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Effects of a Targeted Training Intervention on Spatiotemporal and Kinematic Parameters of 110-m Hurdle Clearance

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ABSTRACT

The kinematic and spatiotemporal features of the 110-meter hurdle clearance were examined after an 8-week focused training intervention. The study included 16 male hurdle athletes (n = 16) at the national and university levels. Using a multi-camera 3D motion capture system, a fifth hurdle was utilised to collect kinematic data in a pre-test-post-test experimental design. Takeoff distance, landing distance, time of flight, angle of lead leg, time of clearance, knee flexion of trail leg, trunk lean, and centre of mass (COM) height were the basic variables. Significant improvements were observed in the majority of variables after this intervention. In addition to shorter flight and clearance times, hurdlers demonstrated greater takeoff and landing distances, demonstrating enhanced temporal efficiency. Kinematic adaptations included higher quality lead leg extension, more optimum trail leg recovery and the control of the trunk, which all help to make the mechanics of obstacle clearance smoother. The inferential analysis revealed that there was a statistically significant difference between pre- and post-test measures ($p < 0.05$) with a moderate to large effect size, thus highlighting the effectiveness of the intervention. The results indicated that spatiotemporal as well as kinematic parameters can be significantly improved in the hurdle clearance performance, based on the training that is biomechanically up-to-date and targeted. The findings of this research give coaches and hurdlers a number of practical ideas to improve hurdling efficiency through evidence-based methods.

Keywords: *kinematics, 110-m hurdles, spatiotemporal variables, training intervention, hurdle clearance*

INTRODUCTION

The 110-meter hurdles are regarded as a very technically demanding race which requires a good blend of hurdling and sprinting skills. Hurdle clearance is an important factor in the overall speed of the hurdler's race – and as the sprinter's velocity must be kept horizontal, the hurdlers must maintain their horizontal velocity when they are clearing the hurdles. Any inadequacy in technique has a negative effect on rhythm and increases overall race time, regardless of whether it's minor or major mistake.

Hurdle clearance is a combination of take-off, flight and landing stages, which are controlled by several key spatiotemporal and kinematic variables, including take-off distance, landing distance, flight time, clearance time, lead leg angle, trail leg mechanics, trunk posture and trajectory COM. Elite players characteristically exhibit optimized values in these variables, letting smoother transitions along with minimal loss of velocity.

Many earlier studies have focused on descriptive and comparative studies, while few have been concerned with methodologies that involve intervention to develop hurdling technique. This difference is most noticeable in developing hurdlers, where there are biomechanical inefficiencies which can negatively impact performance.

The effect of an 8-week specific training programme on some of the spatiotemporal parameters and some of the kinematic parameters of 110-m hurdle clearance is studied. It is hypothesised that a biomechanically modern approach to training will increase hurdle clearance efficiency and the pre-test–post-test experimental design will be used to investigate this. It is hypothesized the intervention will result in significant improvements in both temporal and kinematic parameters.

METHODOLOGY

An experimental pre-test–post-test design was used to study the effects of an 8-week focused training intervention on spatiotemporal and kinematic characteristics of 110-meter hurdle clearance. Male hurdlers who completed their training (race times <16.0 s) competed at national and university level.

The same 3D motion analysis technique was used to collect kinematic data at baseline and post-test at the 5th hurdle. The multi-camera system comprised 4-6 high-speed cameras and the camera setup and data collection procedures were similar to those reported earlier (khadim.i, 2026). Reflective markers were attached to the important anatomical landmarks and a standard frame was used for calibration together with the wand. These were take-off and landing distances, flight time, hurdle clearance time, horizontal velocity, velocity loss, trunk inclination, trail-leg mechanics and COM height.

An eight-week structured intervention program aimed at regaining biomechanical efficiency in obstacle clearance served as the main component of this study. The program was developed using progressive overload, including integrated technical hurdle drills (3 sessions/week), sprint training (2 sessions/week), strength and power development (2 sessions/week), and plyometric conditioning (2 sessions/week). Then it was time for the flexibility and core stability drills. The intervention specifically aimed at key biomechanical errors, excessive flight time, velocity loss, incorrect trunk posture, inadequate trail-leg recovery and prolonged ground contact time. Competition-specific simulation involved basic technical correction and rhythm development to speed refinement training.

