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Apply an Inclined Track to Enhance the Performance of Fosbury Flop High Jump Athletes

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Abstract

Background and Aim: The high jump was a dominant sport in China, with three athletes breaking the world record five times. However, in the following period, the high jump performance of Chinese athletes showed a declining trend, and the gap with the world's best high jump athletes was obvious. Many studies have shown that speed ability is the main influence factor of the high jump, to change the current situation of the Chinese Fosbury flop high jump sport, this study designed an inclined track to improve the speed ability of athletes, to achieve the purpose of improving performance. This paper aims to apply the inclined track to improve Fosbury flop high jumpers' speed ability.

Materials and Methods: 10 experts were selected for this study and interviewed to determine the test metrics. An inclined track was designed and made, and 5 experts conducted IOC tests on the inclined track. In addition, 5 Fosbury flop high jumpers from Xi'an Physical Education University were selected for the study to experiment. t-test independent was performed on the technical index data using a computer software package.

Results: The research results show that: (1) Inclined track had a high validity (IOC=.97) and safety for training. And (2) Comparison within 5 high jumpers found that all of the variables (Velocity of center of gravity, Step lengths for the last 2 steps, Step lengths for the last 1 step) were significant (*P<.05).

Conclusion: The research suggests that the inclined track is a valid and safe training method. Additionally, the study found significant differences in key variables among high jumpers, emphasizing the importance of these factors in high jump performance.

Keywords: Fosbury Flop High Jump; Outstanding Athletes; Assisted Running Technique; Technical Analysis

Introduction

As a "war" without gunfire in peacetime, competitive sports are attracting increasing attention worldwide. The high jump, one of the most complex events in athletics, plays a crucial role in exploring and mastering the technical difficulties and training aspects of high jumping. Its importance is not only evident in the field of athletics but also extends to other sports. The performance of a country's track and field team often reflects the overall level of sports development in that country.

The high jump holds a significant position in Chinese sports history. In the past, three athletes, including Zheng Fengrong, Ni Zhiqin, and Zhu Jianhua, broke world records multiple times. Additionally, many high jump athletes have achieved world-class standards (Li, et al, 2022; Zhao, 2014; Wang, 2022). However, Chinese athletes' high jump performance has declined, showing a considerable gap compared to international top high jumpers. Therefore, there is an urgent need for the government to implement athlete development policies.

High jump is an athletic competition where athletes leap over a horizontal bar on one foot,

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involving four phases: the approach, takeoff, clearing the bar, and landing. The technique in the approach phase is a prerequisite for the success of the entire backflip high jump. Athletes achieve a fast speed before takeoff to provide the necessary speed for the jumping phase through the approach run (Zhu & Zhu, 2023). Problems in the approach phase can affect other technical parts. The approach involves a straight run followed by a curved run, with the curve typically consisting of 4-5 steps where the body is relaxed and legs swing naturally forward (Huai, 2019). The curved run usually includes 4 steps, where the body naturally leans inward, the pace gradually accelerates, and the center of gravity lowers, preparing for the takeoff phase (Shao, 2017).

According to the research of Gang (2023), the significant advantage of the Fosbury flop high jump lies in using an arc-like motion similar to a normal sprint before takeoff. This curved motion helps the body incline inward to lower the center of gravity. Utilizing centrifugal force, the body swiftly transitions from an inward incline to a vertical position, enhancing the center of gravity and increasing vertical speed, creating favorable conditions for rapid and powerful takeoff. In their extensive literature review. The increasing running speed positively affects subsequent stages of the Fosbury flop high jump. Improving running speed is a breakthrough for further enhancing performance, provided athletes have good jumping ability and strength. When coaches design speed training programs, they must tap into the potential of sprinting.

Cheng et al (2019) found that appropriate steps in the last 2 steps of running contribute to the coherence between running and the aerial movement, reducing braking force during landing and relieving the forced burden on the takeoff leg. This helps the takeoff leg achieve a greater push-off speed, creating favorable conditions for takeoff. Practicing correct takeoff techniques assists athletes in jumping higher. Cultivating excellent high-jumping skills is a process that requires effort and time. However, with determination and perseverance, athletes can achieve their goals.

