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Research Progress of Ski Jumping Training Theory and Preparation Strategy for the Milan Winter Olympics

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Abstract: Current research on ski jumping predominantly employs sports biomechanics to describe the kinematic and dynamic characteristics of athletes' takeoff and flight phases, yet lacks a systematic synthesis of training theory advancements and consideration of competition preparation strategies. This study employs literature review, expert interviews, and fieldwork to comprehensively analyze domestic and international ski jumping research and training requirements, so as to provide references for the Milan Winter Olympics from aspects such as competition rules, technical characteristics, and preparation strategies. The research results reveal that the takeoff-early flight phase is the decisive segment of the entire movement process, where technical proficiency directly impacts final performance. The key technical challenge during the takeoff phase is how to rapidly elevate the center of gravity to generate forward angular momentum while maintaining proper posture to counteract air resistance. Although a higher takeoff speed can reduce launch time, impair athletes' control over their movements. Therefore, an adaptive choice between higher speeds and better technical control should be made based on individual athletes' specialized control capabilities. During the flight phase, vertical velocity demonstrates a more significant influence on performance compared to horizontal velocity, while angular parameters show a greater impact than relative velocity parameters. CFD calculations indicate that surface pressure acting on athletes' bodies has a far greater aerodynamic effect than air resistance. The optimal ski board angle of 24-3° was determined through L/D ratio analysis. To meet the needs of the four core technical phases of ski jumping, it is necessary to introduce leveraging low-speed return wind tunnels for environmental simulation, wearable devices for posture testing, and multi-parameter physiological monitoring, and construct athletes' multi-parameter digital twin models. These measures can provide support for their preparation for the Milan Winter Olympics.

Keywords: Ski jumping; Sports biomechanics; In-run; Take-off; Early flight

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1. Preface

Ski jumping originated in Norway and spread to countries including Sweden, Switzerland, the United States, France, and Italy by the late 19th century. It was officially included as an event in the 1924 Chamonix Winter Olympics, making it one of the longest-standing snow sports in competitive history. This sport has three defining characteristics: (1) Short duration — the entire process from takeoff to landing takes just over ten seconds; (2) Extreme vertical drop — athletes descend over 100 meters vertically with approximately 100 meters of horizontal distance; (3) High-speed performance — maximum downhill speeds exceed 100 km/h; (4) Intense physical demands — athletes must maintain balance and execute precise transitions between in-run, takeoff, mid-air maneuvers, and landing postures; (5) Significant drag resistance — strong crosswinds in mountainous terrain create substantial pulling forces. These unique characteristics impose exceptionally high and specialized requirements on athletes' training regimens and competition preparations.

Given the high technical difficulty and competitive risk in ski jumping, this sport has required scientific validation and technological support for every advancement since its inception. This includes technical innovations—from "traditional in-run techniques" to "V-shaped in-run techniques", from "parallel double-board flight techniques" to "V-shaped flight techniques", and from "two-foot landing techniques" to the "Taylor-Mack landing technique"; as well as equipment upgrades like improved ski suit materials, evolved ski board designs, and refined waxing techniques. The ski jumping sport's development in China started relatively late, with the national team officially established in 2017. In the Beijing Winter Olympics, seven athletes qualified for the competition, marking the first-ever coexistence of male and female participants. Although all seven athletes ultimately failed to advance beyond the qualification round, this achievement represented a breakthrough for the five-year-old national team.

Chinese scholars have primarily focused their research on ski jumping's kinematics, dynamics, fluid mechanics, aerodynamics, and computer simulations, while few have focused on its training characteristics and competition preparation strategies. This study adopts a sports training perspective, systematically discussing three key issues: the evolution of competition rules, specialized technical features, and technology-assisted training strategies. It synthesizes the training principles of ski jumping, equips frontline coaches with essential training knowledge, and addresses competition demands. The findings provide theoretical support for enhancing the scientific rigor and safety of training and preparation plans for the Milan Winter Olympics. In the training process, lower limb explosive power, body coordination, core control ability, and so on are put forward with very high requirements. Additionally, it is expected to provide a reference for the majority of scholars to further understand the international high-level ski jumping training theory, training key, and training needs.

