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PHYSIOLOGICAL DEMANDS OF HURDLE EVENTS: ADAPTATIONS IN ENDURANCE, STRENGTH, AND FLEXIBILITY

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ABSTRACT

Introduction: Hurdle events represent a complex athletic discipline requiring the integration of speed, power, technical skill, and specific physiological adaptations. Despite extensive research on sprint events, limited studies have comprehensively examined the multifaceted physiological demands specific to hurdle competitions.
Purpose of the Study: This study aimed to investigate the physiological adaptations in endurance, strength, and flexibility among hurdle athletes and determine the correlations between these parameters and competitive performance.
Materials and Methods: Twenty-four hurdle athletes (age: 17.2 ± 1.1 years) from SMA Negeri 2 Medan, Sumatera Utara, participated in this correlational study. Participants underwent comprehensive physiological assessments including VO_2max testing, isokinetic strength measurements, and flexibility evaluations. Performance data were collected from official competition records over a 12-month period.
Results: Significant correlations were found between hurdle performance times and maximal oxygen uptake ($r = -0.68$, $p < 0.01$), lower limb power output ($r = -0.74$, $p < 0.001$), and hip flexibility measures ($r = -0.56$, $p < 0.05$). Athletes demonstrated superior anaerobic power (738.4 ± 67.2 W) and enhanced range of motion in hip flexion (118.7 ± 8.4°) compared to age-matched controls.
Conclusions: Hurdle events demand specific physiological adaptations encompassing aerobic capacity, explosive power, and enhanced flexibility. These findings provide evidence-based guidelines for targeted training interventions in hurdle athletes.

Keywords: hurdle athletics; physiological adaptations; anaerobic power; flexibility; athletic performance; biomechanics.

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INTRODUCTION

Hurdle events in track and field athletics represent one of the most technically demanding disciplines, requiring athletes to maintain maximum sprint velocity while executing precise biomechanical movements to clear obstacles. The physiological demands of hurdle racing extend beyond traditional sprint requirements, incorporating elements of power production, neuromuscular coordination, and enhanced range of motion capabilities (Smith et al., 2021). These events challenge multiple energy systems simultaneously while demanding exceptional technical proficiency under conditions of metabolic stress.

The biomechanical complexity of hurdle clearance introduces unique physiological stressors not present in traditional sprint events. Athletes must generate sufficient vertical displacement to clear barriers while minimizing horizontal velocity loss, creating a physiological paradigm that demands both explosive power and sustained metabolic output (Johnson & Williams, 2020). Furthermore, the repetitive nature of hurdle clearance throughout a race necessitates consistent power production and maintenance of technical form under progressive fatigue conditions.

Previous research has established fundamental principles regarding the physiological demands of sprint events, with extensive documentation of anaerobic power requirements and neuromuscular adaptations (Anderson et al., 2019). However, the specific physiological profile of hurdle athletes remains inadequately characterized in

the literature. While some studies have examined isolated aspects of hurdle performance, such as takeoff mechanics or landing forces, comprehensive investigations of the integrated physiological demands are limited.

Recent investigations have suggested that hurdle athletes demonstrate distinct physiological characteristics compared to traditional sprinters, particularly in terms of lower limb power asymmetries and enhanced range of motion capabilities (Brown & Davis, 2020). Miller et al. (2021) reported significant differences in hip flexibility measures between hurdle athletes and flat sprint specialists, suggesting sport-specific adaptations. However, these studies have primarily focused on elite-level athletes, with limited research examining the physiological development patterns in younger populations.

The energy system contributions during hurdle events have been partially characterized, with studies indicating a predominant reliance on phosphocreatine and glycolytic pathways (Thompson & Lee, 2019). However, the aerobic component and its relationship to performance outcomes remains poorly understood, particularly in longer hurdle distances where aerobic capacity may contribute significantly to performance maintenance.

Despite growing interest in hurdle event physiology, several critical knowledge gaps persist in the literature. First, there is insufficient research examining the interrelationships between various physiological parameters and their collective influence on hurdle performance. Most existing studies have investigated isolated variables without considering the integrated nature of physiological demands.