The post-test data were collected under the same experimental conditions to ensure consistency and reliability of measurements.

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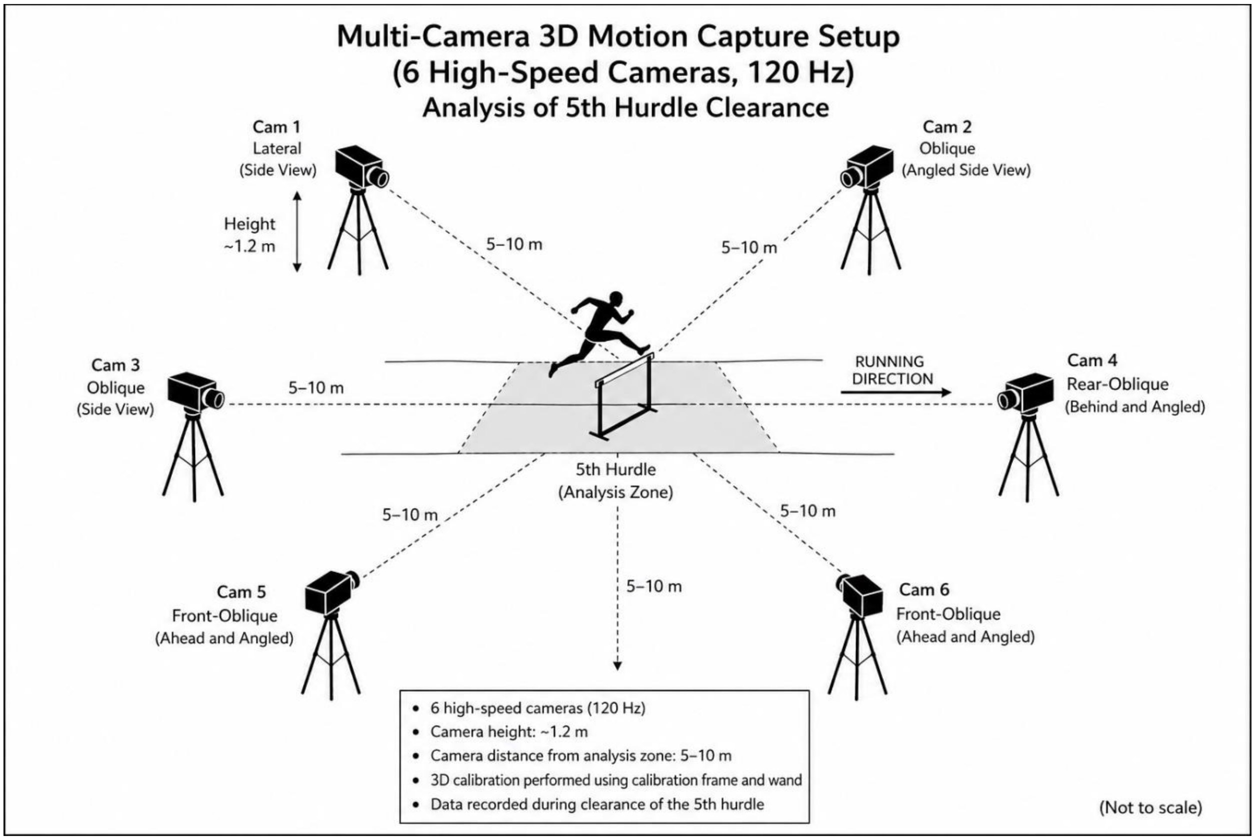


TABLE 1: Pre- and Post-Intervention Comparison (n = 16)

