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OPTIMIZING HURDLE CLEARANCE BIOMECHANICS AND INTER-HURDLE RHYTHM STABILITY IN 16-17-YEAR-OLD 110 M HURDLERS

Talipov Gulomjon Adiljanovich
Teacher, National University of Uzbekistan
talipovgulomjon306@gmail.com

Abstract:

High performance in the 110 m hurdles requires athletes to combine horizontal sprinting velocity with precise hurdle clearance biomechanics. In youth training, developing flat sprint speed separately from hurdle clearance mechanics often leads to excessive vertical oscillation of the center of mass and velocity loss on landing. This study evaluated a three-stage integrated training model designed to optimize hurdle step biomechanics and stabilize the three-step inter-hurdle rhythm in 16-17-year-old male hurdlers. Twenty-four adolescent hurdlers (hurdle height: 0.914 m) were equally assigned to a control group (CG, n=12) and an experimental group (EG, n=12). The CG followed a traditional program that separated flat sprint conditioning from technical hurdle drills. The EG completed a phased intervention combining spatial-kinematic modeling, reactive-rhythm stabilization, and competitive velocity integration three times per week. Performance was assessed using the 30 m crouch start sprint, 110 m hurdles, 110 m flat sprint, Technical Performance Index (Δt = t_110mH - t_110m_flat), and standing triple jump. Post-intervention independent Student's t-tests (df=22) showed statistically significant advantages for the EG over the CG in the 30 m sprint (4.12 ± 0.11 s vs. 4.26 ± 0.13 s; t=2.85, $p < 0.01$), 110 m hurdles (14.85 ± 0.32 s vs. 15.42 ± 0.38 s; t=3.97, $p < 0.001$), Technical Performance Index (1.75 ± 0.12 s vs. 2.17 ± 0.16 s; t=7.27, $p < 0.001$), and standing triple jump (8.36 ± 0.24 m vs. 7.98 ± 0.26 m; t=3.72, $p < 0.01$). The groups did not differ significantly in 110 m flat sprint time (13.10 ± 0.30 s vs. 13.25 ± 0.33 s; t=1.17, $p > 0.05$). Combining reactive strength conditioning with modified-spacing rhythm drills effectively reduces time loss during hurdle clearance and improves rhythm stability in adolescent hurdlers.

Keywords: Track and field, 110 m hurdles, adolescent athletes, hurdle step biomechanics, Technical Performance Index, inter-hurdle rhythm, reactive strength.

Introduction

The 110 m hurdles is an acyclic-cyclic speed-power event requiring rapid horizontal acceleration and precise spatial-temporal motor control over ten barriers positioned at fixed intervals. In flat sprinting, stride length and frequency evolve naturally according to neuromuscular output. Hurdle running imposes fixed spatial constraints: a 13.72 m approach

to the first hurdle, 9.14 m intervals between hurdles covered in a three-step rhythm, and a 14.02 m run from the last hurdle to the finish. In adolescent hurdlers aged 16-17 years (U18 category, hurdle height 0.914 m), longitudinal bone growth often outpaces neuromuscular coordination. When flat sprint speed and hurdle clearance drills are trained separately, athletes frequently use a jumping clearance pattern instead of a continuous stepping-over action. The resulting technical flaw raises the trajectory of the body's center of mass (CM), prolongs flight time over the barrier, and induces severe braking forces upon landing.

Research on short-hurdle performance has addressed both biomechanical and pedagogical determinants. Kinematic studies by M. Coh and J. Iskra established that elite hurdlers minimize horizontal velocity loss by maintaining a take-off-to-landing distance ratio of approximately 60-65% before the hurdle and 35-40% after it, together with a brief post-hurdle ground contact time of 0.08-0.10 s. B. McFarlane emphasized that maintaining a high stride frequency across the 9.14 m inter-hurdle zones depends on hip joint mobility, an aggressive lead-leg snap-down, and forward postural lean. In athletic training theory, V.N. Platonov demonstrated that exercises during in-depth specialization (ages 16-17) must closely reproduce the biomechanical and bioenergetic demands of competition. Yu.V. Verkhoshansky's principle of dynamic correspondence holds that the reactive-ballistic strength of the ankle plantar flexors and hip extensors must be developed at the exact angular velocities required by the technical movement. In domestic track and field methodology, N.G. Ozolin and K.T. Shakirjanova systematized long-term teaching progressions for hurdle mechanics, emphasizing specialized flexibility and rhythm drills to prevent technical breakdown under fatigue.