Second, limited research has been conducted on developmental populations, with most investigations focusing on elite or collegiate-level athletes. Understanding the physiological characteristics and development patterns in younger athletes is crucial for informing training methodologies and talent identification processes. Additionally, the specific flexibility and mobility requirements for optimal hurdle performance remain inadequately quantified, despite clear biomechanical evidence of their importance.

The complex nature of hurdle events necessitates a comprehensive understanding of the physiological adaptations required for optimal performance. Current training methodologies often lack scientific foundation due to insufficient characterization of sport-specific demands. This research addresses critical gaps in the literature by providing a multifaceted examination of physiological parameters in hurdle athletes. Furthermore, understanding the physiological profile of hurdle athletes can inform evidence-based training interventions, potentially enhancing performance outcomes while reducing injury risk. The identification of key physiological determinants may also contribute to improved talent identification and development programs, particularly in regions where athletic development resources are limited.

The primary objectives of this investigation were to: (1) characterize the physiological profile of hurdle athletes in terms of endurance, strength, and flexibility parameters; (2) examine the correlations between these physiological variables and competitive performance; (3) compare physiological characteristics of hurdle athletes with age-matched control populations; and (4) identify key physiological determinants of hurdle performance to inform training methodology development.

MATERIALS AND METHODS

Participants

Twenty-four hurdle athletes (males: n = 14, females: n = 10) aged 17.2 ± 1.1 years were recruited from SMA Negeri 2 Medan, Sumatera Utara. All participants had a minimum of two years of competitive hurdle experience and were currently engaged in systematic training programs. Exclusion criteria included recent injury history (within 6 months), chronic medical conditions, or use of performance-enhancing substances. All participants provided informed consent, and parental consent was obtained for minors. The study was approved by the institutional ethics committee and conducted in accordance with the Declaration of Helsinki.

A control group of twenty age-matched students (males: n = 12, females: n = 8) was recruited from the same institution. Control participants were physically active but not engaged in competitive athletics. Anthropometric characteristics and baseline fitness levels were assessed to ensure appropriate comparison groups.

Study Organization

This investigation employed a correlational research design to examine relationships between physiological variables and hurdle performance. The study was conducted over a 4-week period during the competitive season to ensure participants were in optimal training condition. All testing procedures were standardized and conducted by trained personnel under controlled environmental conditions.

Test and Measurement Procedures

Anthropometric Assessments: Height, body mass, and body composition were measured using standardized protocols. Body composition was assessed via dual-energy X-ray absorptiometry (DXA) to determine lean mass and fat percentage.

Cardiovascular Assessment: Maximal oxygen uptake (VO_2max) was determined using a progressive treadmill protocol with breath-by-breath gas analysis. The protocol involved 3-minute stages with velocity increments of 1 km/h until volitional exhaustion. Heart rate was monitored continuously using telemetry systems.

Anaerobic Power Testing: Peak power output and anaerobic capacity were assessed using the Wingate anaerobic test on a cycle ergometer. Participants performed a 30-second maximal effort against a resistance equivalent to 7.5% of body weight. Power output was recorded at 1-second intervals.

Strength Assessment: Isokinetic strength testing was conducted using a dynamometer for knee extension/flexion and hip extension/flexion at angular velocities of 60°/s and 240°/s. Peak torque, total work, and power values were recorded for both limbs.

Flexibility Measurements: Range of motion was assessed for hip flexion, hip extension, knee flexion, and ankle dorsiflexion using a digital goniometer. Measurements were taken in standardized positions with three trials averaged for analysis.

Performance Data: Competitive performance times were collected from official results over a 12-month period. Personal best times in appropriate hurdle distances (110m hurdles for males, 100m hurdles for females) were used for correlation analyses.

Statistical Analysis

Quantitative analyses were conducted using SPSS version 27.0 (IBM Corporation, Armonk, NY). Descriptive statistics were calculated for all variables, including means, standard deviations, and ranges. Normality of data distribution was assessed using the Shapiro-Wilk test. Pearson correlation coefficients were computed to examine relationships between physiological variables and performance outcomes. Independent t-tests were used to compare differences between hurdle athletes and control groups. Multiple regression analysis was employed to identify predictors of hurdle performance. Statistical significance was set at $p < 0.05$ for all analyses..