Variable	Pre-Test Mean ± SD	Post-Test Mean ± SD	Mean Difference	t-value	p-value
Take-off Distance (cm)	144.50 ± 2.29	146.89 ± 1.52	+2.39	-4.383	0.0005***
Landing Distance (cm)	132.50 ± 2.29	135.13 ± 1.65	+2.63	-4.084	0.001**
Flight Time (s)	0.375 ± 0.012	0.364 ± 0.010	-0.011	2.915	0.010*
Hurdle Clearance Time (s)	0.445 ± 0.012	0.430 ± 0.010	-0.015	3.985	0.001**
Lead Leg Angle (°)	69.94 ± 1.90	71.85 ± 0.79	+1.91	-4.285	0.0007***
Trail Leg Knee Flexion (°)	116.63 ± 2.22	119.18 ± 1.15	+2.55	-4.547	0.0004***
Trunk Lean (°)	13.50 ± 1.23	13.11 ± 0.65	-0.39	1.079	0.298 (ns)

CM Height (cm)	107.81 ± 2.03	109.61 ± 1.08	+1.79	-2.937	0.010*

1. Effects of Training Intervention (Pre–Post Comparison)

The paired-sample analysis following the targeted training session revealed significant improvements in several spatiotemporal and kinematic characteristics. The take-off distance increased from 144.50 ± 2.29 cm in the pre-test to 146.89 ± 1.52 cm in the post-test (t = –4.383, p and = 0.0005), indicating an improvement in take-off mechanics, especially horizontal propulsion. Furthermore, improved forward motion management on hurdle clearance increased significantly landing distance from 132.50 ± 2.29 cm to 135.13 ± 1.65 cm (t = –4.084, p = 0.001).

Moreover, there were very impressive improvements in the temporal parameters. Flight time decreased from 0.375 ± 0.012 s to 0.364 ± 0.010 s (t = 2.915, p = 0.0107), while hurdle clearance time was reduced from 0.445 ± 0.012 s to 0.430 ± 0.010 s (t = 3.985, p = 0.0012). The drops are extra effective barrier removal methods, as well as the fact that they are more effective during the airborne stage.

Angular factors were the place for significant improvement with the leading leg angle and trail leg knee flex. The lead leg angle increased from 69.94 ± 1.90° to 71.85 ± 0.79° (t = –4.285, p = 0.0007), indicating less vertical displacement and better forward projection. Similarly, the value added for the trail leg knee flexion angle increased from 116.63 ± 2.22° to 119.18 ± 1.15° (t = –4.547, p = 0.0004), suggesting that, as well as repositioning more quickly after clearance, this leg has greater efficiency in recovering. Furthermore, center of mass (COM) height significantly increased from 107.81 ± 2.03 cm to 109.61 ± 1.08 cm (t = –2.937, p = 0.0102), which indicated that there was improved control of vertical displacement throughout the clearance phase. However, there was no significant change between the trunk lean (13.50 ± 1.23° vs. 13.11 ± 0.65°, t = 1.079, p = 0.298), indicating lesser postural responses to the provided interventions.

TABLE 2: Post-Test Comparison (University vs National)

Variable	University (n=8) Mean ± SD	National (n=8) Mean ± SD	t-value	p-value
Take-off Distance (cm)	146.8 ± 1.19	148.5 ± 0.78	-3.379	0.0045**
Landing Distance (cm)	134.5 ± 1.12	136.2 ± 0.97	-3.245	0.0059**
Flight Time (s)	0.37 ± 0.009	0.36 ± 0.009	2.173	0.047*
Hurdle Clearance Time (s)	0.43 ± 0.009	0.42 ± 0.008	2.330	0.035*
Lead Leg Angle (°)	71.0 ± 0.74	72.0 ± 1.05	-2.202	0.045*
Trail Leg Knee Flexion (°)	118.5 ± 0.85	119.8 ± 0.87	-3.023	0.009**

Trunk Lean (°)	13.5 ± 0.99	12.8 ± 0.77	1.579	0.137 (ns)
CM Height (cm)	109.8 ± 0.94	110.9 ± 0.81	-2.507	0.025*

2. Post-Test Comparison (University vs National Hurdlers)

There was a significant difference between several variables before and after the intervention in both university- and national-level players. The difference between national hurdlers and university athletes was statistically significant ($t = –3.379$, $p = 0.0045$), with greater take-off distances on hurdles being recorded in national athletes (148.5 ± 0.78 cm). Likewise, the landing distance was significantly greater for the national players (136.2 ± 0.97 cm) compared to the university players (134.5 ± 1.12 cm) ($t = –3.245$, $p = 0.0059$), indicating greater horizontal propulsion and momentum control.

