VIRTUAL RECONSTRUCTION KINEMATICS ON THE START ACTION OF ELITE MALE SHORT TRACK SPEED SKATERS UNDER NEW RULES: A COMPARISON ANALYSIS

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Short track speed skating has been a traditional advantage project of China. In the 500m competition of short track speed skating, occupying a good position in the starting phase has an important influence on the whole process of the competition, which can make the athlete enter the corner in advance and thus successfully complete the acceleration phase. The International Skating Union (ISU) changed the rules of the start action, and various starting actions emerged. The athlete of National Short Track Speed Skating Team named Wu Dajing (Champion of Men's 500m in 2016/17 Season) changed his technique of start action; he is the only one who use lateral type start action in National Team. This paper used the three-dimensional video analysis method to analyze kinematic parameters of the start action of Wu Dajing and Canadian athlete Charles Hamelin (who has been using the lateral starting action) at the 500m competition of 2016/17 ISU World Cup in Shanghai. The technical parameters of the start action of Wu Dajing (center of gravity, trunk angle, pedal ice angle, lower limb joint angle, etc.) were better than Charles which shows he has a good learning ability of the new technology. It is recommended in training he should focus on improving the stability of start action.

KEYWORDS: shock-track speed skating; starting action; visual reality.

INTRODUCTION: 3D Virtual Reality is a comprehensive technology integrating computer, image recognition, graphics and other disciplines. It is a computer system that can perform human-computer interaction and experience virtual worlds. It is widely used in military, games, and medicine [1,2]. The improvement of competitive sports performance and ability puts forward higher requirements on the scientific level of training, and it is an important method and means to reproduce the simulation of the athlete's movements. VR technology, with its strong interactivity, real-time and immersive experience, has become a popular choice for researchers and has become an important means for data reconstruction and demonstration in the technological service process. Short track speed skating is an official competition event of the Winter Olympic Games and is also a traditional advantage project of China. 500m is the shortest competition project in short track speed skating. Different from the acceleration strategies of the 1000m and 1500m, the athletes in the 500m races adopt the quick start and full speed skating strategy. Studies have shown that having a quick start in the starting stage can occupy a favorable position, which has a significant impact on the whole process of the game. If you can enter the corner first, it will lay a good foundation for the follow-up sliding phase. Research shows that in the short track 500m race, the position of the athlete entering the first corner has a greater correlation with the final ranking (r=0.59).

From the perspective of sports training, the success of short track speed skating competition belongs to athlete or team who has the maximum speed, the ranking of competition mainly depends on the athlete's performance in the game, the opponent's performance in the game and competition rules. In 2015, in order to reduce damage to the ice, the International Skating Union made modification on the starting rules. The new rules require that all the blades of the skates must be on the ice when the athletes start running. The new rules have brought about a variety of changes in the starting technique. The start-up postures used by athletes in competitions are also divided into internal rotation, outward rotation and lateral rotation. Chinese short-track speed skating team has investigated the starting technology, because the effect of the external rotation start is better than that of the internal rotation type. Most of the players use the external rotation type start-up. Most of the athletes have a start-up technique. In the 2016-2017 season, Wu Dajing tried to make adjustments to his starting position and tried to use lateral-type starting techniques. He successfully ranked first in the

world's men's 500m total standings this season and crowned the championship of the year. Canadian athlete Charles Hamelin ("Charles") has always used lateral starting techniques. This article uses the three-dimensional video analytics method to perform on-the-spot shooting of the men's 500m race of the 2016/17 Shanghai International Short Track Speed Skating World Cup in Shanghai. The immersive three-dimensional virtual reality system is used to reconstruct the starting technical movements of Wu Dajing and Charles. The similarities and differences between the starting techniques of the world's top athletes, the characteristics of lateral start-sports movements of elite short track skaters, and the theoretical basis and data support for the scientific training of short track speed skating are provided, and suggestions for improving the starting movement techniques are provided.