The literature reveals a methodological gap between biomechanical diagnostics and the design of youth training. Kinematic studies quantify target movement parameters in mature elite hurdlers but do not provide structured pedagogical protocols for correcting high CM trajectories and passive landings in 16-17-year-old athletes. Traditional coaching manuals, meanwhile, often place plyometric conditioning, sprint acceleration, and technical hurdle drills in separate training blocks. The quantitative effect of combining reactive strength exercises with variable-spacing hurdle rhythm drills on the Technical Performance Index, the time difference between 110 m hurdles and 110 m flat sprinting, therefore remains insufficiently verified in adolescent athletes.

The aim of this study was to design and experimentally verify a three-stage integrated training model intended to optimize hurdle clearance biomechanics and stabilize inter-hurdle running rhythm in 16-17-year-old 110 m hurdlers.

Materials and methods

Twenty-four male hurdlers aged 16-17 years (U18 category, competing over the standard 0.914 m hurdle height) participated in the pedagogical experiment. Each had 3-4 years of prior track and field training. Based on baseline diagnostic testing, athletes were matched and randomly allocated to two homogeneous groups of equal size: the Control Group (CG, n=12) and the

Experimental Group (EG, n=12). Both groups trained six times per week (12 hours total weekly volume) under identical environmental and track surface conditions.

Training intervention. The CG followed the standard youth athletics curriculum. Technical hurdle drills at standard 9.14 m spacing, flat sprint repetitions, and plyometric bounding exercises were performed in separate training sessions or isolated blocks.

The EG performed the experimental three-stage integrated program in three sessions per week (45-50 minutes per session), replacing the isolated technical and speed-strength blocks:

Stage 1: Spatial-Kinematic Modeling (Weeks 1-3). Hurdles were lowered by 5-7 cm (to 0.84-0.86 m), and inter-hurdle spacing was shortened by 30-50 cm (to 8.64-8.84 m). The aim was to eliminate high jumping over the barrier and establish an active step-over motor pattern. Visual tape markers were placed 2.05-2.15 m before each hurdle to enforce an optimal take-off distance. Athletes performed 5-6 hurdle runs, focusing on rapid lead-leg downward acceleration immediately after the foot crossed the crossbar.

Stage 2: Reactive-Rhythm Stabilization (Weeks 4-6). Reactive ankle-stiffness drills, consisting of drop jumps from a 30 cm box followed immediately by two low-hurdle clearances, were integrated into the running series to minimize braking forces and ground contact time after landing. Variable inter-hurdle spacing was used within the same run: hurdles 1-3 were set at 8.80 m and hurdles 4-6 at the standard 9.14 m. Athletes maintained a strict three-step rhythm while training neuromuscular adaptability.

Stage 3: Competitive Velocity Integration (Weeks 7-9). Hurdles were returned to the standard U18 competition height (0.914 m) and spacing (9.14 m). Athletes performed high-intensity runs over 6 to 10 hurdles from a crouch start. These were combined with contrast sprints, alternating a 6-hurdle run with a shortened-spacing high-frequency run, to prevent rhythm degradation in the second half of the race.

Testing procedures. All participants completed five standardized motor and technical tests before and after the 9-week intervention:

30 m crouch start sprint (s): Start acceleration was assessed on a synthetic track using an electronic photocell timing system.

110 m hurdles (s): Athletes ran from a crouch start over 10 hurdles set to standard U18 specifications (height: 0.914 m; approach: 13.72 m; interval: 9.14 m; run-in: 14.02 m). Time was recorded electronically.

110 m flat sprint (s): Athletes ran from a crouch start in a flat synthetic lane without hurdles to establish baseline sprint speed over the exact competitive distance.

Technical Performance Index (Δt, s): For each athlete, the index was calculated as the time difference between the 110 m hurdles and the 110 m flat sprint ($\Delta t = t_{110mH} - t_{110m_flat}$). A lower Δt indicates greater biomechanical efficiency over the 10 barriers.