2. Specialized technical features

For a long time, Chinese scholars have focused on simulation studies such as CFD calculations in ski jumping research. In recent years, researchers like Hu Qi and Liu Yu have conducted studies on aerodynamic advancements in ski jumping, the impact of ski angle and body posture asymmetry on aerodynamic characteristics during the flight phase, and summarized the influence of ballistics, aerodynamics, and fluid mechanics on ski jumping techniques both domestically and internationally [1–3].

Ski jumping is a non-periodic sport comprising a series of coordinated movements. Based on technical characteristics, it can be divided into four phases: in-run, take-off, flight, and landing, each with distinct technical priorities [1, 4]. The in-run phase aims to maximize initial take-off velocity. The take-off phase focuses on generating maximum kinetic energy for aerial flight. During flight, the key is to optimize body control for maximum aerodynamic lift, enabling longer distances. The landing phase emphasizes a safe and stable touchdown in the Mark Taylor position, with the goal of achieving the highest technical landing score.

A review of literature spanning nearly three decades reveals that the previous ski jumping research mainly focused on different disciplines depending on the phase of the movement. Take-off is primarily studied through ballistics, while aerial flight involves aerodynamics research [1, 3, 5–6]. Most aerodynamic studies are conducted in wind tunnels, where researchers simulate the movement process by adjusting wind speed and direction, then use computer algorithms to optimize an athlete's posture. The propulsive force generated during the take-off push-off is the focus of dynamics research [7–8]. Throughout the entire movement, particularly in the early flight phase, studies concentrate on kinematics [1, 5, 9–14]. Notably, the take-off-to-early flight phase is the decisive stage of the entire movement, where the quality of techniques directly impacts the final outcome.

2.1. In-run

The flight techniques in ski jumping are categorized into traditional two-ski flight and V-shaped flight, with distinct corresponding in-run postures [15].

Comparing two takeoff techniques, the traditional in-run features a narrow trunk-to-runway angle of approximately 0–5°, nearly parallel to the runway, with knee angles (β) of 65–75° and ankle angles (γ) of 55–65° (**Figure 1**). This technique positions the hips higher, allowing the body's center of gravity to remain at the front of the takeoff stance. The larger knee angle reduces the extension range during the takeoff phase, thereby facilitating a quicker jump and increased speed. However, the shorter extension distance limits full muscle power release. Additionally, the narrow trunk angle requires rapid post-takeoff posture adjustment to meet flight demands, prolonging the transition from takeoff to stable flight. Finland's Matti Niikinäinen exemplifies this technique with his signature low takeoff stance and powerful jump, generating a force equivalent to 2.5 times his body weight.

The "V" shaped flight posture, exemplified by Swedish athlete Boklov, features a 20° trunk-to-runway angle, 55–65° knee flexion (β), and 45–55° ankle flexion (γ) (**Figure 1**) [16]. This technique optimizes the transition between takeoff and flight stability. Its forward-leaning takeoff direction, slightly elevated upper body posture, and reduced hip flexion with increased knee and ankle flexion enhance performance. The advantages are as follows: it maximizes knee extension to harness takeoff power, and its upper body alignment closely matches flight requirements without major adjustments.