METHODS: Three-dimensional Video Analysis: At the game site of 2016/17 ISU World Cup Short Track (Shanghai), we used two JVC GC-PX10AC cameras (with a shooting frequency of 50 frames/s) to record the whole process of the competition. The angle between the main optical axis of the two cameras is about 60°. The 3-D Signal TEC V1.0C 3D video analysis system was used to analyze the athlete's starting technology. The raw data was smoothed by a low-pass filter and the cut-off frequency was 8 Hz (Figure 1).

Table 1. Basic information of the study object

Name	Starting techniques	Nationality	Height (cm)	Body Weight (kg)
Wu Dajing	Lateral-type	China	182	73
Charles	Lateral-type	Canada	175	70

Figure 1. The game site (left) and analysis stick figure (right)

3D Virtual Reality Technology: The three-dimensional kinematics data obtained by video analysis is imported into the virtual reality system to drive the human body model (as shown in Figure 2), and the accurate virtual reproduction of the athlete's technical movements is achieved through a 360°rotation angle. The motion technology makes a more accurate diagnosis. The system can realize the synchronization point marking, as well as the simultaneous display of the trajectory and speed of each link, and improve the technical analysis level.

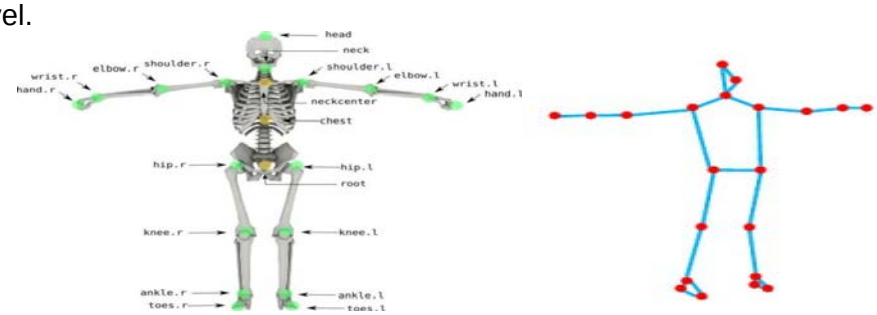

Figure 2. 3D human body model

RESULTS: Definition of the moments and division of stages: Similar to the start of sprint project of track and field, the goal of starting of short track speeding is to enable the athlete to obtain maximum speed in the shortest time and in the shortest distance. In order to

facilitate our comparative analysis of the starting technique, we divided the athlete's starting and ending technical movements into the following 6 moments according to the left and right legs:

T0--the end of preparation moment； T1--right foot off ice moment；

T2--right foot on ice moment； T3--left foot off ice moment；

T4--left foot on ice moment ； T5--right foot re-off ice moment

5 stages: T0--T1：preparation stage ； T1--T2：left leg single support stage；

T2--T3：first double support stage； T3--T4：right leg single support stage；

T4--T5：second double support stage

Analysis of the preparation stage

Table 2. Kinematic Parameters of the end of preparation moment (T0)

Name	Height of COG（m）	Front stability angle（°）	Trunk angle（°）	Pedal angle（°）	Hip angle（°）		Knee angle（°）	
					Left	Right	Left	Right
Wu Dajing	0.88	15.6	36.4	43.6	82.4	112.2	110.8	128.7
Charles	0.72	17.8	41.5	45.7	86.0	105.3	98.1	142.9

At the end of preparation, Charles has a lower body height, which is conducive to greater horizontal speed. At this moment, Wu Dajing's trunk angle and pedal angle are both smaller than those of Charles, which helps to break the balance and start quickly;

Analysis of the left leg single support stage

Table 3. Kinematic parameters of right foot off ice moment (T1)