Standing triple jump (m): Athletes jumped into a sand pit from a two-footed take-off to assess horizontal explosive power and reactive elastic strength of the lower extremities.

Each athlete completed two trials per test with full recovery, including 6-8 minutes between sprint trials. The best result was recorded for analysis.

Statistical analysis. Data are presented as arithmetic mean ($\bar{X}$) and standard deviation (SD). Relative within-group changes were expressed as percentage improvements (Δ%). Between-group comparisons at baseline and after the intervention used the two-sample independent Student's t-test, with degrees of freedom df = n1 + n2 - 2 = 22. For df = 22, critical t-values for statistical significance were t = 2.074 ($p < 0.05$), t = 2.819 ($p < 0.01$), and t = 3.792 ($p < 0.001$).

Results

Baseline measurements confirmed that the CG and EG were statistically homogeneous across all five assessed variables before the intervention (Table 1). Between-group t-values ranged from 0.13 to 0.34 ($p > 0.05$ for all comparisons).

At baseline, the mean Technical Performance Index (Δt) was 2.25 ± 0.18 s in the CG and 2.26 ± 0.19 s in the EG. The loss of more than 2.2 seconds over 10 hurdles, an average difference of 0.22-0.23 s per barrier compared with flat sprinting, reflected suboptimal clearance mechanics, specifically delayed lead-leg descent and excessive braking upon landing.

Table 1. Baseline physical and technical performance indicators of 16-17-year-old hurdlers (n=12 per group)

Assessment Test	CG ($\bar{X}$ ± SD)	EG ($\bar{X}$ ± SD)	Absolute Difference	t-value and p
30 m crouch start sprint (s)	4.32 ± 0.14	4.34 ± 0.15	0.02	t=0.34; p > 0.05
110 m hurdles (s)	15.65 ± 0.42	15.68 ± 0.44	0.03	t=0.17; p > 0.05
110 m flat sprint (s)	13.40 ± 0.35	13.42 ± 0.36	0.02	t=0.14; p > 0.05
Technical Performance Index Δt (s)	2.25 ± 0.18	2.26 ± 0.19	0.01	t=0.13; p > 0.05
Standing triple jump (m)	7.85 ± 0.28	7.82 ± 0.30	0.03	t=0.25; p > 0.05

After the 9-week training period, both groups improved, although the magnitude of improvement differed substantially between the experimental and traditional protocols (Table 2).

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Table 2. Post-intervention comparison of physical and technical performance indicators (n=12 per group)

Assessment Test	CG ($\bar{X} \pm SD$)	EG ($\bar{X} \pm SD$)	Change (CG / EG, %)	t-value and p
30 m crouch start sprint (s)	4.26 ± 0.13	4.12 ± 0.11	1.39% / 5.07%	t=2.85; p < 0.01
110 m hurdles (s)	15.42 ± 0.38	14.85 ± 0.32	1.47% / 5.29%	t=3.97; p < 0.001
110 m flat sprint (s)	13.25 ± 0.33	13.10 ± 0.30	1.12% / 2.38%	t=1.17; p > 0.05
Technical Performance Index Δt (s)	2.17 ± 0.16	1.75 ± 0.12	3.56% / 22.57%	t=7.27; p < 0.001
Standing triple jump (m)	7.98 ± 0.26	8.36 ± 0.24	1.66% / 6.91%	t=3.72; p < 0.01

In the speed-power tests, the EG improved significantly more than the CG. The EG reduced its 30 m crouch start sprint time by 0.22 s (5.07%), compared with 0.06 s (1.39%) in the CG; the between-group difference was statistically significant (t=2.85, p < 0.01). In the standing triple jump, horizontal reactive power increased by 0.54 m (6.91%) in the EG and 0.13 m (1.66%) in the CG (t=3.72, p < 0.01).

The comparison of 110 m flat sprint times, 110 m hurdle times, and the Technical Performance Index (Δt) showed different patterns of change. Both groups recorded modest reductions in 110 m flat sprint time (CG: 1.12%; EG: 2.38%). The post-intervention difference between the CG (13.25 ± 0.33 s) and EG (13.10 ± 0.30 s) was not statistically significant (t=1.17, p > 0.05). For the 110 m hurdles, performance improved by 0.83 s (5.29%) in the EG and 0.23 s (1.47%) in the CG, with a highly significant between-group difference (t=3.97, p < 0.001).