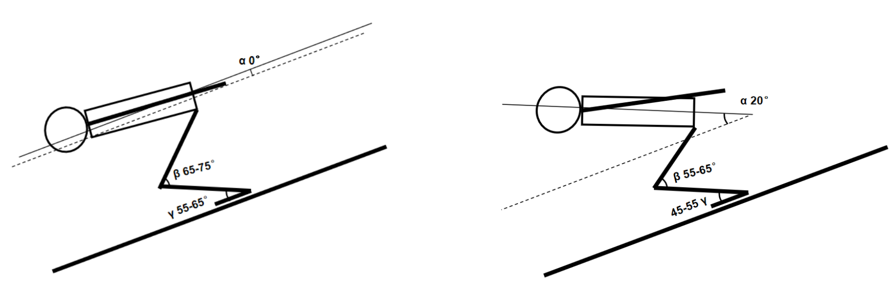


Figure 1. Comparison of in-run phases between the traditional two-board technique (left) and the V-shaped technique (right)

2.2. Take-off

In ski jumping, performance is primarily evaluated based on athletes' flight distance and technical execution. As the sport relies on a human open-loop control system, the irreversible nature of movements requires precise control at every phase. The take-off phase serves dual purposes: it builds momentum from the in-run and powers the flight phase. The quality of this phase directly determines the athlete's overall jump performance [4, 17]. Factors influencing take-off include the athlete's physical strength, coordination, and environmental elements like wind speed, direction, and equipment. Diagnosing the take-off technique from a biomechanical perspective facilitates its optimization.

The purpose of ski jumping takeoff is to elevate the center of gravity and generate forward angular momentum, maintain proper posture to counteract resistance, and sustain body balance during flight [4, 18]. As the run phase concludes, the track's curvature gradually diminishes, with gravitational potential energy from the run phase progressively converting into forward kinetic energy, increasing the centripetal force the athletes experienced [17]. In the initial takeoff phase, athletes extend their bodies using the centripetal force from the semi-squat run position, shifting their center of gravity forward. During this stage, the sacrum and femur simultaneously rotate toward the front, with the thigh's angular velocity exceeding that of the lower leg, resulting in increased knee joint angle. As lower limb extension completes, the lower leg's rotational angle increases [18]. Research indicates that the increased lower leg angular velocity compensates for body sway caused by rapid knee extension, making smaller lower limb movements advantageous for enhancing angular momentum [19–20]. This conclusion aligns with Virmavirta's findings that elite athletes employ coordinated techniques with minimized lower leg movements and trunk-femur coordination [18]. In the final phase of takeoff, the sacrum exhibits greater angular velocity than other lower limb joints, driving the thigh to generate forward angular velocity and propelling the body forward into the initial flight phase [18]. Zanevskyy's team demonstrated that ski jumpers' ankle, knee, and hip joint angles, body posture angles, and body attack angles are significantly correlated with takeoff distance [21]. Virmavirta et al. also found that hip and knee angular velocities are crucial for takeoff distance [19]. During takeoff, pressure in the big toe region increases markedly, reaching peak values among the three zones simultaneously. Electromyographic parameters indicate that high contribution rates from the vastus lateralis and gluteus maximus muscles (**Figures 2–3**) [7]. These studies highlight that kinematic parameters of lower limb joints (hip, knee, and ankle) provide critical diagnostic value for athletes' takeoff techniques. Moreover, efficient momentum transfer through the body's kinetic chain during takeoff enhances ski jumping performance.

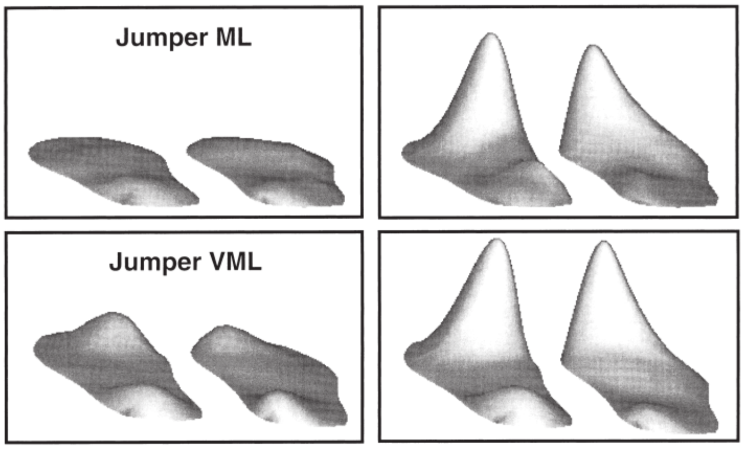
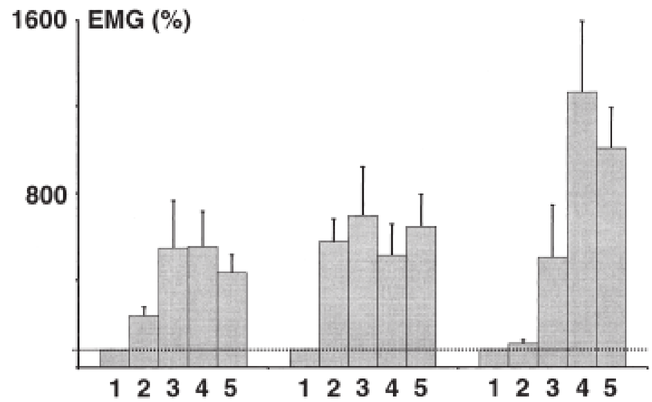


