Biomechanical analysis of the 626b technique in China's elite male platform divers

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Abstract: This study employed methods such as literature review, expert interviews, video analysis, and mathematical statistics to conduct a comparative biomechanical analysis and diagnosis of the 626B maneuver performed on the 10-meter platform by elite Chinese divers Qiu Bo, Yang Jian, Huo Liang, and Xie Siyang. The results indicate that during the buffer phase, smaller elbow and knee joint angles along with a larger shoulder joint angle contribute to generating greater angular momentum. At the moment of takeoff, a smaller reduction in the shoulder joint angle and a larger takeoff angle are more conducive to increasing the height of the jump. During the execution of the half to one-and-a-half somersaults, achieving a "counter-rotation" between the torso and lower limbs helps the body rapidly reduce the moment of inertia and increase the rotational speed.

Keywords: Platform Diving, Elite Athletes, 626B, Technical Analysis

1. Introduction

Diving, as one of the representative sports of China's competitive athletics, has earned countless accolades for the nation on the international stage. However, in recent years, with the rapid development of diving, the continuous improvement in the difficulty and stability of foreign athletes' performances has posed a significant threat to the Chinese team [1]. This is especially evident in the last two Olympic Games, where Chinese athletes failed to win gold in the men's 10m platform individual event consecutively. Faced with this challenge, the Chinese diving team must seek new breakthroughs to enhance the difficulty and stability of their routines. Among all platform diving movements, the characteristics of Chinese divers in terms of technical style and physical conditioning have generally resulted in lower difficulty and poorer stability in Group 6 actions (armstand dives), which has become a weakness for the Chinese team. The 626B (i.e., armstand back triple somersault pike), with a difficulty coefficient of 3.5, is a high-difficulty move. It aligns with the technical style of Chinese athletes, who excel in somersault-type movements characterized by a small moment of inertia, fast rotational speed, refined entry, and minimal splash [2]. This dive is utilized by several top male divers on the Chinese team. However, based on current training and competition observations, the quality of its execution is not optimistic. At this juncture, conducting a biomechanical analysis and diagnosis of the 626B technique among China's elite male platform divers becomes particularly crucial. The purpose of this study is to explore the biomechanical principles underlying the 626B technique on the 10m platform for elite male Chinese divers, providing a theoretical foundation for the scientific training of diving athletes.

Table 1 Athletes' Basic Information

	Age (years)	Weight (kg)	Height (cm)	Years of Training	Athletic Level
Qiu Bo	20	62	163	13	International Master of Sport
Yang Jian	19	63	167	12	Master of Sport
Huo Liang	24	62	162	15	International Master of Sport
Xie Siyang	18	62	164	10	Master of Sport

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Table 2 Summary of Joint Angles and Body Posture of Athletes at the End of the Buffer Phase

	Elbow Angle (°)	Shoulder Angle (°)	Knee Angle (°)	Buffer Angle (°)	Horizontal Velocity (m/s)	Vertical Velocity (m/s)	Buffer Angular Momentum (kg·m²/s)
Qiu Bo	139.8	167.3	45.1	43.8	-0.92	-0.68	61.3
Yang Jian	146.2	160.2	49.2	40.9	-1.02	-0.61	56.9
Huo Liang	142.2	154.7	46.3	36.7	-1.37	-0.36	57.1
Xie Siyang	152.4	165.4	53.7	51.4	-0.84	-0.50	54.2

Table 3 Summary of Joint Angles and Body Posture of Athletes at the Moment of Takeoff

	Shoulder Angle (°)	Hip Angle (°)	Center of Mass Height (m)	Center of Mass Distance (m)	Takeoff Angle (°)	Horizontal Velocity (m/s)	Vertical Velocity (m/s)
Qiu Bo	155.7	164.5	0.89	0.82	50.2	-1.32	-0.74
Yang Jian	146.6	162.7	0.82	0.74	50.8	-1.36	-0.68
Huo Liang	140.4	158.6	0.67	0.89	39.6	-2.28	-0.49
Xie Siyang	135.8	154.4	0.78	0.66	49.6	-1.40	-0.26

Table 4 Summary of Kinematic Indicators for Qiu Bo During the Aerial Tumbling Phase

	Hip Angle (°)	Time Required (s)	Resultant Velocity of Center of Mass (m/s)	Resultant Velocity of Trunk (m/s)	Height of Center of Mass (m)
Half Somersault	58.7	0.28	-1.72	-1.33	0.96
One Somersault	30.6	0.19	-2.46	-2.17	0.13
One and a Half Somersaults	28.4	0.16	-4.94	-4.76	-1.02
Two Somersaults	28.7	0.16	-6.48	-6.23	-4.36
Three Somersaults	209.3	0.56	-13.62	-13.41	-9.03