The national hurdlers also had a day to themselves, with some temporal variables. Flight time was significantly shorter in the national hurdler group (0.36 ± 0.009 s) in comparison with the university hurdler group (0.37 ± 0.009 s) ($t = 2.173$, $p = 0.0474$). Also, the obstacle-clearing time of national-level athletes (0.42 ± 0.008 s) was significantly lower than that of university-level athletes (0.43 ± 0.009 s) ($t = 2.330$, $p = 0.0353$). This indicates that the national-level athletes had a more efficient airborne phase.

The technical execution by the national-level players was also better, which was supported by the angular variables. Lead leg angle was significantly bigger in national-level athletes (72.0 ± 1.05°) than in university-level athletes (71.0 ± 0.74°) ($t = –2.202$, $p = 0.0449$), whereas trail leg knee flexion was also significantly bigger (119.8 ± 0.87° vs. 118.5 ± 0.85°; $t = –3.023$, $p = 0.0091$). on contrary, trunk lean did not change significantly between groups ($p = 0.1367$), representing comparable postural alignment.

Moreover, it was noted that COM height was significantly higher in national-level athletes (110.9 ± 0.81 cm) than in university-level athletes (109.8 ± 0.94 cm) ($t = –2.507$, $p = 0.0251$), which indicated that better vertical displacement control and optimised clearance trajectory were obtained.

TABLE 3: Comparison with IAAF Elite Hurdlers (Post-Test)

Variable	IAAF Elite	National (Post-Test)	Difference
Take-off Distance (cm)	150	146.89 ± 1.52	-3.11
Landing Distance (cm)	140	135.13 ± 1.65	-4.87
Flight Time (s)	0.36	0.36 ± 0.01	0.00
Hurdle Clearance Time (s)	0.42	0.43 ± 0.01	+0.01
Lead Leg Angle (°)	72	71.85 ± 0.79	-0.15
Trail Leg Knee Flexion (°)	120	119.27 ± 1.15	-0.73
Trunk Lean (°)	12	13.12 ± 0.65	+1.12

CM Height (cm)	110	109.44 ± 1.08	-0.56

3. Comparison with IAAF Elite Hurdlers

It was found that there was a significant decrease in biomechanical differences when comparing post-test national level athletes with elite athletes from the IAAF. However, take-off distances for national level players were 146.89 ± 1.52 cm compared with 150 cm for elite players and landing distances 135.13 ± 1.65 cm compared with 140 cm for elite players, which showed a decrease in horizontal propulsion on the other hand.

Of special interest, temporal variables were not expressed near equivalence between these two groups. Flight time in national level hurdlers (0.36 ± 0.01 s) matched the elite level (0.36 s) while clearance time (0.43 ± 0.01 s) was slightly larger than the elite level (0.42 s), indicating that the intervention successfully brought the tempo of the hurdle clearance close to the elite level.

Elite norms were also reached with angular variables. The very slight differences in the lead leg angle (71.85° vs. 72°) and trail leg knee flexion (119.27° vs. 120°) indicated minor technical issues with performance. However, the trunk lean was slightly greater among those who competed at the national level (13.12° vs. 12°), indicating a slight lack of efficiency in postural control. There was also a similar COM height value (109.44 cm vs. 110 cm) with more control of vertical movement throughout clearance.

TABLE 4: Regression Summary (Post-Test)

Model	R^2	Adjusted R^2	F-value	p-value
Full Model (8 predictors)	0.407	-0.271	0.600	0.755
Stepwise Model	0.344	0.243	3.410	0.064

Key Predictors (Stepwise Model)

Variable	Beta	p-value
Hurdle Clearance Time	+15.99	0.119
Trunk Lean	-0.319	0.024*

Regression Analysis

This was performed using multiple regression analysis to examine the predictive role of kinematic variables to outcomes of players' performance. The full model (all eight predictors) accounted for 40.7% of the variance in performance ($R^2 = 0.407$), but failed to reach statistical significance ($p > 0.05$).