Figure 2. Pressure diagram of two athletes at the initial phase of in-run and the instant of take-off. This figure is adapted from the study by Mikko Virmavirta [7].



Lateral thigh muscle Gastrocnemius Gluteus maximus

Fgure 3. Average muscle work during the glide phase (periods 1 and 2) to take-off (periods 3 to 5). This figure is adapted from the study by Mikko Virmavirta [7].

Except for athletes' technical execution, aerodynamic factors during flight significantly impact ski jumping performance [21]. With the evolution of techniques, the traditional parallel ski technique has been replaced by the "V" technique, as it generates greater air assistance during flight [22]. Achieving an optimal lift-to-drag ratio during takeoff is crucial for success, with individualized ski angle and joint positioning determined by each athlete's physique [23]. After leaving the run, athletes experience three primary forces: gravity, lift, and drag. Effective aerodynamic control hinges on lift direction management. Mountain wind conditions dramatically shorten takeoff time compared to the factors of indoor environments [8]. Virmavirta notes that higher takeoff speeds impair movement control, making it harder to balance body position with wind speed during actual competitions [7]. Crosswinds and asymmetric force application during takeoff increase initial velocity deflection angles relative to ski direction, creating lateral yaw forces that hinder optimal speed utilization and body posture scoring [2]. Research reveals that surface pressure affects aerodynamics more than air resistance, while taller athletes do not necessarily face greater drag [1]. During movement, the separation of airflow behind the head and hands tends to create low-velocity zones, which hinder lift generation [24]. Research on elite athletes reveals that while a larger trunk angle during takeoff increases air resistance, the short duration of this phase may not necessarily compromise flight distance [4]. This suggests that the takeoff stage's critical success factors lie in optimizing lift acquisition and elevating the center of gravity, with an appropriate trunk angle being pivotal for lift generation. These findings provide theoretical guidance for ski jumping athletes' training.

During the takeoff phase, athletes experience combined forces from air lift (L), air resistance (D), gravity, and friction. The air lift and drag forces are directly related to the takeoff posture. International wind tunnel studies on ski jumping predominantly use scaled human models. Cutter's aerodynamic research on the "V" shaped flight pattern involved scaling the human body at a 1:5.5 ratio and conducting wind tunnel tests, and found that an optimal lift-to-drag ratio of 22.5° V angle, 20° angle of attack, and L/D=1.55 [25]. Guan Ruhua et al. applied multi-rigid-body system dynamics and mathematical programming methods to analyze decisive factors in the takeoff stage. By combining the principle of momentum moments, ski jumping technical requirements, and human physiological conditions, they identified relative angles of body segments (captured through high-speed video) as key variables. This led to the derivation of nonlinear equations (NP(j)) for calculating the center of mass's horizontal/vertical velocity and takeoff angle at the moment of impact. Using Li Baoquan, a two-time National Winter Games champion in ski jumping, as a case study, they concluded that Li's adoption of the "II" takeoff technique performed better [26].