Table 5 Summary of Kinematic Indicators for Xie Si yang During the Aerial Tumbling Phase

	Hip Angle (°)	Time Required (s)	Resultant Velocity of Center of Mass (m/s)	Resultant Velocity of Trunk (m/s)	Height of Center of Mass (m)
Half Somersault	52.1	0.21	-2.64	-2.45	0.62
One Somersault	33.2	0.29	-3.71	-4.34	-0.29
One and a Half Somersaults	31.7	0.24	-5.72	-6.46	-1.12
Two Somersaults	30.8	0.20	-7.11	-7.21	-4.67
Three Somersaults	223.7	0.48	-13.84	-14.13	-9.63

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2. Research subjects and methods

2.1. Research subjects

This study conducted a comparative biomechanical analysis of the 626B maneuver performed on the 10-meter platform by elite Chinese male divers Qiu Bo, Yang Jian, Huo Liang, and Xie Siyang. The aim was to identify the critical points of the technique and propose suggestions for improvement. The basic information of the athletes is provided below (as shown in Table 1).

2.2. Research methods

2.2.1. Literature review

Diving-related literature was reviewed, and both Chinese and international literature databases were searched using keywords such as "platform diving", "technical analysis", and "626B" to establish the theoretical foundation for this study.

2.2.2. Expert interviews

The study involved participating in on-site technical feedback sessions with the national diving team and conducting interviews with renowned national team coaches. This was done to obtain insights into the specific technical characteristics of platform diving and the evaluation criteria for the quality of the 626B maneuver.

2.2.3. Video analysis

This study involved video data collection and analysis based on the athletes' performances during internal team test competitions and the 2014 FINA Diving World Series Beijing stop.

Two Japanese Star High-Titan high-speed cameras were used to film the entire pushing-off and takeoff process of the athletes' 626B dives, with a frame rate of 100 frames per second. The filming setup was as follows: two high-speed cameras were positioned and focused at fixed points. Camera 1 was placed at approximately 50° to the left front of the platform, with the camera body 1.2 meters above the platform height and 20 meters away. Camera 2 was placed at approximately 50° to the right front of the platform, with the camera body also 1.2 meters above the platform height and 20 meters away. Concurrently, a SONY HDR-AX2000 standard-speed video camera (50 frames per second) was used to synchronously track and film the complete 626B dives of the athletes from the lateral side of the platform. The SIMI Motion and Dartfish motion analysis systems were employed, utilizing the Hanavan human body model, to analyze the athletes' movements. Data smoothing was performed using the Digitize low-pass digital filter.

2.2.4. Mathematical statistics

The SPSS 18.0 statistical analysis software was used for relevant calculations and processing of the data obtained from the analysis.

3. Results and analysis

As a crucial aspect of diving research, accurate phase division not only facilitates the measurement and analysis of data but also clarifies the actual structure of the movements. It serves as the foundation and prerequisite for scientifically and objectively revealing the biomechanical principles of each action [3]. Based on the characteristics of the platform diving movement, this study defined the biomechanical research scope for the 626B maneuver as the period from the moment the athlete stabilizes in a handstand position until the entry into the water is complete. Using the trajectory of the athlete's center of mass as the key visual reference, the entire 626B action was accordingly divided into the buffer phase, the takeoff phase, and the tumbling phase.

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Figure 1

3.1. Kinematic characteristics analysis of the buffer phase

The buffer phase refers to the period from when the athlete stabilizes in a handstand to the moment when the flexion angles of the shoulder, elbow, and knee joints reach their minimum. As shown in Table 2, at the end of the buffer phase, Qiu Bo achieved the greatest buffer angular momentum at 61.3 kg m²/s, which is more conducive to completing the push-off and takeoff action compared to the other three athletes. Huo Liang followed with 57.1 kg m²/s, while Xie Si yang had the smallest buffer angular momentum, at only 54.2 kg m²/s. The reasons for these differences lie in the varying power and effectiveness of muscular work output by the four athletes at the end of the buffer phase, manifested in differences in shoulder, elbow, and knee joint angles, buffer angle, horizontal velocity, and vertical velocity. When executing this maneuver, Qiu Bo achieved the tightest body contraction, with elbow and knee joint angles of 139.8° and 45.1° respectively, the smallest among the four athletes. This indicates a large buffer amplitude and a long duration of force application, allowing the muscles of various body segments to be significantly pre-stretched. This facilitates an increase in the energy generated by the body's work during the takeoff action. Meanwhile, his shoulder joint angle was the largest at 167.3°, which ensured his body's center of mass did not lean forward excessively. This helped maintain an appropriate buffer angle, reducing horizontal velocity, and resulted in the highest vertical velocity among the four at -0.68 m/s.