Adashevskiy, et al (2013) found that speed and center of gravity height are the main factors affecting high jump performance. Takeoff speed influences height because height is primarily determined by horizontal speed transformed into vertical speed through the takeoff motion and further converted into upward force affecting height. The speed at which athletes approach the center of gravity height affects takeoff speed. Approaching the center of gravity height more quickly and effectively helps athletes maintain takeoff speed and power, making high jumping and precision possible (Murphy, et al, 2017; Suchomel, et al, 2013). Therefore, practicing a fast approach, maintaining stable and continuous speed toward the takeoff point, and regular, consistent practice is essential.

Cheng & Yuan (2021) believe that the approach provides the initial speed before takeoff. Adjusting the rhythm of the action and the body's inclined posture promptly can create favorable conditions for takeoff and have a positive impact. Looking at the development trend of the Fosbury flop high jump on the international stage, "speed jumping" is the most popular topic, and coaches and experts universally recognize the impact of "speed" on the competitive level of the Fosbury flop high jump (Li, et al, 2013).

In summary, takeoff speed is the key factor influencing the final high jump performance. To improve Fosbury flop high jump performance, enhancing speed-related abilities will be the top priority for athletes and coaches in the future. Although repetitive training in all stages of the high jump is crucial for accuracy, currently, there are few tools or equipment available for guiding technical training. Therefore, researchers are interested in conducting a study to create an inclined trajectory. As a training tool that controls takeoff speed, it aims to develop athletes' bouncing ability, thereby enhancing high jump performance.

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Objectives

To apply the inclined track to improve Fosbury flop high jumpers' speed ability.

Literature Review

The concept of "jumpers' speed ability" is a crucial factor in the domain of sports and athletic performance, especially in disciplines like high jump, long jump, and pole vaulting. Speed ability refers to an athlete's capacity to generate and sustain high velocity or acceleration during the approach and takeoff phases of a jump, which is essential for maximizing the vertical or horizontal distance cleared.

In a study by Shih et al. (2018), which investigated the relationship between speed ability and long jump performance in collegiate athletes, it was found that the velocity achieved during the takeoff phase significantly correlated with jump distance. This highlights the importance of jumpers' speed ability in achieving optimal results in the long jump. Similarly, speed ability is equally relevant in the high jump, where the sprinting approach leading to the takeoff is a critical phase, directly impacting the athlete's ability to clear the bar successfully.

Furthermore, jumpers' speed ability is closely linked to their technical proficiency and efficiency during the takeoff phase. In the pole vault, for instance, the vaulter's speed on the approach significantly affects their ability to maintain a rigid pole position and generate the required lift. Research by Zanetti et al. (2016) investigated the influence of speed and plant time on pole vault performance, concluding that faster speeds during the approach were associated with better results. This emphasizes the crucial role of speed ability in this specific field event.

Overall, the concept of jumpers' speed ability is a multifaceted and fundamental aspect of athletic performance, playing a pivotal role in various jumping events. It directly impacts an athlete's capacity to generate the necessary force and velocity during the takeoff phase, ultimately influencing the outcome of the jump. Researchers continue to explore and analyze this essential factor to better understand its implications and improve training methodologies in the realm of track and field sports.

Conceptual Framework

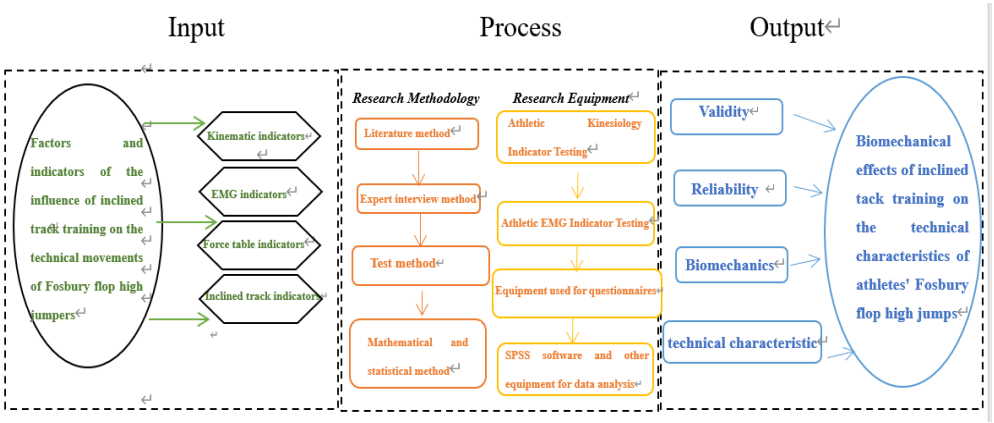

Figure 1 Conceptual Framework

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Methodology

Population and Sample

1. 10 experts（ sports scientist ） interviewed

2. 5 experts who inspect research equipment, consisting of trainers. Sports scientists and engineers (kinesiology)