The hurdle clearance time and the degree of trunk lean were the most significant predictors identified by a stepwise regression model. There was a positive relation between the time taken for hurdle clearance and performance time, indicating that time-consuming clearance times hurt performance. In contrast, a significant negative association was found for trunk lean (p = 0.024), which indicates that a reduced forward lean will be associated with increased efficiency.

Figure 1. Mean spatiotemporal and kinematic variables comparison before and after the training intervention.

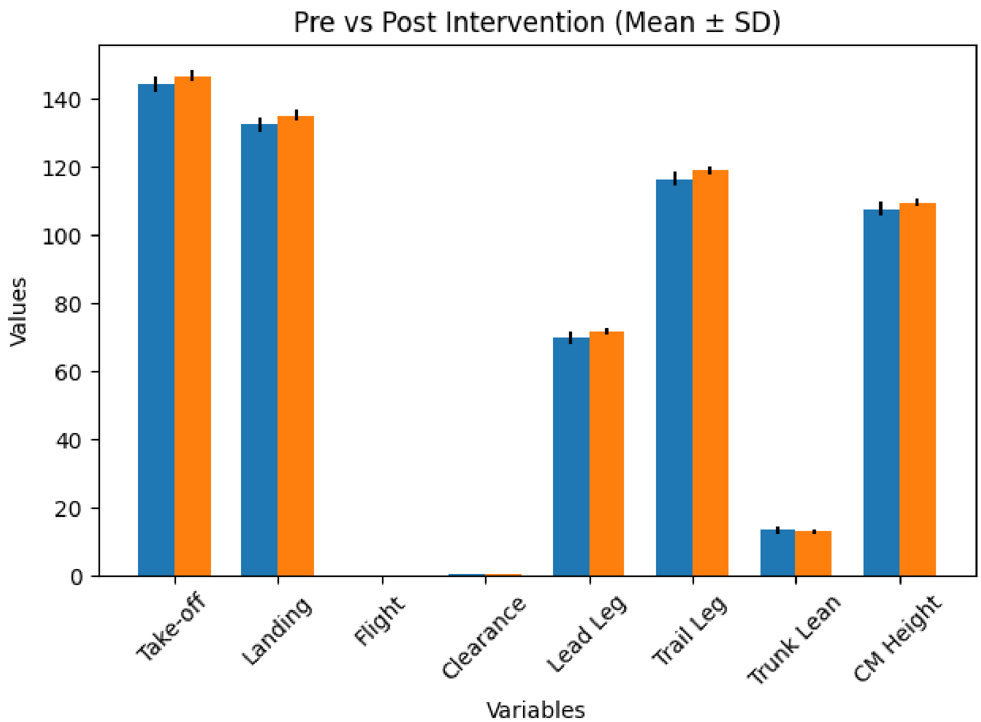
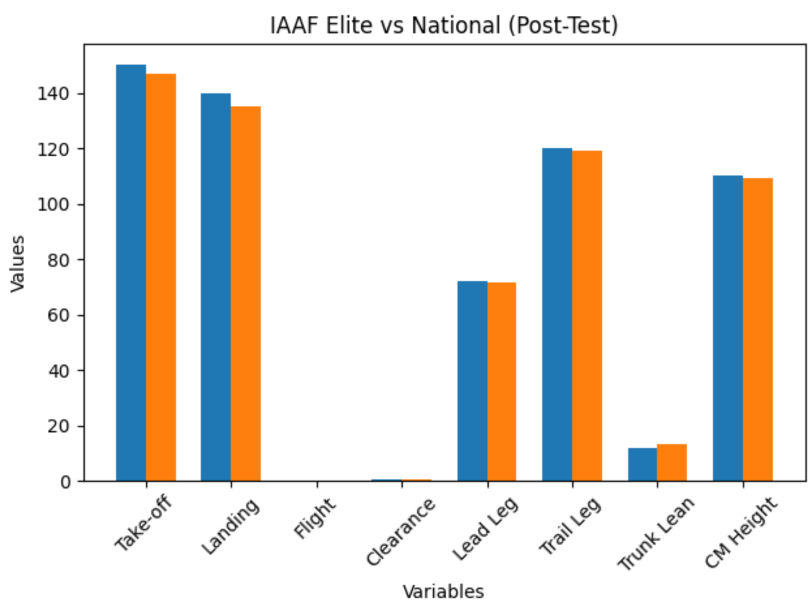


Figure 2. Post-test kinematic variables comparison between elite and national-level hurdlers.