Name	Height of COG（m）	Velocity of COG（m/s）	Trunk angle（°）	Pedal angle（°）	Hip angle（°）		Knee angle（°）	
					Left	Right	Left	Right
Wu Dajing	0.83	2.66	40.7	38.2	90.1	125.7	112.9	106.5
Charles	0.74	1.63	43.2	41.3	91.8	127.0	112.8	112.9

Table 4 Kinematic parameters of right foot on ice moment (T2)

Name	Height of COG（m）	Velocity of COG（m/s）	Trunk angle（°）	Hip angle（°）		Knee angle（°）	
				Left	Right	Left	Right
Wu Dajing	0.93	3.42	42.3	144.7	100.7	151.4	102.5
Charles	0.85	3.07	46.0	138.4	111.1	129.3	109.7

In the left-leg single-support stage, Wu Dajing's left hip and knee joint stretched more than Charles, and it took a shorter period of time, indicating that the pedal extension was rapid and powerful;

Analysis of the first double support stage

Table 5 Kinematic parameters of left foot off ice moment (T3)

Name	Height of COG（m）	Velocity of COG（m/s）	Trunk angle（°）	Hip angle（°）		Knee angle（°）	
				Left	Right	Left	Right
Wu Dajing	0.94	3.50	44.8	143.5	105.1	131.7	102.8
Charles	0.86	3.27	48.6	127.8	108.8	114.4	106.1

Wu Dajing spent 0.02s at this stage and Charles spent 0.04s. Some literatures suggest that the first double-support stage has less impact on athletic performance. Due to the double support stage, since the skates of both feet of the athletes are in contact with the ice surface and the friction force is increased, the time of the double support stage should be shortened as much as possible. Shorter use of time can reduce the time for the first step of the athlete, which helps the athlete to increase the cadence.

Analysis of the right leg single support stage

Table 6. Kinematic parameters of left foot touch ice moment (T4)

Name	Height of COG（m）	Velocity of COG（m/s）	Trunk angle（°）	Hip angle（°）		Knee angle（°）	
				Left	Right	Left	Right
Wu Dajing	0.94	3.50	44.8	143.5	105.1	131.7	102.8
Charles	0.86	3.27	48.6	127.8	108.8	114.4	106.1

In the right leg single support stage, Wu Dajing's right hip and knee joints have larger but longer stretches. Compared with the left-leg single-support stage, the strength of the left lower extremity is better than that of the right. It is recommended to strengthen the right leg;

Analysis of the second double support stage

Table 7. Kinematic parameters of right foot off ice moment again (T5)

Name	Height of COG（m）	Velocity of COG（m/s）	Trunk angle（°）	Hip angle（°）		Knee angle（°）	
				Left	Right	Left	Right
Wu Dajing	1.01	5.10	47.6	95.7	173.2	84.2	134.9
Charles	0.97	5.03	52.3	92.4	146.6	97.8	110.4

From Table 7 we can see that at this time, the heights of the center of gravity of Wu Dajing and Charles are 1.01m and 0.97m respectively, and the velocity of center of gravity velocity Wu Dajing (5.10m/s) is greater than Charles (5.03m/s) and both speeds reach the maximum; Charles' forward torso (52.3°) is slightly larger than Wu Dajing (47.6°), and Wu Dajing had a fully stretched action.

CONCLUSION: Through the virtual replay analysis of Wu Dajing and Charles's starting technical moves, we come to the following conclusions: In the first step of the starting, Charles's center of gravity heightened, and Wu Dajing first lowered and then raised. In comparison, Wu Dajing's lowering of the height of the center of gravity is beneficial to the advancement of lower limb muscles and the storage of more elastic potential energy. From time T1 to moment T6, Wu Dajing's speed was higher than that of Charles, indicating that he had obtained better starting results. Wu Dajing's technical parameters and effects in the start of this competition are slightly better than those of Charles. This shows that he has a strong ability to learn and master new technologies. It is suggested that he should focus on the practice of starting reaction skills in the training process. The stability of the large starting technique movements should be strengthened at the same time.

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