2.3. Flight phase

Research on the kinematics of ski jumping during the early flight phase can be categorized into two in-runs. The first one treats the human body as a mass center, analyzing its altitude, horizontal velocity, and vertical velocity along the trajectory. While conventional theory suggests that a higher flight posture contributes more to distance, Mikko Virmavirta's team found that top competitors maintained significantly lower postures than others. This discrepancy may be directly linked to the competition venue's high altitude (> 2000 m), low air density, and reduced buoyancy [11]. The study conclusion indicates that in low-density air environments, maintaining optimal speed during flight is crucial for performance. Arndt's research on the 1994 Winter Olympics K90 individual event athletes found that, through early flight phase analysis, trajectory parameters (altitude and velocity) did not significantly influence total flight distance [12]. Du Yunyun's study demonstrated that increased horizontal and vertical initial velocities both extended flight time and distance. Vertical velocity had a more pronounced effect on flight duration, while horizontal velocity showed greater impact on distance. The findings highlight that higher horizontal initial velocity has a more substantial influence on ski jumping performance [27]. Fuli scholars applied multibody system dynamics to model ski jumpers as a tree-structured multibody system with finite hinges. Using tensor-matrix relationships, they developed a four-body mechanical model, derived the system's center-of-mass dynamics equations and attitude equations, and ultimately created the Program for Human Body Dynamics in Flight (PHBD) for computational analysis [28].

Another category focuses on studying human body posture during sports, conducting independent research on angular parameters, velocity parameters, and distance parameter changes of body segments in the air. Compared to angular and velocity parameters, research on distance parameters remains scarce, with only a few metrics mentioned. Arndt's study specifically noted the distance between snowboards, demonstrating a correlation coefficient of $R^2 = 0.84$ when analyzing five customized flight angles at 17 meters post-launch. Among these angle parameters, trunk posture showed the highest individual value with an $R^2 = 0.77$. Examining both angular and center-of-mass velocity parameters in this study reveals that a more compact body position (i.e., "V" -shaped flight posture) within the first 5 meters post-launch provides favorable conditions for initial flight speed. For the subsequent flight phase, an extended body posture offers greater aerodynamic lift [12]. Mikko Virmavirta et al. investigated the correlation between horizontal and vertical velocities during the first 1.6 seconds of flight and performance outcomes [11]. Their findings indicate that horizontal velocity showed no significant correlation with performance at the instant of takeoff, while vertical velocity demonstrated a more pronounced correlation. This discrepancy may relate to athletes' rapid descent during the takeoff phase, contradicting Du Yunyun et al.'s findings [27]. This inconsistency could be directly associated with adaptive body posture adjustments during actual takeoff on ski jumping platforms. Through these studies, we can infer that vertical velocity exhibits a more significant correlation with performance compared to horizontal velocity. Some scholars argue that angular parameters contribute more significantly to performance than relative velocity parameters [6, 11–14]. This indicates that athletes' body posture control and technical execution during movement are decisive factors for performance outcomes. The skislope angle affects the aerodynamic characteristics of the skier-board system, with a 24–32° range being identified as the optimal angle through CFD simulations and L/D ratio analysis [3].

The angle parameters can be divided into two categories:

(1) Internal Relationships of the Human-Board System. Common angle parameters include:

(a) Body posture angle: The angle between the line connecting the ankle and the cervical vertebrae and the ski board—considered the most significant indicator related to jump distance, especially during the first 0.1 seconds and the latter half of the early flight phase 0.6–1.6S. Therefore, it is believed that the ski board should be lifted immediately after takeoff, and during the later part of the early flight phase, the ski board should be as close to the body as possible;

(b) Trunk angle: The angle between the line connecting the hip joint and the cervical vertebrae and the ski board;

(c) Body lean angle: The angle between the line extending the tibia and the ski board, which in some studies is indicated by the angle between the line connecting the cervical vertebrae and the ankle and the ski board;

(d) Leg abduction angle: The angle between the two legs;

(e) Ski board angle: The angle between the lines extending the two ski boards, also known as the "V" angle. See **Figure 4** for details.