The divergence was directly driven by the reduction in the Technical Performance Index (Δt). The CG reduced the difference between hurdle and flat running by 0.08 s (3.56%), reaching 2.17 ± 0.16 s. The EG reduced Δt by 0.51 s (22.57%), reaching 1.75 ± 0.12 s (t=7.27, p < 0.001). These data confirm that the EG's 0.57 s advantage in the 110 m hurdles was primarily attributable to improved hurdle clearance efficiency and rhythm preservation rather than differences in raw flat sprint speed.

Discussion

The experimental findings support the hypothesis that combining biomechanical modeling with reactive-rhythm conditioning accelerates technical mastery in 16-17-year-old hurdlers. In line with the biomechanical principles outlined by M. Coh and J. Iskra, reducing the Technical Performance Index (Δt) below 1.80 s requires less vertical displacement of the CM and an active landing directly beneath the body's projection. In the CG, isolated plyometrics and standard-spacing hurdle drills produced only a marginal reduction in Δt (0.08 s), demonstrating that general explosive strength does not automatically transfer to the specific coordinative structure of the hurdle step.

Two complementary neuromuscular mechanisms can explain the pronounced reduction in Δt in the EG (0.51 s, p < 0.001). First, Stage 1 used shortened inter-hurdle spacing (8.64-8.84 m)

and slightly lowered barriers. This allowed adolescent athletes to overcome the speed barrier and trained the central nervous system to execute the three-step rhythm at a higher stride frequency without fear of hitting the crossbar. Second, pairing drop jumps with immediate hurdle clearances in Stage 2 enhanced musculo-tendinous stiffness of the ankle plantar flexors. Athletes were thereby able to absorb landing impact elastically and transition rapidly into the first inter-hurdle stride. This interpretation aligns with Yu.V. Verkhoshansky's concept of dynamic correspondence and B. McFarlane's emphasis on reactive ground contact after hurdle clearance.

The improvement in the 30 m crouch start sprint (5.07% in EG vs. 1.39% in CG) reflects the specific focus on the seven-to-eight stride approach to the first hurdle (13.72 m). This phase demands aggressive initial acceleration while maintaining an upright transition at the take-off mark.

The study has several methodological limitations. The sample comprised only 24 male hurdlers aged 16-17 years competing over the 0.914 m barrier. The quantitative norms for spacing reduction may therefore require adjustment for female 100 m hurdlers or senior athletes competing over 1.067 m hurdles. The Technical Performance Index (Δt) provides an objective macro-indicator of technical efficiency, but future research should include high-speed 2D/3D video kinematics to measure take-off angles, CM clearance heights, and individual touch-down times across all 10 barriers.

5. Conclusions and Practical Recommendations

Combining spatial-kinematic hurdle modeling, reactive plyometric coupling, and variable-spacing rhythm drills is significantly more effective than traditional isolated training for improving 110 m hurdle performance in 16-17-year-old athletes.

Post-intervention 110 m flat sprint times did not differ significantly between groups ($t=1.17$, $p > 0.05$). The experimental group nevertheless achieved a highly significant reduction in 110 m hurdle time (14.85 ± 0.32 s vs. 15.42 ± 0.38 s; $t=3.97$, $p < 0.001$) due to a 22.57% improvement in the Technical Performance Index ($\Delta t = 1.75 \pm 0.12$ s; $t=7.27$, $p < 0.001$).

Practical Recommendations: Coaches of 16-17-year-old hurdlers should use the Technical Performance Index (Δt = t_110mH - t_110m_flat) as a primary diagnostic criterion for monitoring technical efficiency independently of flat sprint speed.

During the special preparatory period, coaches should reduce inter-hurdle spacing by 30-50 cm and barrier height by 5-7 cm for 2-3 weeks to establish a high-frequency stepping-over clearance pattern before returning to standard competition parameters.

Reactive ankle-stiffness exercises, such as low-box drop jumps, should be paired directly with 2-3 hurdle clearances within a single exercise set to shorten ground contact time after landing.

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