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Kinematic Analysis of Rotating Skills of Elite Women' Hammer Thrower

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Abstract

This study is intended to provide a theoretical basis for improving the performance of Asian female hammer throwers by analyzing and diagnosing their rotational skills, clarifying their kinematic characteristics, and finding the technical gap with the world's best athletes. This experiment utilized three Japanese JVC high-speed cameras and a DLT radiation-type three-dimensional calibration frame to collect technical action images. The cameras are placed in the left, right and back threes a test system come directions of the hammer throwing circle, and the distance from the center of the throwing circle is 12m, the camera lens is 1.2m high, the main optical axis angle is 90°, and the shooting frequency is 120 frames per second. The conclusions obtained through the analysis of the images taken using the APAS program and the DLT technique are as follows. 1) Athletes' one-foot and two-foot support times are getting shorter. 2) The increase in rotational speed and the speed rhythm shows a relatively big difference from the world's top athletes. 3) The trajectory angle of hammer operation showed a big difference compared to the world's best athletes. 4) As the rotation increases, the height of the center of gravity increases at the moment of supporting two feet, and the width of change of the height of the center of gravity at the moment of support of one foot is relatively small.

Keywords: *Women's hammer throw, Rotation technique, Kinematics*

1. Introduction

At present, the Asian women's hammer throw performance has been greatly improved. Of course, there are many factors that promote the performance improvement, but one of the most important points is that the technology of hammer throwing has developed greatly. Regardless of whether male or female hammer throwers, on the premise of having coordinated and flexible fast strength qualities, only the technical elements are more reasonable and the speed is faster, they can achieve good results.

According to Baronietz, 2001, Hammer is a re-injection of the throwing discipline that requires good body quality, rational technical structure, and related professional skills. Scholars

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such as Otto and Baronietz report that hammer throw technology is a key, professional skill is an important part, strength is the foundation, and these three elements are mutually constrained by mutual promotion. In Dapena et al., (2003) and Gutierrez-Davila (2002), studies show that the time needed to be reduced depending on the ratio of the throw process, the time needed to be reduced in one-turn support and two-legged support, and the speed of hammer throwers' release is key. According to Otto et al., (1992) and Simonyi (1980), in order to counter the centrifugal action of the hammer constantly accelerating its motion during rotation, the player must constantly adjust his posture, and when the hammer is at its lowest and highest points, the body must reduce the knee angle as much as possible. Researchers such as Susanka and Bartonietz (2007) analyzed the parameters of the hammer throw time during the rotation of the competitors, and found that in the hammer throw, the difference in parameters such as the time and speed of the competitor is clear, and that the high-level thrower has a fast and quickness characteristic. Scholars such as Susanka and Bartonietz point out that although the main acceleration of a hammer throw is the two-foot support phase, the time ratio of one-foot support and two-foot support alone cannot assess a player's hammer throwing technique. According to Ellerbe (2004), in the hammer throwing process, one foot support time increased and two-foot support time decreased in order for players to maintain the rotational speed according to the acceleration of each step faster, but good hammer throwers do not even have high rotation speed It is reported that the two-foot support time can last longer.

Mastering and understanding the advanced sports technology of individual characteristics can give full play to the skill potential to create the best results. Improving the special skills of women's hammer is an urgent problem for athletes and coaches to solve. Therefore, this research analyzes their technical movements in detail, summarizes the kinematic characteristics of the current outstanding female hammer thrower's throwing technique, grasps the status and development trend of the athlete's throwing technique, and finds out the technical characteristics and technical differences with the world's outstanding athletes. The differences and advantages and disadvantages provide references and references for the training of reserve forces for women's hammer throwing, the teaching and training of women's throwing techniques, and the future scientific research of the project, and further promote the scientificization of women's hammer training.

2. Research method

This study uses the kinematics test method to perform peak shooting and video analysis of excellent female hammer throwers and youth hammer players. At the same time, after strengthening the monitoring of the state of muscle power during the rotation process of athletes, comparing and analyzing with international excellent female hammer throwers, finding differences and shortcomings, and feeding back the results of kinematic data to the leader, hammer throwers They aim to provide scientific guidance for future training of professional skills, strength, and cultivation of prospective talents. The experiment subjects, experimental equipment, analysis tools, and statistical methods of this study are as follows.

2.1. Research subject

According to the data published by Luona and IAAF, in 2018, Chinese hammer throw national representatives, Xujing and Chiyang, ranked 5th in the world and 1st in Asia in 2018. The details are shown in [Table 1].

Table 1. Player's basic situation statistics

Athlete	Year	Height	Body weight	Highest record	Measurement	Time
A	27	175	90	75.02	70.90	15
B	23	172	85	61.96	59.80	11
C	22	176	92	61.01	58.20	10

2.2. Experimental and analysis tools

The experimental tools and analysis tools in this study are related to the kinematic test and analysis system. The specifics are shown in [Table 2].