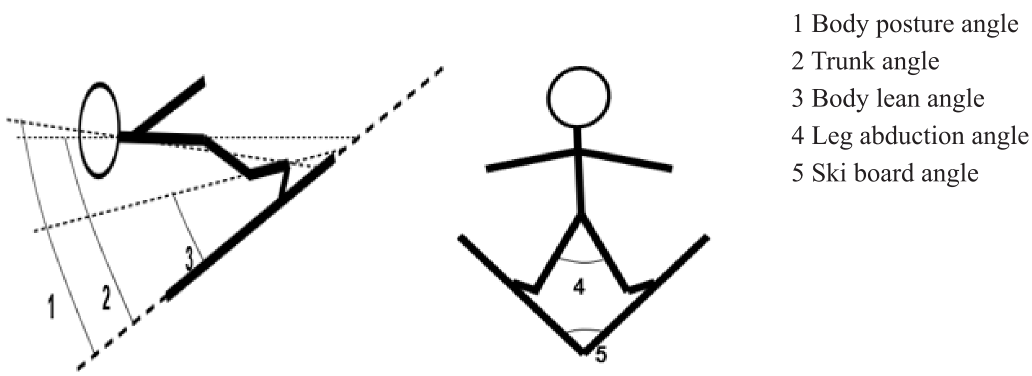


Figure 4. Internal relationship angle of the human-board system

(2) Body Segments and External Relations. Key angle parameters include:

(a) Snowboard attack angle: defined as the angle between the snowboard and the instantaneous velocity direction;

(b) Lower limb attack angle: defined as the angle between the tibial extension line and the instantaneous velocity direction;

(c) Flight angle: the angle between the instantaneous velocity direction and the horizontal plane;

(d) Snowboard position angle: the angle between the snowboard and the horizontal plane;

(e) Lower limb angle: the angle between the ankle-cervical spine line and the horizontal plane;

(f) Trunk angle: the angle between the hip-cervical spine line and the horizontal plane. See **Figure 5** for details.

