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Comparative Analysis of the Final Force Technique Between Two Shot-Putting Methods Based on Data Project

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Abstract. In this paper, the 3D high-speed camera is used to shoot the shot put of the men's shot put competition in the National Track and Field throwing Event (Chengdu Station). And the analysis was made for the top four athletes' shot-putting revolving and slide step techniques, and related kinematics parameters and characteristics were thus obtained. Analysis results show that: on the moment of the left foot on the ground, compared with the slide step technique, the revolving shot-putting has the larger body twist effect, the larger range of shoulder beyond the hip, the more full muscle extension, and the larger twisting range of upper and lower limbs. Slide-step and rotary shot put at the moment have strong left leg support pedaling ability, right leg stretch capacity is weak. Athletic performance is mainly determined by the initial speed of the shot put. It has nothing to do with throwing, the rotating shot put is closer to the best shot angle, the slide shot put shot angle is too large, and shot height and athlete's height have a great relationship, so rotary and slide push shot put the impact of the height of the smaller. Compared with the backsliding of the shot, the shot-putting revolving speed when it is left foot on the ground is less. In the last exertion stage, revolving shot-putting can more effectively increase the running speed of the shot compared with the slide step. The slide-step technique can score good results by lengthening the straight line of the last exertion action, while the revolving shot-putting is to rely on the good body twist state during rotation of the body. The revolving technique with less time in the last exertion stage is better than the slide step technique.

Keywords. Data Project;The final force technique;Throwing technique

1. Introduction

The sport of shot put has a long history, and the types of male shot put throwing techniques around the world are constantly changing [1], from side sliding to back sliding to rotary throwing [2]. The rotating shot put technique continuously sets new world records for men's shot put[3-4], The game of two final force throwing techniques has always been a hot topic [3]. In this paper, in the throwing event series game (Chengdu) of the National Track and Field sport. A three-dimensional high-speed camera was used on

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the last exertion technique of male athletes' shot-putting. And the analysis was made for the top four athletes' shot-putting revolving and slide step techniques, and related kinematics parameters and characteristics were thus obtained. Through exploring the technique characteristics of revolving and slide-step shot-putting, the advantages, disadvantages, and differences between the two throwing techniques can be better understood to provide a theoretical basis and technical references for improving the throwing technology of Chinese shot putters.

2.Research Subjects and Methods

2.1.Subjects

In this paper, the top four male shot putters of China's track and field throwing events are selected as the research objects, Table 1 shows the basic information of athletes.

Table 1 Athlete basic situation table

Name	Technology type	Height (cm)	The athletic performance (m)
Li Jun	Rotating	190	18.66
Han Zibin	Rotating	189	18.40
Wang Guangfu	Slide	186	19.23
Tian Zizhong	Slide	196	18.25

2.2.Methods

This paper mainly adopts the methods of 3D video analysis, literature review, and mathematical statistics. In the final of the throwing event series game of China's Track and Field sport, three-dimensional fixed-point high-speed cameras were used to record the movement of the top four male shot putters. Two JVC GC-PX10AC cameras were placed directly behind and to the right of the shot-throw circle. The shooting frequency was 50 Hz, SignaltEC3D video analysis software was applied to parse the video and the Matsui Xiuji model of the human body (21 points, 16 links) was selected for experimental use. The three-dimensional space was calibrated. Original data was handled through a low-pass filter smoothly at a cut-off frequency of 8Hz, obtaining kinematics-related parameters and analyzing the data.

3.Results and Analysis

3.1.Features Analysis on the Last Exertion Stage

The last exertion technique is the most important part of shot-putting. From the moment that the right foot supporting and the left foot is on the ground to the moment of shot release, the force accumulating and acceleration stage of shot-putting are all included. The shot release speed mainly comes from the last exertion stage, exerting a direct impact on athletic performance [1].