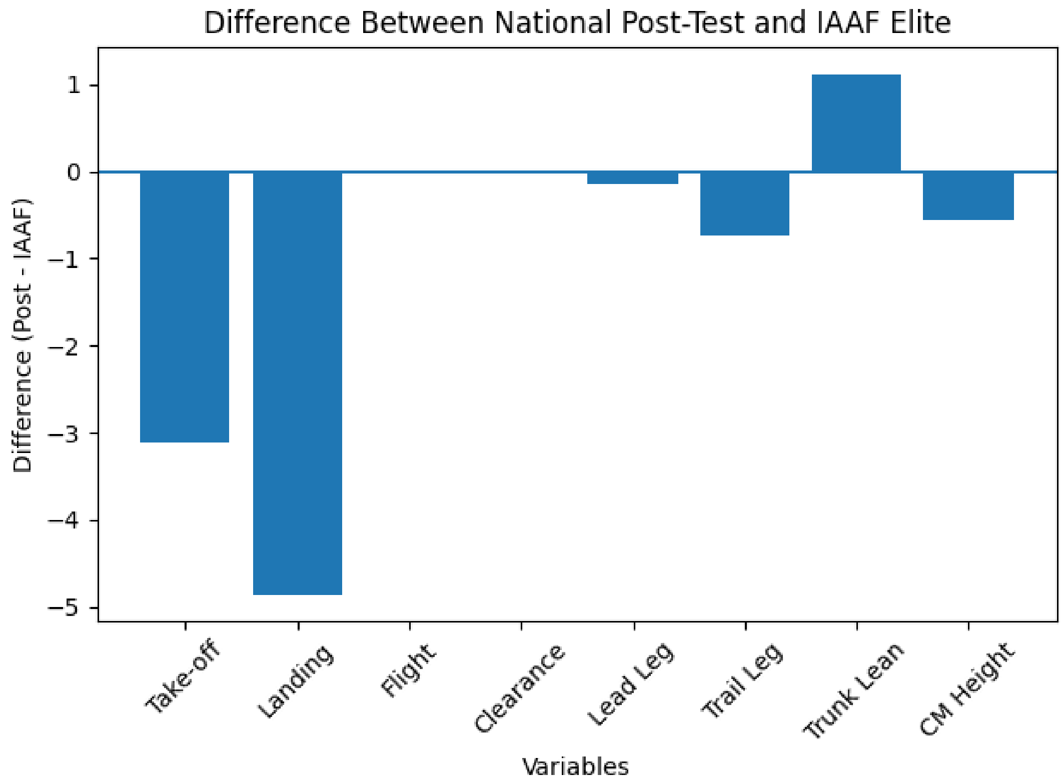


Figure 3. Difference between post-test national hurdlers and IAAF elites' values across key kinematic variables.

DISCUSSION

This study is a study of both the spatiotemporal and kinematic properties of 110-m hurdle clearance following a targeted training intervention. The results indicate that the intervention had an impact on certain biomechanical variables, which is an improvement in the efficiency of movement during the hurdle clearance phase. The observed increases in take-off plus landing distances suggest that the quality of the horizontal force production has improved, as well as the ability of the stride to be regulated during the approach and landing. There are a couple of definite changes that need to be made for further progression and for the ball to have a trajectory level to the ground over the obstacle. The flight time is shorter, and hurdler clearance time is better as hurdlers could reduce flight time while maintaining height clearance. This type of improvement is in line with the biomechanical concept of high-level performance and is representative of good ways to clear obstacles.

