Biomechanical analysis of 626B technical movement in elite male Chinese platform divers

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Abstract: This study employed literature review, expert interviews, video analysis, and mathematical statistics to conduct a biomechanical comparative analysis and diagnosis of the 626B dive performed by elite Chinese divers Qiu Bo, Yang Jian, Huo Liang, and Xie Si yang on the 10m platform. The results indicated that smaller elbow and knee joint angles combined with larger shoulder joint angles during the buffering phase facilitate greater buffering angular momentum; at the instant of takeoff, smaller reductions in shoulder joint angle and larger takeoff angles are conducive to increasing takeoff height; and during the transition from half somersault to full somersault, the "opposing movement" between the trunk and lower limbs helps the athlete rapidly reduce moment of inertia and increase rotational speed.

Keywords: platform diving, elite athletes, 626B, technical analysis

1. Introduction

Diving, as one of the representative events of China's competitive sports, has won countless honors for the country on the international stage. However, in recent years, with the rapid development of diving, foreign athletes have continuously improved their performance in both difficulty and stability, posing a significant threat to the Chinese team [1]. Particularly in the past two Olympic Games, Chinese athletes have consecutively failed to win gold medals in the men's individual 10m platform event. Faced with these challenges, the Chinese diving team must seek new breakthroughs to enhance both difficulty and stability. Among all platform diving movements, due to the technical style and physical characteristics of Chinese athletes, Group 6 movements (armstand dives) generally exhibit lower difficulty and poor stability, becoming a weakness for the Chinese team. The 626B (armstand backward 2½ somersaults with 1½ twists in pike position), with a difficulty coefficient of 3.5, is classified as a high-difficulty movement. It aligns with the technical style of Chinese athletes who excel in somersaulting movements, featuring small moment of inertia, fast rotation speed, delicate water entry, and minimal splash [2]. This dive has been adopted by several first-tier male divers on the Chinese team. However, based on current training and competition performance, the quality of execution remains unsatisfactory. Therefore, conducting biomechanical analysis and diagnosis of the 626B technical movement for China's elite male platform divers is particularly important. The purpose of this study is to explore the biomechanical principles underlying the 10m platform 626B technique among China's elite male divers, providing theoretical foundations for scientific training.

2. Research objects and methods

2.1. Research objects

This paper conducted a biomechanical comparative analysis of the 626B dive on the 10m platform performed by elite male divers from the Chinese national diving team—Qiu Bo, Yang Jian, Huo Liang, and Xie Siyang—to identify key technical points and propose improvement suggestions. The basic information of the athletes is presented below (see Table 1).

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Table 1 Basic Information of Athletes

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

2.2. Research methods

2.2.1. Literature review method

Relevant diving literature was reviewed, and Chinese and foreign literature databases were searched using "platform diving," "technical analysis," and "626B" as keywords to establish the theoretical foundation for this study.

2.2.2. Expert interview method

The researcher participated in on-site technical feedback sessions with the national diving team and conducted interviews with renowned national team coaches to obtain specific technical characteristics of platform diving and evaluation criteria for 626B movement quality.

2.2.3. Video analysis method

This study collected video footage and performed data analysis based on athletes' performances in internal test competitions and the 2014 FINA Diving World Series Beijing leg.

A Japanese-made Seikoh Titanium high-speed camera was used to film the entire process of the athletes' 626B handstand push-off and takeoff at a shooting frequency of 100 frames/second. The filming method involved two fixed high-speed cameras positioned at fixed focal points: Camera 1 was located approximately 50° to the left front of the platform, 1.2m above the platform height, and 20m away; Camera 2 was positioned approximately 50° to the right front of the platform, 1.2m above the platform height, and 20m away. Simultaneously, one SONY HDR-AX2000 standard-speed camera (50 frames/second) was used to synchronously track and film the complete 626B movement from the direct 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, with data smoothing performed through Digitize low-pass digital filtering.

2.2.4. Mathematical statistics method

SPSS 18.0 statistical analysis software was used to perform relevant calculations and processing on the data obtained from video analysis.