3. Selected 5 male Fosbury Flop high jump athletes from Xi'an Physical Education University for the test (all with training experience exceeding 5 years).

Data collection

1. Search literature and information related to the inclined track for relevant data.

2. 10 experts were consulted through face-to-face, telephone, and e-mail interviews to determine that the parameters for designing the inclined track were reasonable and feasible and to confirm the relevant biomechanical indicators.

3. IOC testing for validity and safety of inclined track training by 5 experts.

4. 5 Fosbury Flop high jump athletes from Xi'an Physical Education University were selected for the test.

Results

Validity of inclined track

Table 1 The content validity of the inclined track was content relevance using IOC

Questionnaire questions	Experts' opinion					Total
	Exp1	Exp2	Exp3	Exp4	Exp5	
Objective						
1. Inclined track training can improve running speed	1	1	1	1	1	1
2. Inclined track training can improve the speed of arm swings	1	1	1	1	1	1
3. Inclined track training can improve the 2 step of leg length	1	1	1	1	1	1
Construction						
4. The inclined track was constructed with material that makes it strong and stable.	1	1	1	1	1	1
5. Has a suitable height, width, and length, that allows athletes to control running and jumping well.	1	0	1	1	1	0.8
6. The material for making the track floor was suitable and the quality was comparable to the floor of a standard track.	1	1	1	1	1	1
7. The device was safe and can be used to train athletes.	1	1	1	1	1	1
IOC						**0.97**

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The opinions of experts on Inclined track Validity (IOC) were 0.97.

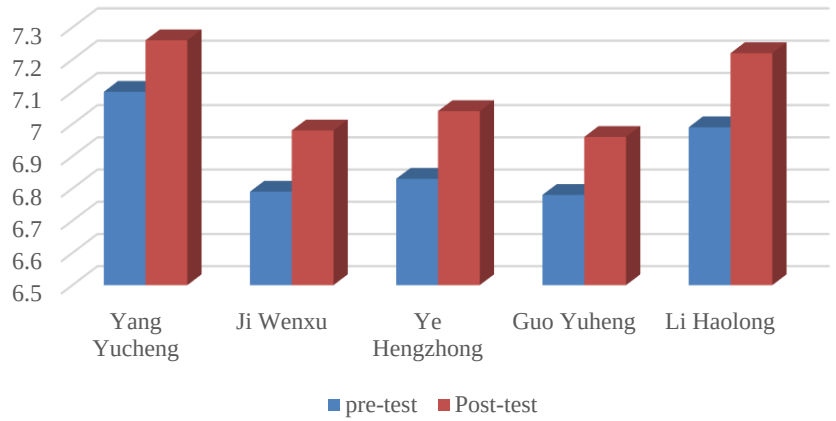
The average speed of the last two steps pre-test and post-test

The speed of the approach in the high jump, analogous to the wheels of a car or the gunpowder in a cannonball, forms the essence and foundation of this sport. As the saying goes, "he who gains speed conquers all." A rapid and powerful approach is the key to generating sufficient momentum and initial lift-off speed. It is no exaggeration to say that the speed of the approach fundamentally determines, from a foundational perspective, whether an athlete can complete various stages and intricate details throughout the entire high jump process. It dictates the athlete's ability to execute high-quality performances at different heights, making speed a pivotal and decisive factor in the overall technique.