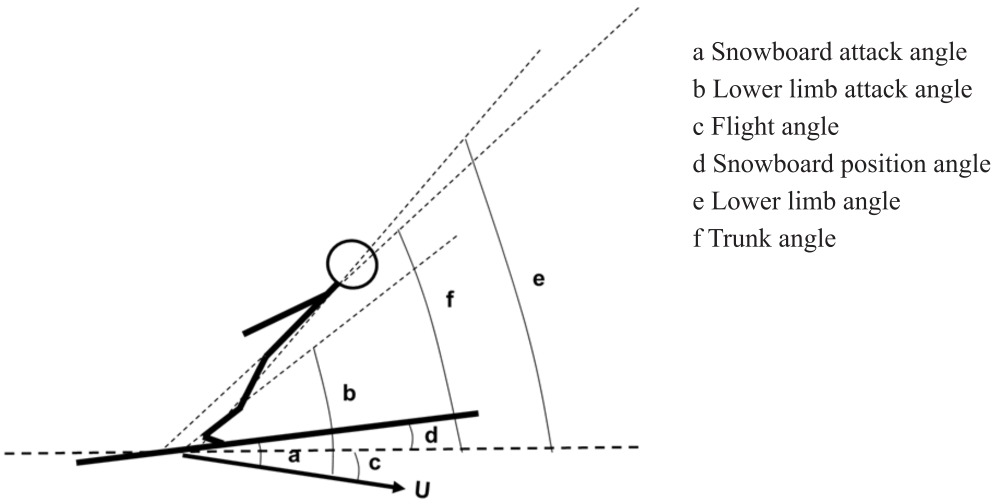


Figure 5. Body segments and external relationship angles

3. Strategies for technology-assisted training

3.1. Conducting simulation training

Due to the limitations of the actual ski jumping environment, training on real ski jumps is inefficient. Indoor training using simulated ski jumps can enhance effectiveness. Current indoor ski jumping training primarily involves take-off practice with roller skis and wind tunnel simulations to improve subjective perception [24, 29]. The key to ensuring training quality depends on simulating both the actual ski jump environment and movement patterns, which requires exploring similarities and differences between indoor training and real ski jumps to optimize training methods. The primary distinction between indoor training and real ski jumps lies in fluid dynamics. Without the speed generated during the in-run phase, athletes 'simulated take-off initial velocity cannot match the required aerodynamic speed, resulting in lower lift utilization during indoor take-offs [30]. The lower take-off speed also makes decision-making during indoor training less challenging compared to real ski jumps. With technological advancements, wind tunnel training can effectively simulate real ski jump conditions, but the difference in speed perception still needs to be reflected in actual ski jump training. Studies show that real ski jumps have earlier take-off times than simulation ones, indicating that speed perception differences may affect athletes' decision-making capabilities [31]. Besides the fluid dynamics, there are also differences in equipment between indoor and real ski jumps. The most significant distinction lies in the ankle joint restrictions between indoor training shoes and ski boots. The greater stiffness of ski boot uppers limits plantar flexion during take-off, hindering the extension needed for push-off and causing forefoot pressure to shift forward, thereby restricting vertical force generation [23]. While indoor training differs from actual ski jumping, the controlled environment of indoor facilities effectively enhances athletes' technical execution [30, 32]. Extensive research confirms that increased muscle strength and loading rates in hip and knee extension muscles significantly improve athletic performance [23, 32]. It was proven that performing 80%1RM bodyweight squat jumps after 60%–80%1RM muscle activation optimally recruits motor units for maximum training effectiveness [33]. Studies on elite athletes' takeoff techniques reveal that top ski jumpers achieve more coordinated takeoff states compared to average athletes, with these differences being particularly evident in indoor training [31]. Additionally, rehabilitation methods targeting weak links in the takeoff kinetic chain demonstrate significant improvement [34]. These findings collectively reflect the diversification of ski jumping training methodologies.

3.2. Weight control

Zhang Guizhen and others found that through studying the competition results and influencing factors of ski jumpers, excellent ski jumpers generally have lighter body weights. Apart from developing the necessary lower limb (mainly around the knee joints) muscle strength, they almost do not increase the weight of upper limb and trunk muscles. They believe that the ratio of height (cm) to weight (kg) can be used as a standard. The range of the ratio of height (cm) to weight (kg) for athletes is 2.95 ± 0.5, with 2.90 being the minimum excellent standard, 2.95 being the higher excellent standard, and 3.0 being the optimal standard, which aligns with the conclusions of Liu Shuming and others [4, 35]. Park Xuefeng and others proposed the view that the lighter the body weight, the better, without reducing specialized strength [36]. B. Scholer, Adrien Sedeaud, Wolfram Muller, et al., all studies show that as athletes' body weight decreases, their ski jumping performance in distance significantly improves [37–40]. This is also one of the important reasons why ski jumpers have chosen lower body weights over the past decade, with some athletes even having a BMI of 16.6 kg/m^2.

To prevent athletes from excessively losing weight to gain longer jump distances, the International Ski Federation (FIS) established a Body Mass Index (BMI) requirement in 2004, which mandates a BMI of at least 20 and limits the maximum ski length to 146% of the athlete's height [19]. These regulations reduced the impact of body weight and equipment on jump performance, indirectly emphasizing the importance of technical execution during takeoff. Mikko Virmavirta noted that an athlete's weight had a more significant effect on jump results than ski length [41]. A comparative analysis by Luca Oggiano et al. of 1970–2006 data revealed that ski jumpers 'average BMI dropped from over 23 to below 20, indicating that the trend toward weight management to enhance performance persisted even after the FIS's new rules were implemented [42].