3. Results and analysis

As a crucial component of diving research, accurate phase division not only facilitates measurement and data analysis but also clarifies the actual movement structure, serving as the foundation and prerequisite for scientifically and objectively revealing the biomechanical principles of each movement [3]. Based on the characteristics of platform diving movements, this study defined the biomechanical research scope of the 626B dive from the moment the athlete stabilizes the handstand to water entry, using the trajectory of the athlete's center of gravity as the effective characteristic reference. Accordingly, the entire 626B movement was divided into three phases: the buffering phase, the takeoff phase, and the somersaulting phase.

3.1. Kinematic characteristics analysis of the buffering phase

The buffering phase refers to the period from when the athlete stabilizes the handstand to when the shoulder, elbow, and knee joints reach their minimum flexion angles. As shown in Table 2, at the end of the

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buffering phase, Qiu Bo obtained the maximum buffering angular momentum of 61.3 kg·m²/s, which was more favorable for completing the handstand push-off and takeoff compared to the other three athletes. Huo Liang ranked second with 57.1 kg·m²/s, while Xie Siyang obtained the minimum buffering angular momentum of only 54.2 kg·m²/s. The reasons for these differences lie in the varying muscle power output and effectiveness among the four athletes at the end of the buffering phase, manifested in differences in shoulder, elbow, and knee joint angles, buffering angle, horizontal velocity, and vertical velocity. When performing this movement, Qiu Bo maintained the tightest body contraction, with elbow and knee joint angles of 139.8° and 45.1° respectively—the smallest angles among the four athletes. This large buffering amplitude and long duration of action allowed the muscles throughout the body to be pre-stretched to a greater extent, thereby increasing the energy generated by the body during the takeoff action. Meanwhile, his shoulder joint angle was the largest at 167.3°, which ensured that his center of gravity did not lean excessively forward, helping maintain an appropriate buffering angle, reducing horizontal velocity, and resulting in the highest vertical velocity among the four athletes at -0.68 m/s.

Table 2 data shows that Huo Liang had relatively small elbow and knee joint angles of 142.2° and 46.3°, indicating a large body buffering amplitude that would generate substantial energy during force exertion. However, due to his smaller shoulder joint angle, his body leaned excessively forward with a buffering angle of only 36.7°, resulting in the largest horizontal velocity among the four athletes at -1.37 m/s and the smallest vertical velocity. This affected the arc of his parabolic trajectory after takeoff and reduced his takeoff height. Although his final buffering angular momentum was relatively large, it failed to improve his movement quality; instead, the excessive horizontal momentum at water entry created larger splashes. Xie Siyang, on the other hand, had the largest elbow and knee joint angles among the four athletes at 152.4° and 53.7° respectively, with a relatively large shoulder joint angle of 165.4°. This manifested as loose movement execution with insufficient body buffering force, resulting in relatively small horizontal and vertical velocities and the minimum buffering angular momentum of 54.2 kg·m²/s among the four athletes.

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

	Elbow Angle (°)	Shoulder Angle (°)	Knee Angle (°)	Buffering Angle (°)	Horizontal Velocity (m/s)	Vertical Velocity (m/s)	Buffering 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

3.2. Kinematic characteristics analysis of the takeoff phase

The takeoff phase refers to the period from the end of the buffering phase to the instant of leaving the platform. As shown in Table 3, at the instant of takeoff, all four athletes showed reduced shoulder joint angles compared to the end of the buffering phase, with forward shift of the center of gravity, decreased height of the center of gravity, and changes in takeoff angle—all of which affect the quality of the takeoff action. At the instant of takeoff, Qiu Bo and Yang Jian had shoulder angles of 155.7° and 146.6° respectively, with relatively small changes compared to the end of the buffering phase. This resulted in higher platform departure heights for their centers of gravity, reaching 0.89m and 0.82m. Moreover, at the end of the takeoff phase, both athletes showed large body extension and full opening, with hip joint angles of 164.5° and 162.7°, indicating that they did not rush to flex their hips and draw in their legs to complete the tuck position after the handstand push-off, thereby increasing the time and space for body ascent. Qiu Bo in particular demonstrated an elegant and fluid movement with an appropriate takeoff angle of 50.2°, which helped reduce horizontal velocity to a certain extent and facilitated the effective conversion of elastic potential energy stored during the buffering phase into vertical kinetic energy, thereby increasing flight

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height and prolonging air time. Yang Jian's technical movement was relatively similar to Qiu Bo's, but lacked refinement in details and requires more practice.