Table 2 Average speed of the last two steps of pre-test and post-test (m/s)

No.	Name	Pre-test	Post-test
1	Yang Yucheng	7.10	7.26
2	Ji Wenxu	6.79	6.98
3	Ye Hengzhong	6.83	7.04
4	Guo Yuheng	6.78	6.96
5	Li Haolong	6.99	7.22
	M±SD	6.90±0.13	7.07±0.15

Fig. 1 Average speed of assisted running before and after the test (m/s)



According to the results shown in Table 1, The average assisted running speeds for the pre-test and post-test of the 5 athletes were Yang Yucheng: 7.10m/s and 7.26m/s; Ji Wenxu: 6.79m/s and 6.98m/s; Ye Hengzhong:6.83m/s and 7.04m/s; Guo Yuheng: 6.78m/s and 6.96m/s; Li Haolong:6.99m/s and 7.22m/s. The M±SD were 6.90±0.13 and 7.07±0.15.

After the inclined track training, the approach speed of the five athletes significantly increased. This indicates that practicing the approach on an inclined track can effectively enhance the approach speed, leading to an increase in training intensity and ultimately improving the final performance.

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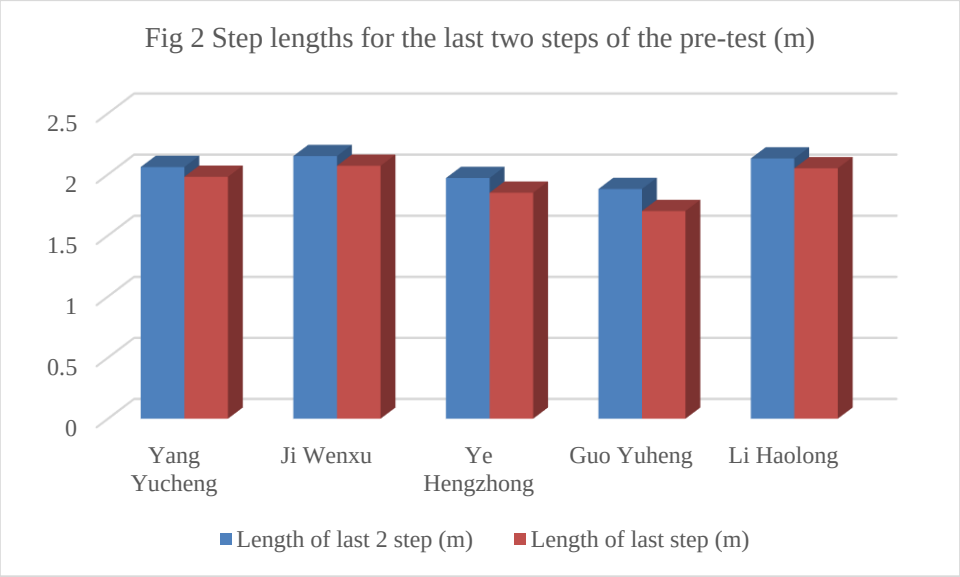
Currently, athletes in Chinese universities should focus on improving their approach speed as much as possible. They should continually enhance specific strength qualities, refine speed training, and improve their ability to acquire and maintain horizontal speed during the approach.

The step lengths for the last two steps of the pre-test and post-test

The approach is a fundamental and crucial technical component of the high jump, significantly influencing the speed, stability, and precision of the approach. In actual competitions, the rhythm of the approach varies due to differences in athletes' body shapes, fitness levels, training, and technical characteristics. However, the study revealed that athletes, especially during the last two steps of the curved approach, adjust the rhythm based on their traits. This tailored rhythm ensures a stable transition from the approach to the takeoff, facilitating a seamless connection between the approach and the jump.

Table 3 The step lengths for the last 2 steps of pre-test (m)

Number	Name	Length of last 2 steps (m)	Length of last step (m)
1	Yang Yucheng	2.06	1.98
2	Ji Wenxu	2.15	2.07
3	Ye Hengzhong	1.97	1.85
4	Guo Yuheng	1.88	1.70
5	Li Haolong	2.13	2.05
	M±SD	1.82±0.04	1.82±0.01



According to the results shown in Table 2, the last two step lengths of the five athletes' assisted run before the inclined track training were Yang Yucheng: 2.06m and 1.98m; Ji Wenxu: 2.15m and 2.07m; Ye Hengzhong: 1.97m and 1.85m; Guo Yuheng: 1.88m and 1.70m; Li Haolong: 2.13m and 2.05m.