The data in Table 2 show that Huo Liang's elbow and knee joint angles were relatively small, at 142.2° and 46.3° respectively, indicating a relatively large body buffer amplitude, which can generate greater energy during the power application. However, due to the small shoulder joint angle, his body leaned forward excessively, resulting in a buffer angle of only 36.7°. This led to the highest horizontal velocity among the four at -1.37 m/s, while the vertical velocity was the smallest. This affected the trajectory of his parabola after takeoff, reducing the takeoff height. Although the final buffer angular momentum was relatively large, it could not help improve the quality of his maneuver. On the contrary, the excessive horizontal momentum at entry resulted in a larger splash. In contrast, Xie Si yang's elbow and knee joint angles were the largest among the four, at 152.4° and 53.7° respectively, while his shoulder joint angle was also relatively large at 165.4°. This manifested as a loose action with insufficient body buffer force. Both his horizontal and vertical velocities were relatively small, resulting in a buffer angular momentum of only 54.2 kg·m²/s, the smallest among the four athletes.

3.2. Kinematic characteristics analysis of the takeoff phase

The takeoff phase refers to the period from the end of the buffer phase to the moment the athlete leaves the platform. As shown in Table 3, at the moment of takeoff, the shoulder joint angles of all four athletes decreased compared to the end of the buffer phase, and the center of mass shifted forward while its height decreased. The takeoff angle also changed, all of which influence the quality of the takeoff action. At the moment of takeoff, the shoulder angles of Qiu Bo and Yang Jian were 155.7° and 146.6°, respectively, showing a relatively small change compared to the end of the buffer phase. This resulted in a higher takeoff height for both, reaching 0.89m and 0.82m. Furthermore, at the end of the takeoff, both athletes exhibited a large degree of body extension, opening up fully, with hip joint angles of 164.5° and 162.7°. This indicates that they did not rush to flex the hips and tuck the legs to initiate the pike position immediately after pushing

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off, thereby increasing the time and space for the body to ascend. This is especially true for Qiu Bo, whose entire action was fluid and graceful, with an appropriate takeoff angle of 50.2°. This facilitated a certain reduction in horizontal velocity, promoting the effective conversion of the elastic potential energy stored during the buffer phase into vertical kinetic energy. This increased the flight height and prolonged the hang time. Yang Jian's technique is relatively similar to Qiu Bo's, but shows deficiencies in movement details, requiring more diligent practice.

Huo Liang's shoulder angle did not change significantly during the takeoff phase. However, due to the small shoulder angle in the buffer phase, his body leaned forward excessively, resulting in a lower body center of mass and a greater distance from the platform at takeoff. His takeoff angle was only 39.6°, which increased his horizontal velocity to the highest among the four at -2.28 m/s, while his upward vertical velocity was relatively small. This ultimately affected his flight height and hang time. Xie Siyang's execution of this phase was relatively poor. At the moment of takeoff, his shoulder joint flexion was substantial, and his hip joint angle was the smallest among the four at 154.4°. His vertical velocity was also the smallest among the four, at only -0.26 m/s. These indicators suggest that Xie Siyang's body did not extend fully, showing a noticeable "hip flexion" action. He rushed to exert force to initiate the tuck, failing to effectively utilize the kinetic energy stored during the buffer phase. Consequently, this resulted in insufficient space for the body to rise, reducing the takeoff height and creating an obstacle for the subsequent aerial tumbling maneuvers. (As shown in Table 3)

3.3. Kinematic characteristics of the aerial tumbling phase

The aerial tumbling maneuvers of the 626B completed by Qiu Bo and Xie Si yang possess distinct characteristics. This paper will focus on this to explain the key points to note during the execution of this dive. When completing the half somersault, Qiu Bo's hip angle was 58.7°, taking 0.28 seconds, with a resultant velocity of his body's center of mass at -1.72 m/s. In contrast, Xie Si yang's hip angle was 52.1°, taking 0.19 seconds to complete the half somersault, with a resultant velocity of his center of mass at -2.64 m/s. Comparing the two, Xie Si yang held an absolute advantage in this phase. When completing the one somersault, Qiu Bo's corresponding indicators were 30.6°, 0.19 seconds, and -2.46 m/s, while Xie Siyang's were 33.2°, 0.29 seconds, and -3.71 m/s. From this, it can be observed that although Qiu Bo was at a disadvantage in all indicators during the first half somersault, he surpassed Xie Si yang in the data after completing the one somersault.