Table 2. Experimental and analysis tools

equipment	Experimental tools	Manufacturer
	JVC GC-PX10AC	Victor Company of Japan Limited
Analysis equipment	Analysis tools	Manufacturer
	APAS (Ariel performance analysis system)	USA Ariel

2.3. Classification of core technologies

One foot support step is from the moment the adult foot lands on the ground until the next time the right foot lands (E1—E2, E3—E4, E5—E6, E7—E8). The two-foot support phase is from the moment the adult foot lands to the next moment the right foot lands (E0—E1, E2—E3, E4—E5, E6—E7). Among them, there are four rotations with eight moments as follows.

It is as shown in [Figure 1]

Turn1：（E0—E2） 1 turn
Turn2：（E2—E4） 2 turn
Turn3：（E4—E6） 3 turn
Turn4：（E6—E8） 4 turn
Release：（E8—E9） The last moment of strength

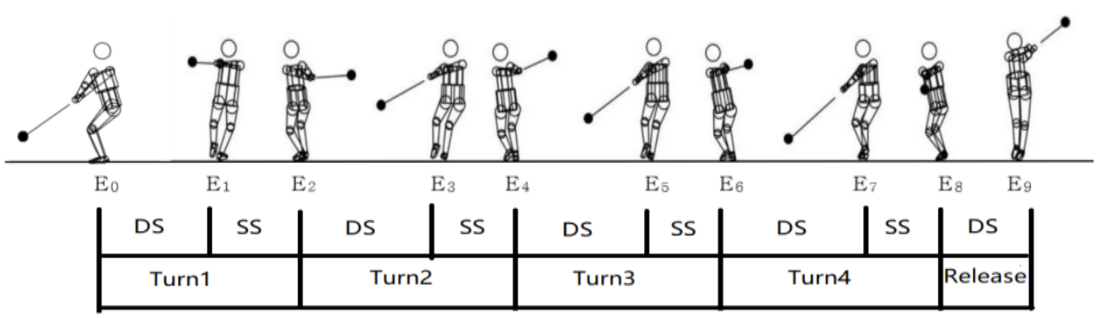
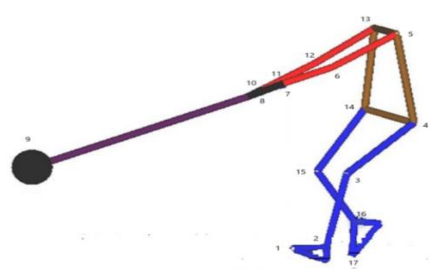


Figure 1. Technical operation time and section division

2.4. Data processing and analysis method

The 3D coordinates were established using DLT frames. According to the regulations, the origin of the coordinates is the centrifuge of the hammer throw. Furthermore, when the hammer thrower stands upright in the throwing sphere and then lifts the instrument to practice swing, if it is left, it is in the forward direction of the Y-axis, and when it is backward, it is in the forward direction of the X-axis. The Z axis is placed vertically on the plane formed by the X and Y axes, and the top is in the forward direction. The cut frequency of the data obtained through this is 10Hz, which is smoothly processed by the low-pass digital filtering method. It is a representation of 16 body joints using the US Dempster human body model. In addition, by adding hammer mechanism points, the total number of points is as shown in [Figure 2].



1. L Tot 10. R Finger
2. L Angle Joint 11. Wrist Join
3. L Knee Joint 12. R Elbow Join
4. L Heel 13. R Shoulder Joint
5. L Shoulder Joint 14. R Heel
6. L Elbow Joint 15. R Knee Joint
7. L Wrist Joint 16. R Angle Joint
8. L Finger 17.R Tot
9. Hammer

Figure 2. Body joint coordinates

3. Research results

It was confirmed that in order to better understand the rotational rhythm of a hammer thrower, it is necessary to rationalize the one-foot support time and the two-foot support time when rotating (Huokelin, 2007; Wuxiaobo, 1989; Woicik, 1980). Time characteristics for one foot support and two-foot support mentioned above According to [Table 3], the average time for both foot support during the 4th rotation is 1.14±0.09sec, and the average time for one foot support is 1.08± It was found to be 0.06s. In other words, the time for both feet support was somewhat longer than the time for one foot support. In addition, the average time of supporting two feet at one rotation was 0.24±0.02sec, and the average time of supporting one foot was 0.33±0.01sec. In addition, since the rotation time gradually decreased from the second rotation and the speed gradually increased, it was confirmed that the support time for one foot was gradually reduced by comparing the support time for both feet.