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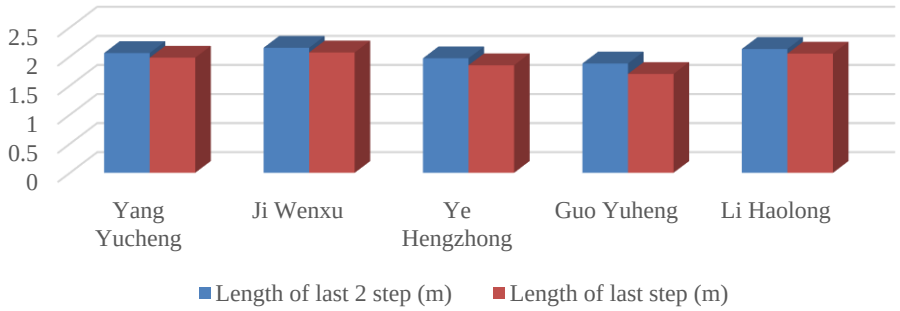
Table 4 The step lengths for the last 2 steps of pre-test (m)

Number	Name	Length of last 2 steps (m)	Length of last step (m)
1	Yang Yucheng	2.16	2.14
2	Ji Wenxu	2.18	2.14
3	Ye Hengzhong	2.09	1.98
4	Guo Yuheng	1.96	1.93
5	Li Haolong	2.18	2.11
	M±SD	2.11±0.08	2.06±0.09

Fig 3 Step lengths for the last two steps of the pre-test (m)



According to the results shown in Table 3, the last two steps lengths of the five athletes' assisted running after the inclined board training were Yang Yucheng: 2.16m and 2.14m; Ji Wenxu: 2.18m and 2.14m; Ye Hengzhong: 2.09m and 1.98m; Guo Yuheng: 1.96m and 1.93m; Li Haolong: 2.18m and 2.11m.

Generally speaking, in the case of athletes with good leg strength and support ability, we should pursue an accurate, fast, and stable running rhythm, especially in the last arc running phase, naturally and positively send the hips, and accelerate the step frequency under the premise of reasonable step length. For the arc running, the length of the last 2 steps should be summarised as the change rule of medium-small step length, and the step lengths of the world's best high jumpers during the last three steps are also the change rule of large-medium-small step length, which is consistent with the results of the research in this paper.

The result of the t-test-dependent

Table 5 Compware mean of 5 athletes for pre-test and post-test of Velocity of the center of gravity, Step lengths for the last 2 steps, Step lengths for the last 1 step by t-test dependent

Variables	test	M±SD	P-value
The velocity of the center of gravity (m/s)	pre-test	6.90±0.13	0.000*
	post-test	7.07±0.15	
Step lengths for the last 2 steps (m)	pre-test	2.04±0.10	0.012*
	post-test	2.11±0.08	
Step lengths for the last 1 step (m)	pre-test	1.93±0.14	0.014*
	post-test	2.06±0.09	

*P<.05

The form table found that all of the variables were significant. (*p < .05)

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Conclusion

1. Inclined track had a high validity (IOC=.97) and safety for training. And Compare within 5 high jumpers found that all of the variables (Velocity of center of gravity, Step lengths for the last 2 steps, Step lengths for the last 1 step) were significant (*P<.05).

Discussion

1. Average speed of last two steps

Speed is considered the essence of the Fosbury Flop. Scholars, both domestically and internationally, agree that speed plays a crucial and fundamental role in high jump techniques. One of the modern trends in the high jump is the continuous emphasis on increasing approach speed. Exceptional high jump athletes consistently exhibit excellent approach speeds. The last two steps of the approach, connecting the run-up to the take-off, are the core of the entire approach, playing a pivotal role in the seamless transition between the two phases.

The technique of the high jump involves energy conversion, transforming forward momentum into upward force. Whether an athlete can leave the ground after take-off and the height they can achieve post-take-off are determined by the speed their center of gravity gains during take-off. Therefore, to clear higher heights, high jumpers need a faster lift-off speed. To attain this ideal lift-off speed, a rapid horizontal speed during the approach is a prerequisite (Yu, 2017).