3.3. Strengthening fatigue recovery

The improvement of athletes' training level follows a cyclical process of "fatigue-recovery-fatigue-recovery." Moderate exercise-induced fatigue, when managed with proper recovery methods, can enhance movement performance. However, excessive fatigue not only hinders athletic achievement but may also lead to sports injuries and even harm athletes' physical and mental health [43]. Monitoring methods for exercise-induced fatigue include subjective evaluation indicators, physiological indicators, and biochemical indicators [43–44]. Ski jumping requires athletes to maintain high levels of concentration, with fatigue in this sport predominantly being central fatigue [45]. In physiological monitoring, flash fusion frequency (FFF) testing and electroencephalogram (EEG) can directly reflect central nervous system fatigue, providing insights into cerebral cortex activity during performance [43–44, 46–50]. Despite its late development and limited scale in China, ski jumping has seen scant research in biological fatigue monitoring and medical supervision. This lack of scientific support not only complicates technological advancement but also leaves coaches without a scientific basis for training planning, significantly increasing the risk of sports injuries.

3.4. Enhancing technology-enabled support measures

In response to the specialized technical requirements of ski jumping across its four core phases, in-run, takeoff, in-flight, and landing, a low-speed return wind tunnel is adopted to simulate air density under different altitudes and temperatures, as well as complex wind field conditions such as track crosswinds and updrafts. With the assistance of wearable devices, athletes can test the lift-drag ratio of various in-flight postures, increasing the lift-drag ratio of the optimal posture by 10%–15% and extending the airborne time by 0.3–0.5 seconds.

Wearable devices can collect data like Heart Rate Variability (HRV), Electromyography (EMG), and blood oxygen saturation. These data can be used to real-time assess athletes' central fatigue levels and muscle activation efficiency. If the HRV indicator drops by more than 15%, the training intensity is adjusted immediately. By establishing a specialized ski jumping data platform that integrates technical movement data, physiological monitoring data, and competition environment data (including track gradient, wind speed, and temperature), an athlete's digital twin model is constructed.

4. Discussion

The natural environment of ski jumping venues presents numerous uncontrollable factors. Due to venue limitations, current biomechanical research primarily focuses on the take-off and early flight phases, which are considered the most critical for performance. Most studies in this phase analyze take-off posture, while dynamic analysis of the flight phase remains limited, typically relying on foot pressure insoles or wind tunnel simulations. To establish the relationship between movement posture, pedaling force, and jump distance in real-world scenarios, this factor must be considered during the initial design of ski jumping venues.

During the take-off phase, the angles of the hip, knee, and ankle joints, body posture angle, and body attack angle all significantly impact the flight distance. Compared to the contribution of speed parameters to athletic performance, variations in angle parameters have a greater impact on final results. In the early flight phase of ski jumping, angle parameter selection is categorized into two main types: the internal relationship angle between the athlete and ski, and the external relationship angle between body segments and the environment. These two categories describe the proximity between the athlete and ski during flight, as well as the relative positions of the athlete/ski to the horizontal plane and velocity direction. Notably, the body posture angle and ski attack angle exhibit stronger correlations with flight distance.

Due to venue limitations and neural fatigue, ski jumping training sessions are often restricted in actual practice. Digital, intelligent, and integrated wind tunnel laboratories provide simulated environments for athletic training. Computational fluid dynamics (CFD) technology enables optimized postures that offer athletes the best reference for performance enhancement. Although the International Ski Federation (FIS) has established clear guidelines on body mass index (BMI) and the ratio of skis to body height, lower body weight can still contribute to technical performance in ski jumping. Therefore, weight management remains a crucial training aspect for athletes. However, research in China regarding fatigue relief methods, in-runs, and their effectiveness evaluation for ski jumpers remains limited, making this area a pressing research priority.

Compared with foreign research, the quantity, depth, and breadth of research on ski jumping in China are far from enough. It is expected that with the development of wearable devices, the research level of ski jumping venue testing and competitive performance will continuously enhance.

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Disclosure statement

The authors declare no conflict of interest.

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