RESULTS

Participant Characteristics

Anthropometric and baseline characteristics of hurdle athletes and control participants are presented in Table 1. Hurdle athletes demonstrated significantly lower body fat percentage ($p < 0.01$) and higher lean muscle mass ($p < 0.001$) compared to controls, while height and total body mass showed no significant differences between groups.

Table 1. Participant Anthropometric Characteristics

Variable	Hurdle Athletes (n=24)	Controls (n=20)	p-value
Age (years)	17.2 ± 1.1	17.0 ± 1.2	0.62
Height (cm)	172.4 ± 8.7	170.8 ± 9.3	0.54
Body Mass (kg)	65.3 ± 9.8	67.1 ± 11.2	0.58
Body Fat (%)	12.7 ± 3.4	16.8 ± 4.1	0.001
Lean Mass (kg)	57.0 ± 8.1	51.9 ± 7.6	0.028

Physiological Parameters

Cardiovascular and metabolic characteristics revealed significant differences between hurdle athletes and controls across multiple parameters. Hurdle athletes demonstrated superior aerobic capacity (VO_2max: 52.6 ± 6.8 vs. 41.3 ± 5.2 mL/kg/min, $p < 0.001$) and enhanced anaerobic power output (738.4 ± 67.2 vs. 542.1 ± 89.6 W, $p < 0.001$).

Table 2. Physiological Characteristics Comparison

Parameter	Hurdle Athletes	Controls	p-value
VO_2max (mL/kg/min)	52.6 ± 6.8	41.3 ± 5.2	<0.001
Peak Power (W)	738.4 ± 67.2	542.1 ± 89.6	<0.001
Mean Power (W)	524.7 ± 51.3	398.2 ± 62.7	<0.001
Fatigue Index (%)	42.8 ± 8.1	51.2 ± 9.4	0.003

Strength and Power Characteristics

Isokinetic strength assessments revealed sport-specific adaptations in hurdle athletes, particularly in hip and knee extensor strength. Peak torque values for knee extension at 60°/s were significantly higher in hurdle athletes (242.6 ± 34.8 vs. 198.3 ± 29.1 Nm, $p < 0.001$). Hip flexor strength showed the most pronounced differences between groups (186.4 ± 28.7 vs. 142.1 ± 25.3 Nm, $p < 0.001$).

Flexibility and Range of Motion

Range of motion assessments demonstrated significant enhancements in hurdle athletes across multiple joint actions. Hip flexion range of motion was markedly superior in hurdle athletes (118.7 ± 8.4° vs. 98.2 ± 12.1°, $p < 0.001$), with similar patterns observed for hip extension and ankle dorsiflexion capabilities.

Table 3. Flexibility Measurements

Joint Action	Hurdle Athletes (°)	Controls (°)	p-value
Hip Flexion	118.7 ± 8.4	98.2 ± 12.1	<0.001
Hip Extension	24.6 ± 4.2	18.9 ± 3.8	<0.001
Knee Flexion	142.3 ± 7.1	135.8 ± 9.6	0.016
Ankle Dorsiflexion	28.4 ± 5.3	22.1 ± 4.7	<0.001

Performance Correlations

Correlation analyses revealed significant relationships between physiological parameters and hurdle performance times. VO_2max demonstrated a strong negative correlation with performance times ($r = -0.68$, $p < 0.01$), indicating that higher aerobic capacity was associated with faster race times. Peak anaerobic power showed the strongest correlation with performance ($r = -0.74$, $p < 0.001$), emphasizing the importance of explosive power capabilities.

Table 4. Correlations Between Physiological Variables and Performance

Variable	Correlation (r)	p-value
VO_2max	-0.68	0.003
Peak Power	-0.74	<0.001
Hip Flexion ROM	-0.56	0.021
Knee Extension Strength	-0.61	0.008
Hip Flexor Strength	-0.59	0.012

Multiple Regression Analysis

Multiple regression analysis identified peak anaerobic power, hip flexion range of motion, and VO_2max as significant predictors of hurdle performance, collectively explaining 67.3% of the variance in performance times ($R^2 = 0.673$, $p < 0.001$). Peak power emerged as the strongest individual predictor ($\beta = -0.412$, $p < 0.001$), followed by hip flexibility ($\beta = -0.298$, $p = 0.008$) and aerobic capacity ($\beta = -0.267$, $p = 0.019$).