Research by Liu (2015) suggests that modern high jumpers typically adopt a curved approach, capitalizing on its ability to enhance speed during the approach phase and effectively utilize the athlete's speed capabilities. The last two steps are crucial technical phases; high jumpers should be aware of the need for a rapid take-off from the second last step. This is manifested in a significantly increased rhythm in the approach and a rapid approach towards the take-off point. The speed during these last two steps is a vital evaluation criterion, demanding the utmost attention from athletes. Chen (2015) believes that speed during the approach directly influences subsequent stages of the jump. Simultaneously, it acts as the primary source of load-bearing for the take-off leg, holding a decisive role in the Fosbury Flop technique.

According to Li (2021), high jump athletes' performance is closely linked to their approach speed. For every 0.10 m/s increase in horizontal speed pre-takeoff, the vertical force during the cushioning phase increases by 12-16 kg. Hence, swift approach speed significantly enhances the take-off effect. Research by Yu (2015) found that exceptional Chinese high jumper Zhu Jianhua achieved a speed of 8.5 m/s during the last two steps when setting the national record of 2.39 m. Similarly, the world record holder Javier Sotomayor reached speeds of up to 8.93 m/s during the curved phase when establishing the 2.45 m world record.

The results of this study demonstrate that inclined track training significantly improves approach speed. Post-experimental trials showed that the approach speed increased by 0.17 m/s, with a significance level of $P < 0.05$. A high-speed approach is indispensable for high jump athletes to achieve outstanding results, directly influencing the quality of take-off techniques and the rate of horizontal speed loss. To ensure a seamless connection between the approach and take-off, athletes should strive to maintain a proactive approach during the last two steps. This finding aligns with the results of our study.

2. The length of the last two steps

Apart from approach speed, athletes must find the right stride length tailored to their physique. This tailored approach is instrumental in shaping a positive and steady approach, allowing athletes to

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maintain an optimal center of gravity height through moderate muscle extension. This balance creates ideal conditions for utilizing speed effectively and achieving swift take-offs. Given the inherent differences in athletes' heights and body proportions, each athlete naturally has a unique stride length during the approach, as pointed out by Wang (2015). Wang Fujun emphasizes that the length of the last two steps is a pivotal factor in evaluating an athlete's approach technique, significantly influencing the approach rhythm and the ability to assume the perfect take-off posture.

The results of this study show that the average step length of the last two steps for the five athletes was 2.04m, 1.93m, 2.11m, and 2.06m before and after the tests. To maintain proportionality, a strategic reduction in the final step's length was made, preserving approach speed while minimizing speed loss. Following inclined board training, the step length of the last two steps became notably more reasonable. The length of these last two steps during the approach is influenced by various factors, including approach speed, take-off force application, and body posture control. Proper stride length is a fundamental aspect of the take-off force structure, underscoring the athletes' need to carefully consider suitable step lengths for the last two steps during their approach.

A noteworthy observation is that high jumpers often adopt a pattern of large-medium-small step lengths in the final two steps of the approach. This deliberate choice accelerates the approach rhythm and facilitates a seamless take-off. This perspective aligns with the strategies employed by many world-class high jumpers, highlighting the significance of large-medium-small step lengths for an effective take-off (Chen, 2019).

Recommendation

1. Inclined track training can enhance running speed, which is the decisive factor in determining various stages of take-off. It is the primary source of load-bearing for the take-off leg and influences the changes in other factors throughout the entire take-off process, thereby significantly impacting the effectiveness of the jump. According to the principles of physics, the body's kinetic energy increases with running speed. Therefore, the kinetic energy generated by athletes running on an inclined track is greater than that on flat ground. Increased running speed facilitates the storage of elastic potential energy during the bending and cushioning phase of the take-off leg, enabling the body to achieve greater vertical velocity during the extension phase. This enhancement is conducive to improved performance. Consequently, inclined track training effectively enhances speed abilities, as confirmed by the results of this study. It can be incorporated into future training sessions to enhance the performance of high jump athletes.

2. Due to the design principles of the inclined track aligning with the technical principles of the high jump, the five athletes showed improved coordination between the approach and take-off techniques before and after the experiment. It also led to more appropriate lengths for the last two steps, following the stride length patterns observed in world-class athletes. This adjustment is beneficial for future improvements in high jump performance. However, the fixed angle of the inclined track used in this study prevented the exploration of different angles' effects on the technique. Therefore, future research could investigate the impact of inclined tracks with various angles to identify the most suitable angle for inclined track training.

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