speed difference is 2.67m / s, lower than the difference of foreign outstanding athletes. This shows that Nu Ermaimaiti’s waist and back when the explosive is not ideal. He should focus on the development of training in the development of core strength training.

5. At final stage, Nu Ermaimaiti’s shot height and angle are within the best reasonable range, but his shot speed is lower than the foreign outstanding athletes’ 1.88m / s. its shot speed is still the absolute impact of sports performance factors. So, strengthening the training of power and speed of pedaling the lower limbs and improving the arm whipping action is the overall potential of Jack mining technology potential.

5. REFERENCES

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