DISCUSSION

The findings of this investigation provide comprehensive insight into the physiological adaptations characteristic of hurdle athletes, revealing a complex profile that extends beyond traditional sprint-specific adaptations. The observed superiority in anaerobic power output among hurdle athletes aligns with the explosive demands of hurdle clearance while maintaining maximum velocity. The strong correlation between peak power and performance ($r = -0.74$) underscores the critical importance of power development in hurdle training programs.

The enhanced aerobic capacity observed in hurdle athletes, while initially surprising given the anaerobic nature of the events, likely reflects the demands of training volume and the contribution of oxidative metabolism to recovery between training sessions and competitive efforts. The significant correlation between VO_2max and performance suggests that aerobic fitness may serve as a foundation for high-intensity training tolerance and performance consistency.

These findings extend previous research by providing quantitative evidence of the multifaceted physiological demands of hurdle events. The observed power output values align with those reported by Thompson & Lee (2019) in collegiate hurdle athletes, suggesting consistency across different populations. However, the aerobic capacity values exceeded those previously reported, potentially reflecting differences in training methodologies or population characteristics.

The flexibility data corroborate findings from Miller et al. (2021), who reported enhanced hip mobility in hurdle athletes. The current study extends these observations by demonstrating significant correlations between range of motion and performance outcomes, providing empirical support for flexibility training in hurdle development programs.

The identification of peak power, hip flexibility, and aerobic capacity as primary predictors of hurdle performance has significant implications for training methodology development. These findings suggest that effective hurdle training programs must integrate power development, flexibility enhancement, and aerobic conditioning in a systematic manner. The relative contributions of these factors (power > flexibility > aerobic capacity) provide guidance for training emphasis and periodization strategies.

The sport-specific adaptations observed in hurdle athletes, particularly the enhanced hip flexor strength and range of motion, highlight the importance of targeted preparation that addresses the unique biomechanical

demands of hurdle clearance. These adaptations likely facilitate efficient hurdle technique while reducing injury risk associated with repetitive high-velocity range of motion demands.

Several limitations should be acknowledged in interpreting these findings. The cross-sectional design precludes determination of causal relationships between physiological variables and performance outcomes. Additionally, the sample consisted of developing athletes from a single institution, potentially limiting generalizability to other populations or competition levels.

The correlational approach, while valuable for identifying relationships, cannot account for the complex interactions between physiological, technical, and psychological factors that influence hurdle performance. Future research should employ longitudinal designs to examine the development of these adaptations over time and their responsiveness to specific training interventions.

The study also did not account for individual technical proficiency, which may influence the relationship between physiological capabilities and performance outcomes. Elite hurdle technique may allow athletes to optimize the utilization of their physiological attributes, while technical deficiencies may limit performance despite superior physical capabilities.

CONCLUSION

This investigation provides comprehensive evidence of the specific physiological adaptations characteristic of hurdle athletes, demonstrating the multifaceted nature of performance demands in these events. The findings offer closure and clarity regarding the physiological profile required for hurdle success, reinforcing concepts from the biomechanical and training literature while providing quantitative foundation for evidence-based program development.

The research reinforces the importance of integrated training approaches that address the anaerobic power, aerobic capacity, and flexibility requirements identified as key performance determinants. The strong correlations between these physiological variables and competitive performance highlight the importance and potential impact of targeted training interventions addressing these specific adaptations.

The correlation of evidence for hypotheses from the introduction with discussion findings supports the premise that hurdle events require distinct physiological adaptations beyond those typically associated with sprint events. The identification of peak power as the primary performance predictor, combined with significant contributions from flexibility and aerobic capacity, provides a framework for optimizing training program design.

Future research should investigate the longitudinal development of these adaptations and examine the effectiveness of specific training interventions targeting the identified performance determinants. Additionally, investigation of the optimal integration of power, flexibility, and endurance training within periodized programs would enhance the practical application of these findings.

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Conflict of Interests

The authors declare no competing financial interests or personal relationships that could have influenced the work reported in this paper. All funding sources are academic in nature and do not present conflicts of interest with the research objectives or interpretation of findings.

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