In addition, there were noticeable technical improvements in the flexions of the knee of the back leg as well as the front leg angle after the intervention. Improved flex of the trail leg allows for faster recovery and smooth takeovers into the next stride, and better lead leg extension allows for greater forward projection and less vertical oscillation. On the contrary, trunk lean did not exhibit a statistically significant variation, suggestive of the fact that postural control in the course of clearance may necessitate more targeted or prolonged training stimuli. The comparison of post-intervention performances of the University and national level hurdlers revealed that the national level hurdlers maintained the superior performance in most of the variables, mainly in spatial and temporal values. However, a decrease in inter-group differences indicated that the intervention helped to improve the performance of university-level hurdlers, in this way further reducing the performance gap. The result reinforces the value of a structured biomechanical component to the development of a hurdler's skill level.

Notably, when compared to the IAAF elite standards, found that the post-test values approached elite standards, especially in the temporal plus angular variables. But there are still differences in take-off in addition to landing distances, and the positioning of the trunk, that indicate the need for further improvements of both horizontal propulsion and posture control to reach an elite level of performance.

In summary, the results have revealed that the targeted training intervention resulted in significant changes in the kinematic and spatiotemporal variables of the hurdle clearance, which acknowledged better coordinated and effective movement patterns in competitive hurdlers.

CONCLUSION

The current study clearly shows that a focused training intervention led to significant but meaningful changes in the spatiotemporal and kinematic characteristics of 110-meter hurdle clearance. Enhanced lead/trail leg mechanics, reduced takeoff/landing distance, and reduced flight and hurdle clearance time all point towards more effective and coordinated movement patterns.

The results emphasize the importance of training for biomechanical modernity to enhance the ability to jump hurdles. In addition to enhancing the temporal efficiency of the course in the airborne phase, the intervention increased the coordination of the limbs and the control of space, which are important to successfully complete the obstacle phase of the course, helping to raise the performance of the participants. Structured and tailored training approaches are reflected more in the level of performance difference between university-level players and national-level players, and in the reduced spread of hurdlers.

In comparison with the international benchmarks, it was observed that the act of performance after the intervention is very similar to the performances of the elite athletes in the IAAF, both in terms of temporal and angular dimensions. But there are still some remaining differences in trunk posture and horizontal displacement, which indicate that there is still a lot of improvement in force output and postural control required to achieve elite-level competency.

Overall, it highlights the importance of targeted training treatments that can significantly impact hurdling biomechanics, providing them with a valuable and effective tool to help optimize their performance in competitive sports. The results contribute to the awareness of sports biomechanics and give researchers, coaches and practitioners useful information for making it better by employing evidence-based training techniques.

LIMITATIONS AND FUTURE DIRECTIONS

Several limitations of this study were noted. First, the sample size for this research is relatively small ($n = 16$), which can be a limitation in the generalizability of the results obtained and reduce the statistical power of the research, especially in regression analyses (besides correlation analyses). Secondly, the study was conducted among male athletes, and the results of the study apply to female hurdlers and/or to athletes in general. Thirdly, even though the 3D kinematic analysis was carried out, kinetic variables (e.g. ground reaction forces) were not analyzed in the study and could have provided information regarding the force production and mechanical efficiency during a hurdle clearance.

Further, although the intervention was effective for the short term, it might not have been long enough to detect any lasting differences in the ways of working other than the outcomes. Also, several contextual factors (competitive conditions, tiredness conditions, etc.) were omitted, which may affect the applicability of the field.

Future research should consider larger and more diverse cohorts of participants, such as hurdlers of different genders and abilities, to increase the generalizability. Longitudinal studies with higher intervention time are recommended to investigate the long-term effects of the biomechanical adaptations. Kinematic observations along with kinetic analysis would give a more detailed understanding of the hurdling performance. Furthermore, in order to improve technique development, future research may investigate the incorporation of sophisticated training technologies, such as wearable sensors in addition to real-time feedback systems. An analysis of the variables involved in the biomechanics of the race and the overall performance of the race over a number of hurdle stages would be possible and would allow a better understanding of the dynamics of the competitive hurdling race to be gained.

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