Table 3. Time for one foot support and two-foot support (unit: sec)

Athlete	Turn1		Turn2		Turn3		Turn4	
	DS	SS	DS	SS	DS	SS	DS	SS
A	0.22	0.32	0.34	0.24	0.28	0.24	0.22	0.22
B	0.24	0.34	0.32	0.30	0.32	0.26	0.24	0.24
C	0.26	0.32	0.38	0.28	0.32	0.24	0.28	0.24
M	0.24	0.33	0.35	0.27	0.31	0.25	0.25	0.23
SD	0.02	0.01	0.03	0.03	0.02	0.01	0.03	0.01

3.2. Speed parameter during rotation

The factors that greatly influenced the hammer projection speed in the projection process were the rotational speed, the gradual acceleration ability, and the motion rhythm (Hukelin, Cho Youngju, Oh Yunkyung, 2004; Dapena, 1989). The rotational speed and speed increase for each rotation are as shown in [Table 4]. According to the graph, the speed of the hammer gradually increased during the overall rotation process of the player. Since the second rotation speed is faster than the first rotation, the acceleration trend is clear, and the average of the speed increase in the final force exertion stage was 5.0±1.6m/s, which was confirmed as the stage with the strongest acceleration ability in the overall rotation process.

Table 4. Hammer speed increase for each rotation (unit: m/s)

Athlete	Start	Turn 1	Turn 2	Turn 3	Turn 4	Release
	E0	E2	E4	E6	E8	E9
A	13.84	2.55	6.01	0.48	0.97	3.17
B	12.73	0.33	2.56	2.86	1.7	5.95
C	12.9	0.21	2.54	2.39	1.59	5.9
M	13.2	1.0	3.7	1.9	1.4	5.0
SD	0.6	1.3	2.0	1.3	0.4	1.6

3.3. Trajectory parameters during rotation

It can be clearly seen from the [Figure 3] that athlete A reached 6.03m at the end of the second lap of the double support. At the end of the first lap of the double support, the trajectory length of the hammer is compared with the trajectory length of athletes A and C. At the end of the 4th lap, the single foot support reached 6.09m, which was the largest trajectory length compared with athletes A and C.

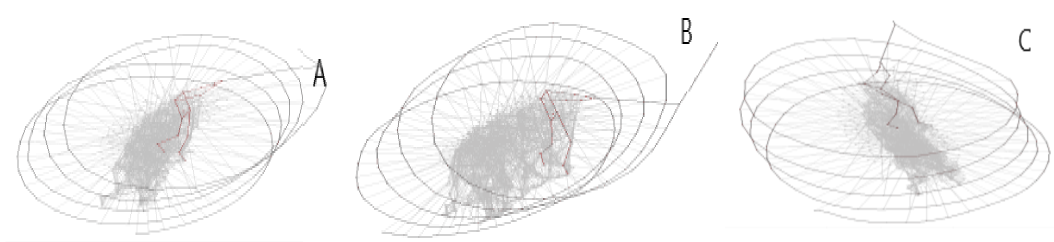


Figure 3. Player's hammers trajectory

3.4 Parameters of human body motion during rotation

Bartonietz (2008) reported that not only the change of the center of mass can be reflected through the height of the center of mass of the player at different perspectives during the rotation stage, but also the extension of the lower extremity of the player and the width at which the upper body is lifted. Player A's center of mass height change curve shows a generally stable trend. Since the change in the center of gravity of athletes B and C was found to be relatively remarkable, the range of change in the center of mass was wide, and in particular, it was confirmed that the center of mass of the support time for one foot in athlete B decreased significantly. [Figure 4] show the changes in the center of mass trajectory of athletes A, B, and C.