During the takeoff phase, Huo Liang showed little change in shoulder angle; however, due to the small shoulder angle during the buffering phase, his body leaned excessively forward, resulting in a low center of gravity and distant departure from the platform. This produced a takeoff angle of only 39.6°, which increased his horizontal velocity to the maximum among the four athletes at -2.28 m/s, while his vertical upward velocity was relatively small, ultimately affecting his flight height and air time. Xie Siyang performed poorly during this phase. At the instant of takeoff, he showed large flexion of the shoulder joint and the smallest hip joint angle among the four athletes at 154.4°, with the minimum vertical velocity of only -0.26 m/s. These indicators demonstrate that Xie Siyang did not fully open his body, exhibited obvious "hip flexion" movement, rushed to exert force to complete the leg tuck, and failed to effectively utilize the kinetic energy stored during the buffering phase. Consequently, his body ascent space was insufficient, reducing takeoff height and creating obstacles for subsequent aerial somersaulting movements (see Table 3).

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

	Shoulder Angle (°)	Hip Angle (°)	Center of Gravity Height (m)	Center of Gravity 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

3.3. Kinematic characteristics of the aerial somersaulting phase

3.3.1. Comparative analysis of somersaulting performance between Qiu Bo and Xie Siyang

The aerial somersaulting movements of the 626B performed by Qiu Bo and Xie Siyang exhibit distinctive characteristics, which this paper will focus on to elaborate the key points requiring attention during execution of this movement.

When completing the half somersault, Qiu Bo had a hip angle of 58.7°, taking 0.28s with a resultant velocity of the body's center of gravity at -1.72 m/s; whereas Xie Siyang had a hip angle of 52.1°, completing the half somersault in 0.19s with a resultant velocity of the body's center of gravity at -2.64 m/s. In comparison, Xie Siyang held an absolute advantage during this phase. When completing the full somersault (one revolution), Qiu Bo's corresponding indicators were 30.6°, 0.19s, and -2.46 m/s, while Xie Siyang's were 33.2°, 0.29s, and -3.71 m/s. From this we can observe that although Qiu Bo was at a disadvantage in all indicators during the first half somersault, he actually surpassed Xie Siyang in data performance after completing the full somersault.

3.3.2. Mechanism of the "opposing movement" technique

The reason for this phenomenon lies in Qiu Bo's execution of the first half somersault in the air. After the handstand push-off and takeoff, in order to maximize the elevation of his center of gravity, he extended his body substantially backward and upward, increasing the moment of inertia and reducing rotation speed. This manifested as a larger hip angle during the half somersault completion, smaller resultant velocity of the body's center of gravity, and longer time taken, but with a higher center of gravity height at 0.96 m. In contrast, after completing the handstand push-off, Xie Siyang immediately leaned his trunk backward and flexed his hips to draw in his legs, reducing the body's ascent space. Although his tuck was tight with small moment of inertia and fast rotation speed, this was only a temporary advantage, with his center of gravity height merely at 0.62 m. As shown in Tables 4 and 5, significant differences appeared

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in the resultant velocity of the body's center of gravity between the two athletes during the transition from half somersault to full somersault. Qiu Bo's resultant velocity of the body's center of gravity decreased relatively slowly during this phase, while Xie Siyang's velocity decreased more rapidly. The underlying reason is that the resultant velocity of Xie Siyang' s trunk center of gravity decreased faster; immediately after the handstand push-off, he first leaned his trunk backward and dropped his shoulders, actively accelerating the trunk backward. Qiu Bo's trunk center of gravity velocity, however, showed a trend of slow decrease, with a trunk resultant velocity of only -2.17 m/s, smaller than Xie Siyang' s -4.34 m/s. This indicates that Qiu Bo did not exhibit active backward acceleration of the trunk during this phase; although passive backward rotation occurred under the influence of rotational torque, data from Tables 4 and 5 reveal that during the transition from half to full somersault, the absolute value of Qiu Bo's trunk resultant velocity was smaller than that of his center of gravity resultant velocity, whereas Xie Siyang's trunk resultant velocity absolute value was larger than his center of gravity resultant velocity absolute value. This is because Qiu Bo, through conscious neuromuscular control, gradually reduced the rate and amplitude of backward trunk rotation, and through the combined action of core muscle groups and lower limb muscle groups, moved his trunk forward and upward, completing an "opposing movement" with the lower limbs in the air, thereby reducing the trunk resultant velocity value (Figure 1). During this process, Qiu Bo changed mass distribution and shifted the body's center of gravity by adjusting limb positions and movement directions, elevating the center of gravity. The "opposing movement" between the trunk and lower limbs was gradually completed, the body was rapidly tightened, and the moment of inertia of the human body relative to its own axis was maximally reduced, ultimately achieving the goal of controlling the body's rotation speed [6]. Xie Siyang, at this point, had not fully completed the leg tuck action, resulting in larger moment of inertia and slower rotation speed. Therefore, in completing the transition from half somersault to full somersault, Qiu Bo took 0.19s while Xie Siyang took 0.29s, gaining an advantage over Xie Siyang and maintaining this advantage through to the completion of the movement.