3.2.Analysis of Parameters of the Shot Speed in the Last Exertion Stage

On the moment of the left foot on the ground, in the last exertion stage, As shown in Table 2,the shot speed of two shot-putters with the slide step technique is 3.45 m/s and 3.66 m/s respectively, and the shot speed of the revolving technique is 2.96 m/s and 3.05 m/s respectively. According to the data of the shot speed of the two techniques when it is left foot on the ground, the shot speed with the revolving is significantly less than that with the backsliding step in the first period of the last exertion stage. The shot speed of two shot-putters with the slide step at the moment of shot release is 13.05 m/s, 12.64 m/s, with the speed of the revolving technique 12.88 m/s and 12.73 m/s respectively. The speed difference between the moment of the left foot on the ground and the moment of shot release is 9.60 m/s and 8.58 m/s respectively for the slide step shot-putting with 9.92 m/s and 9.6 m/s for the revolving shot-putting. According to the data in Figure 1, after 1.2 s, the shot speed was flat, and the acceleration of the shot in the final stage of exertion was 41.33 m/s^2, 37.23 m/s^2, 36.92 m/s^2, 32.07 m/s^2. The comparative analysis of the acceleration data and the speed of the shot in the final stage of exertion shows that the rotary type is more effective than the sliding step in the final push stage to increase the speed of the shot.

Table 2 Shot Speed Parameters

Technology type	Left foot to the moment	Shot put shot moment	Difference	Acceleration
Rotating	2.96 m/s	12.88 m/s	9.92 m/s	41.33 m/s^2
Rotating	3.05 m/s	12.73 m/s	9.68 m/s	37.23 m/s^2
Slide	3.45 m/s	13.05 m/s	9.60 m/s	36.92 m/s^2
Slide	3.66 m/s	12.64 m/s	8.98 m/s	32.07 m/s^2

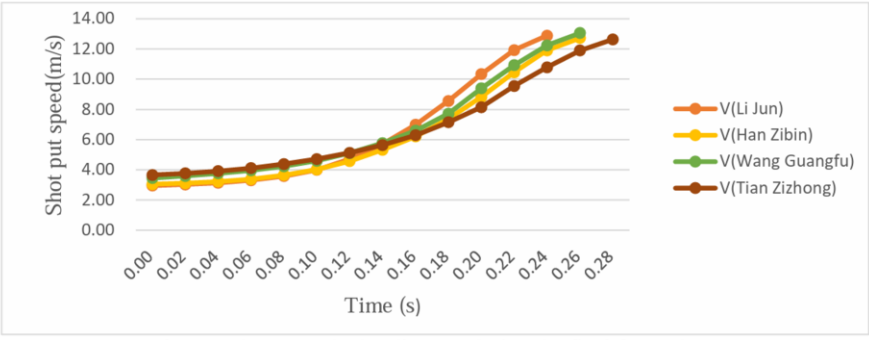

Figure 1 Shot put velocity diagram during the final force phase

3.3.Analysis of Shoulder-hip Angle Parameters in the Last Exertion Stage

The shoulder-hip angle of two shot-putters on the moment of left foot on the ground with the slide step technique is 35.1° and 40.8° respectively with 45.6° and 47.4° for the revolving technique. From the shoulder-hip angle on the moment of the left foot on the ground, the body twist range of the revolving shot-putting is larger than that of the slide step with the left shoulder beyond the hip horizontal axis being larger, muscle stretching being more fully, and the upper and lower limbs twist being greater.

3.4.Analysis of Kinematic Parameters on the Moment of Left Foot on the Ground

As shown in Table 3,the right knee angle of two shot-putters on the moment of left foot on the ground in the last exertion stage with the slide step technique is 102.5° and 102.3° respectively with the revolving technique 102.8° and 108 .4°. So there is no big difference in the joint angle between these two techniques. On the moment of the left foot on the ground, the right hip angle of two shot-putters with the slide step is 120.1° and 112.6° respectively with the revolving technique being 135.9° and 135.4° respectively. The body posture with the revolving technique is higher than that of the slide step. The center of gravity height of the two shot-putters is both 0.87 m with the slide step, and the revolving technique is 0.96 m and 0.91 m respectively. According to the data of the shoulder-hip angle on the moment of left foot on the ground in the last exertion stage, slide step technique can score good results by lengthening the straight line of the last exertion action, while the revolving shot-putting is to rely on the good body twist state during rotation of the body.