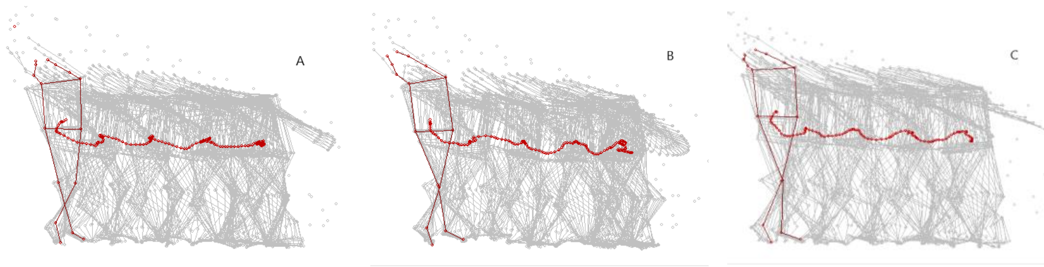


Figure 4. Change of player's central trajectory

4. Discussion

Bondachuk's study showed that the speed of the hammer is the stage of the two-foot support, so to increase the speed of the hammer quickly, the time of the two-foot support is extended during the rotation process, and the motion distance of the lower limb rotation is increased. In this study, since the average value of the athlete's two foot support time from the second round is longer than the one foot support time, it can be seen that the rotational rhythm and trend are consistent with the results of previous studies.Scholars such as Susanka report that the athlete has a more advantage over the final force during the last two rounds, as the time for one foot support is extended and the time for one foot and two foot supports is approximately the same. In the study of Brice & Ness (2008), it is reported that high speed and rapid rhythm is a major feature of modern hammer throwing. In a study by Barclay (2012), it is reported that a hammer thrower can reflect the harmony of the figured situation about the speed of the hammer and the motion technique by increasing the speed acquired by one rotation in the rotation stage. In Dapena's (1986) study, the key to the complete hammer throwing technique is that the speed obtained by the hammer in the rotation phase and the final force exertion phase accounts for about 20% of the release speed, so the impact on the throw distance of the hammer is relatively large. In this study, the amount of exercise gain (3.17m/s) obtained by Athlete A in the final stage of power generation, accounting for 11.7% was smaller than that of the world's excellent athletes, but the amount of increase in speed of Athletes B and C, accounting for 22.7% and 23.1%, respectively. This is similar to the results of previous studies, but the overall speed and rhythm were different than those of the world's top athletes.

In the study of Dapena (1989) and Gutierrez (2002), it is reported that the release speed of the hammer is closely related to the length of the travel trajectory of the hammer. Studies show that the release speed of the hammer mainly depends on the turning radius and angular speed of the hammer, and the length of the turning radius depends on the length of the hammer moving the trajectory during projection, so the length of the hammer's traveling trajectory is also an important parameter that affects the hammer's speed. Player A has the longest trajectory of the hammer at the moment of support of both feet in the second rotation, and that the rotation time is 0.34s and the rotational speed of 6.01m/s is also the largest at a time of 6.03m, which is consistent with the research results of previous studies. However, it is reported that there is a remarkable difference compared to the hammer length of the world's excellent player Wlodarczyk and Deanna.

In this study, the change of the hammer bevel angle during the rotation of the bow was unstable. In the study of Chen Tseng (2004), it is reported that a small or large driving bevel angle makes it difficult to maintain stability during the rotation of the athlete. In addition, the bevel angle is smaller than that of the world's excellent athletes, and while the bevel angles of the second and third turns of the athletes increase, the bevel angles of the fourth turn are not clearly increasing, but a tendency to decrease at the same time. The fact that Player B's final release angle was only 34.8 degrees showed that the player rotation process had problems in engagement with the final force exertion process.

According to Otto, Hay (1992) and Bartonietz (2008)'s research, the key to achieving good results is to maintain the consistency of motion while maintaining the speed of each rotation, and to rationalize the time to sustain with one foot support and two foot support and the center of the lower body , during the rotation process, athletes report that the height of different centers of gravity reflects not only basic information about the center but also the degree of lifting of the athlete's lower body and upper body. In this study, the height of the center of the athlete's moment of support of both feet and the height of the moment of support of one foot are relatively high.

5. Conclusion

The purpose of this research is to conduct kinematic analysis on the spin technique with female hammer throwers as the object, and to provide technical suggestions for hammer throwers to understand their personal technical style and improve their competitive level. For this reason, this experiment utilized three Japanese JVC high-speed cameras and a DLT radiation-type three-dimensional calibration frame to collect technical action images and the following conclusions were drawn through analysis.

(1) the turnaround time of outstanding Chinese women's hammer throwers is gradually shortening. The supporting time and rhythm of one foot and both feet are in line with the results of the first research. However, the total spin time is significantly different from that of the world's outstanding hammer throwers.

(2) the speed increment and speed rhythm of the outstanding Chinese female hammer throwers are significantly different from those of the world's outstanding players. However, during the entire rotation, the speed of the hammer from high to low increases, and the speed from low to high. The loss is minimized by the athletes, which is the same as the results of the previous research.

(3) the change trend of the hammer to the high and low positions and the trajectory slope angle during the rotation process is in line with the results of the first research. Athlete A has the longest hammer trajectory at the moment when the feet support on the second lap, and the engraved rotation time and rotation speed are also the largest, which is consistent with the previous research results, but compared with the world's elite athletes, there are significant differences.

(4) the height of the center of gravity at the moment of the athlete's foot support is higher than the height of the center of gravity at the time of the single foot support during the rotation process, and the height of the center of gravity at the time of the foot support gradually increases with the increase of rotation, and the time of the single foot support the change in the height of the center of gravity is relatively small.

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