The reason for this phenomenon is that during the execution of the first half somersault in the air, Qiu Bo, after pushing off, extended his body significantly backward and upward to maximize the elevation of his center of mass. This increased his moment of inertia, reducing his rotational speed. This is manifested as a larger hip angle during the half somersault, a smaller resultant velocity of the body's center of mass, and a longer duration, but with a greater center of mass height of 0.96m. Xie Siyang, immediately after pushing off, allowed his torso to lean backward and flexed his hips to tuck, reducing the space for his body to ascend. Although his tuck was tighter, resulting in a smaller moment of inertia and faster rotational speed, this advantage was only temporary, and his center of mass height was only 0.62m. As seen in Tables 4 and 5, a significant difference in the resultant velocity of their body's center of mass emerged between completing the half and the one somersault. Qiu Bo's resultant velocity of the body's center of mass decreased relatively slowly during this phase, while Xie Siyang's velocity decreased more rapidly. The reason lies in the faster decline of the resultant velocity of Xie Si yang's torso. After pushing off, he first leaned his torso backward and dropped his shoulders, actively accelerating his torso backward. In contrast, the resultant velocity of Qiu Bo's torso showed a slower declining trend, with a torso resultant velocity of only -2.17 m/s, lower than Xie Si yang's -4.34 m/s. This indicates that Qiu Bo's torso did not exhibit an active backward acceleration action during this phase. Although incidental backward rotation occurred under the action of the turning torque, as learned from (Tables 4 and 5), the absolute value of Qiu Bo's torso resultant velocity was less than the absolute value of his center of mass resultant velocity during the transition from half to one somersault. In contrast, the absolute value of Xie Si yang's torso resultant velocity was greater than that of his center of mass resultant velocity. This is because Qiu Bo, through conscious neuromuscular control, gradually reduced the rate and amplitude of his torso's backward rotation. With the coordinated action of the core and lower limb muscle groups, he moved his torso forward and upward, completing a "counter-rotation" with

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the lower limbs in the air, thereby lowering the torso resultant velocity (Figure 1). During this process, by adjusting limb position and movement direction, Qiu Bo altered his mass distribution, causing a change in his center of mass, which elevated. As the "counter-rotation" between the torso and lower limbs gradually completed, his body quickly tightened into the tuck, minimizing the moment of inertia about the somersault axis to the greatest extent, ultimately achieving the goal of controlling the body's rotational speed [6]. At this point, Xie Si yang had not fully completed the tucking action, resulting in a larger moment of inertia and slower rotational speed. Consequently, in transitioning from the half to the one somersault, Qiu Bo took 0.19 seconds, while Xie Si yang took 0.29 seconds. This gave Qiu Bo an advantage in the comparison with Xie Siyang, an advantage he maintained until the completion of the dive.

4. Conclusions and recommendations

4.1. Conclusions

During the buffer phase, smaller elbow and knee joint angles along with a larger shoulder joint angle in athletes can increase the descent height of the body's center of mass. This is beneficial for obtaining greater buffer angular momentum and increasing the kinetic energy for takeoff.

At the moment of takeoff, a smaller reduction in the athlete's shoulder joint angle and a larger takeoff angle are more conducive to reducing horizontal velocity. This promotes the effective conversion of the elastic potential energy stored during the buffer phase into vertical kinetic energy, thereby increasing the takeoff height.

During the flight phase, after completing the half somersault, athletes can achieve counter-rotation between the torso and lower limbs through conscious control of the torso's movement trajectory by the neuromuscular system. This is beneficial for rapidly reducing the body's moment of inertia and increasing the rotational speed.

4.2. Recommendations

Qiu Bo and Yang Jian have relatively similar technical movements, and their coordination difficulty is low. It is recommended that they be paired as partners for the men's synchronized 10m platform competition. When executing the tumbling maneuvers, after completing the first half somersault, athletes should consciously engage in self-regulation to achieve counter-rotation between the torso and lower limbs. This helps to prolong the hang time and increase the rotational speed. Appropriate training should be added to enhance the athletes' diving-specific "neuromuscular" system and self-control system. This will enable athletes to more accurately perceive their own motion state in space, laying the foundation for achieving "counter-rotation" of the human body in the air.

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