Table 3 Left foot to move the moment kinematics parameters

Technology type	Right hip angle (°)	Right knee angle (°)	Center of gravity height (m)
Rotating	135.9	102.8	0.96
Rotating	135.4	108.4	0.91
Slide	120.1	102.5	0.87
Slide	112.6	102.3	0.87

3.5.Analysis of the Left and Right Knee Angle in the Shot Release Stage

At the moment of shot release, the larger the left knee angle is within a certain range, the more effective the supporting ability of the athlete's left leg is. This means that the supporting role of the left lower limb and torso is very important [5-6], which is mainly to prevent and discourage excessive body forward movement leading to fouls. Also, the supporting role is conducive to increasing the center of gravity and the height of the shot [7]. From Table 4, the left knee angle of two shot-putters with the slide step left shot putting on the moment of shot release is 175.4° and 174.0° respectively with the revolving technique being 174.1° and 172.9°. So there is no big difference in the left knee angle at the moment of shot release between these two techniques. Moreover, the left knee angle of the two techniques at the moment of shot release is close to 180°, indicating that the two techniques at the moment of shot release have a strong left leg supporting capability. Under the good support of the left leg, the athlete must increase the pedaling extension of the right foot, and increase the speed of shot release through the energy transfer (Taking the right hand holding as an example). The knee angle of the right foot pedaling is an important reflection of the right leg pedaling effect [8]. The right knee angle of two shot-putters on the moment of shot release with the slide step technique is 153.3° and 149.5° respectively, with the revolving technique being 151.1° and 149.3°. From the data, we can know that there is no big difference in the right knee angle on the moment of shot release between these two techniques. However, compared with foreign athletes, the right leg pedaling extension effect of four athletes is not ideal and needs to be further strengthened.

Table 4 shot put the moment about the knee angle parameters (°)

Technology type	Right knee angle	Left knee angle
Rotating	151.1	174.1
Rotating	149.3	172.9
Slide	153.3	175.4
Slide	149.5	174.0

3.6.Analysis of the Important Parameters at the Moment of Shot Release

The release speed, angle, and height of shot-putting are all important factors in determining the results [9]. The release speed plays a leading role in athletic performance, [3] followed by the release angle with the release height exerting the smallest influence [10]. As shown in Table 5,The release speed of two shot-putters with the slide step technique is 13.05 m/s, 12.64 m/s respectively, with an average speed of 12.85 m/s. The release speed of two shot-putters with the revolving technique is 12.88 m/s and 12.73 m/s respectively with an average speed of 12.81 m/s. From the average speed point of view is almost the same, sports performance mainly depends on the shot put speed [11], but still has a far cry from the speed of the world's outstanding athletes (14 m/s) [5]. The release angle of two shot-putters with the slide step technique is 43.6° and 43.2°, with the revolving technique being 37.8° and 41.2° respectively. Theoretically, the best release angle is between 38° and 41° [5], which means that the angle with the revolving technique is closer to the best release angle with that of the slide step being larger. The release height of two shot-putters with the slide step technique is 2.06 m and 2.11 m respectively, with that of the revolving technique being 2.06 m and 2.05 m. The release height of the world's top shot-putters is about 2.20 m.[8] which matters greatly with the height of athletes. The height of the world's top shot-putters is around 2.00 m, while that of Chinese athletes is about 1.90 m. This shows that China's shot-putters are physically poorer than their foreign counterparts. So the two technologies have little impact on the release height of shot-putting.

Table 5 Shot putter moment kinematics parameters

Technology type	Shot speed (m / s)	Shot angle (°)	Shot height (m)
Rotating	12.88	37.8	2.05
Rotating	12.73	41.2	2.06
Slide	13.05	43.6	2.06
Slide	12.64	43.2	2.11

3.7.Time Analysis in the Last Exertion Stage

In the last exertion stage, only the increase of acting distance, the shortening of the exertion time[12]., and the improvement of the release speed can obtain better athletic performance [13]. The time of two shot-putters with the slide step technique in the last exertion stage is 0.26 s and 0.28 s, while the time with the revolving technique is 0.24 s and 0.26 s respectively. The time of elite shot-putters is 0.22 s [8]. The parameters show that the revolving technique with less time in the last exertion stage is better than the slide step technique.