Figure 1

Table 4 Kinematic Indicators of Qiu Bo During Aerial Somersaulting Phase

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

Table 5 Kinematic Indicators of Xie Siyang During Aerial Somersaulting Phase

		Hip Angle (°)	Time Required (s)	Resultant Velocity of Center of Gravity (m/s)	Resultant Velocity of Trunk (m/s)

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Half Somersault	52.1	0.21	-2.64	-2.45	0.62
Full Somersault	33.2	0.29	-3.71	-4.34	-0.29
1½ Somersaults	31.7	0.24	-5.72	-6.46	-1.12
Double Somersaults	30.8	0.20	-7.11	-7.21	-4.67
Triple Somersaults	223.7	0.48	-13.84	-14.13	-9.63

4. Suggestions

During the buffering phase, smaller elbow and knee joint angles combined with larger shoulder joint angles enable athletes to increase the descent height of the body's center of gravity, facilitating the acquisition of greater buffering angular momentum and increased takeoff kinetic energy.

At the instant of takeoff, smaller reductions in shoulder joint angle and larger takeoff angles are more conducive to reducing horizontal velocity, promoting effective conversion of elastic potential energy stored during the buffering phase into vertical kinetic energy, and increasing takeoff height.

During the flight phase, after completing the half somersault, athletes who consciously control the movement trajectory of the trunk through the neuromuscular system to achieve opposing movement between the trunk and lower limbs can rapidly reduce the moment of inertia and increase rotation speed.

Qiu Bo and Yang Jian exhibit similar technical movements with relatively small coordination difficulty; it is recommended that they form a partnership for men's synchronized 10m platform competition.

When executing somersaulting movements, athletes should consciously perform self-regulation after completing the first half somersault to achieve opposing movement between the trunk and lower limbs, thereby prolonging flight time and increasing rotation speed.

Training for diving-specific "neuromuscular" systems and self-control systems should be appropriately increased to enable athletes to more accurately perceive their movement states in space, laying the foundation for achieving "opposing movement" of the human body in the air.

5. Conclusion

This study systematically revealed the technical principles and key components of the high-difficulty armstand dive 626B through biomechanical analysis of four elite Chinese male platform divers: Qiu Bo, Yang Jian, Huo Liang, and Xie Siyang. The research findings indicate that reasonable joint angle configuration during the buffering phase, appropriate shoulder angle variation amplitude and takeoff angle during the takeoff phase, and the "opposing movement" technique between the trunk and lower limbs during the somersaulting phase are the core elements affecting the execution quality of the 626B dive. Qiu Bo demonstrated significant advantages in technical movement standardization and aerial posture control, providing a valuable technical reference for other athletes.

Facing the continuous improvement of international diving competitive standards, particularly the fierce competition in the men's 10m platform event, the Chinese diving team must further strengthen technical breakthroughs and stability training for armstand dives while maintaining traditional somersaulting technical advantages. The biomechanical parameters and training recommendations proposed in this study can provide theoretical support for coaches to formulate scientific and personalized training programs, assisting athletes in achieving breakthroughs in both difficulty and quality dimensions, consolidating the competitive position of Chinese diving as a "Dream Team," and continuing to write the glorious chapter of Chinese diving.

6. References

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