4.Conclusions and Recommendations

Based on the data engineering, the kinematic parameters of two kinds of shot put final force technology are compared, and the following conclusions are drawn from the analysis.

4.1 On the moment of the left foot on the ground, compared with the slide step technique, the revolving shot-putting has a larger body twist effect, a larger range of shoulder beyond the hip, more full muscle extension, and a larger twisting range of upper and

lower limbs.

4.2 Slide-step and rotary shot put shots at the moment have strong left leg support pedaling ability, but right leg stretch capacity is weak. Athletic performance is mainly determined by the initial speed of the shot put. It has nothing to do with throwing, the rotating shot put is closer to the best shot angle, the slide shot put shot angle is too large, and the shot height and athlete's height have a great relationship, so the rotary and slide push shot put the impact of the height is smaller.

4.3 Compared with the backsliding of the shot, the shot-putting revolving speed when it is left foot on the ground is less. In the last exertion stage, revolving shot-putting can more effectively increase the running speed of the shot compared with the slide step. Slide step technique can score good results by lengthening the straight line of the last exertion action, while the revolving shot-putting is to rely on the good body twist state during rotation of the body, The revolving technique with less time in the last exertion stage is better than the slide step technique.

References

[1] Zhang Qinglai, Zhang Li, Game Analysis on the Last Exertion Technology of the "Revolving" and "Slide step" Shot Putting, [J]. Journal of Beijing Sport University, 2014, 06: 133-139.
[2] Dong Haijun, Ma Yi, Cong Yuzhen, et al. Comparison of Spin Throwing Techniques between Chinese and Foreign Excellent Male Shot Putters [J]. Medical Biomechanics, 2021, 36 (04): 534-539. DOI: 10.16156/j.1004-7220.2021.04.006
[3] Schofield M, Cronin J B, Macadam P, et al. Rotational shotput:a phase analysis of current kinematic knowledge [J]. Sports bi-omechanics, 2019:1-19
[4] Li P, Zhou J. Kinematic analysis on sliding shot put [J]. In-ternational Journal of Experimental and Computational Biomechan-ics, 2018, 4(2/3):196-203.
[5] Sun Qingjie, Track and Field [M] Higher Education Press, July 2001.
[6] Zhang Qinglai, Wei Yongjing Comparative analysis of the running speed of the human ball system during the acceleration and storage stage of "rotary" and "backsliding" - Taking two excellent male shot put athletes in China as examples [J]. Journal of Shandong Institute of Physical Education, 2020, 36 (04): 82-87. DOI: 10.14104/j.cnki.1006-2076.2020.04.013
[7] Vladimir mar M. Zach Olski, Sports Biomechanics [M] People's Sports Publishing House, 2000.
[8] Lai Qicai, Kinematical Analysis on Zhang Jun's Shot-Putting Technology [D]. Chengdu Sport University, 2012.
[9] Li Jianchen, Kan Fulin, Modern Shot Putting [M] Beijing Sport University Press, 2007.
[10] Liu Yonghao, Three-dimensional Kinematics Analysis on the Backsliding Shot-Putting [J]. Journal of Xi'an Technological University, 2016, 05: 394-400.
[11] Li Houlin, Gao Cong, Yang Yang, et al. Kinematics Research on the 20.35 m Breakthrough of Chinese Elite Female Shot Putter Gong Lijiao [J]. China Sports Science and Technology, 2017, 53 (03): 117-126. DOI: 10.16470/j.csst.201703017
[12] Landolsi M, Labiadh L, Zarrouk F, et al. Kinematic analysisof the shotput:A method of assessing the mechanical work of thehand action force [J]. European journal of sport science, 2018, 18(9):1208-1216
[13] Lai Qicai Comparative Analysis of Kinematics of Chinese Men's Shot Put Record Holder Zhang Jun's Rotating Shot Put Technique [A] Sports Biomechanics Branch of the Chinese Sports Science Society. Proceedings of the 14th National Sports Biomechanics Academic Exchange Conference [C]. Sports Biomechanics Branch of the Chinese Sports Science Society, 2010: 2