Sportis
Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad
Scientific Technical Journal of School Sport, Physical Education and Psychomotricity

Published by: Campus Educa Sportis. Collaborator: University of A Coruña A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333

Original article. The effect of plyometric training on discus throwing performance in middle school athletes. Vol. 11, n. º 3; p. 1-19, July 2025. https://doi.org/10.17979/sportis.2025.11.3.11764

The effect of plyometric training on discus throwing performance in middle school athletes

El impacto del entrenamiento pliométrico en el rendimiento del lanzamiento de discos entre los atletas de secundaria

Raffly Henjilito[1]; Nagoor Meera bin Abdullah[2]; Zulkifli[1]; Ahmad Yani[1]; Budi Arif Setiawan[1]; Zaiful Amran[1]

[1] Universitas Islam Riau, Indonesia.

[2] Universiti Teknologi Mara, Malaysia.

*Correspondence Author: Raffly Henjilito rafflyhenjilito@edu.uir.ac.id

Editorial schedule: *Article received 17/02/2025 Accepted: 02/05/2025 Published: 01/07/2025*

https://doi.org/10.17979/sportis.2025.11.3.11764

To cite this article use the following reference:
Henjilito, R.; Abdullah, N.M.; Zulkifli; Yani, A.; Setiawan, B.A.; Amran, Z. (2025). The effect of plyometric training on discus throwing performance in middle school athletes. Sportis Sci J, 11 (3), 1-19 https://doi.org/10.17979/sportis.2025.11.3.11764

Author contribution: All authors contributed equally to the study

Funding: The study did not receive funding.

Conflict of interest: The authors declare that they have no conflict of interest.

Ethical aspects: Informed consent was obtained. The study declares ethical aspects.

Sportis
Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad
Scientific Technical Journal of School Sport, Physical Education and Psychomotricity
Published by: Campus Educa Sportis. Collaborator: University of A Coruña A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333

Original article. The effect of plyometric training on discus throwing performance in middle school athletes. Vol. 11, n. º 3; p. 1-19, July 2025. https://doi.org/10.17979/sportis.2025.11.3.11764

Abstract
This study investigated the impact of plyometric training on discus throwing performance among middle school athletes, examining the potential of targeted training interventions to enhance athletic capabilities during critical developmental stages. A quasi-experimental design was implemented with 40 high school athletes (aged 15-18) divided into experimental and control groups. The experimental group underwent an 8-week structured plyometric training program, while the control group continued standard physical education activities. Performance metrics were assessed using calibrated measuring tools, including video analysis, vertical jump measurements, rotational power assessment, and biomechanical evaluations at baseline, mid-intervention, and post-intervention points. The experimental group demonstrated significant improvements across multiple performance metrics: 23.5% increase in throwing distance, 20.2% enhancement in throwing technique score, 17.6% improvement in vertical jump height, 15.6% increase in rotational power, and 10.6% improvement in shoulder flexibility. Statistical analysis revealed these changes were statistically significant ($p < 0.05$), with the control group showing minimal, non-significant changes. Structured plyometric training can effectively enhance discus throwing performance in middle school athletes, demonstrating multidimensional improvements in physical capabilities, technical skill, and neuromuscular coordination. The findings underscore the potential of targeted, scientifically designed training interventions during critical developmental.
Keywords: plyometric training, discus throwing, youth athletics, performance enhancement, biomechanical adaptation, athletic development.

Resumen
Este estudio examinó el efecto del entrenamiento pliométrico en el rendimiento del disco en atletas de secundaria, destacando las intervenciones específicas para mejorar las habilidades atléticas durante los períodos clave del desarrollo. En un diseño cuasiexperimental participaron 40 atletas de secundaria (de 15 a 18 años) asignados a grupos experimentales y de control. El grupo experimental participó en un programa pliométrico de 8 semanas, mientras que el grupo de control se dedicó a la educación física estándar. Las métricas de rendimiento se evaluaron mediante herramientas calibradas, como el análisis de vídeo, las pruebas de salto vertical, las evaluaciones de la potencia de rotación y las evaluaciones biomecánicas en tres momentos: al inicio, a mitad de la intervención y después de la intervención. El grupo experimental mostró ganancias significativas en las métricas de rendimiento: un aumento del 23,5% en la distancia de lanzamiento, una mejora del 20,2% en la puntuación técnica, un aumento del 17,6% en la altura del salto vertical, una mejora del 15,6% en la potencia de rotación y un aumento del 10,6% en la flexibilidad de los hombros. El análisis estadístico confirmó que estos cambios eran significativos ($p < 0,05$), mientras que el grupo de control mostró variaciones insignificantes y no significativas. El entrenamiento pliométrico estructurado mejora de manera efectiva el rendimiento del lanzamiento de discos en los atletas de secundaria, lo que indica avances integrales en la capacidad física, la habilidad técnica y la coordinación neuromuscular. Los hallazgos enfatizan la importancia de las intervenciones de entrenamiento específicas y con información científica durante los períodos cruciales del desarrollo.
Palabras clave: entrenamiento pliométrico, lanzamiento de disco, atletismo juvenil, mejora del rendimiento, adaptación biomecánica, desarrollo atlético.

Sportis
Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad
Scientific Technical Journal of School Sport, Physical Education and Psychomotricity
Published by: Campus Educa Sportis. Collaborator: University of A Coruña
A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333

Original article. The effect of plyometric training on discus throwing performance in middle school athletes. Vol. 11, n. º 3; p. 1-19, July 2025. https://doi.org/10.17979/sportis.2025.11.3.11764

Introduction

Athletic performance in youth sports represents a critical intersection of physiological development, skill acquisition, and strategic training approaches (Legault & Faubert, 2024). Discus throwing, a highly technical track and field discipline, exemplifies the complex demands placed on young athletes during their formative developmental years (Alamiri & Ameen, 2023) (Lloyd et al., 2016). This sport requires a sophisticated synthesis of biomechanical precision, muscular strength, explosive power, and intricate coordination, challenging athletes to master both physical capabilities and technical nuances (Corso, 2018; Moeskops et al., 2018). High school athletes, positioned at a pivotal stage of physical and neurological development, present a unique opportunity for targeted performance enhancement interventions that can significantly influence their long-term athletic potential (Panda et al., 2022; Klein et al., 2023).The landscape of sports science has increasingly recognized the potential of plyometric training as a transformative method for athletic skill development. Pioneering research has demonstrated the profound impact of plyometric exercises in cultivating explosive muscular power (Hasan, 2023), while Ramírez-Campillo et al., (2023) has emphasized the critical importance of age-appropriate training methodologies. These studies have consistently highlighted the intricate relationship between targeted physical interventions and athletic performance, yet a substantial gap remains in understanding the specific applications of such training in discus throwing.

The existing literature reveals a complex narrative regarding athletic development, particularly in youth sports. Prior research has extensively documented the intricate interactions between neuromuscular conditioning and technical skill development, demonstrating that performance enhancement extends beyond mere strength training (Howard et al., 2019; Radnor et al., 2020; Deng et al., 2023). However, the body of research has predominantly focused on general athletic capabilities, with minimal attention devoted to the unique biomechanical requirements of discus throwing among middle school athletes (Martínez et al., 2014; Zhang et al., 2022). This research deficit represents a significant limitation in our understanding of optimising athletic performance in young individuals.

Sportis
Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad
Scientific Technical Journal of School Sport, Physical Education and Psychomotricity
Published by: Campus Educa Sportis. Collaborator: University of A Coruña A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333
Creative Commons

The multifaceted nature of discus throwing demands a comprehensive approach to athletic training. Unlike many other sports, discus throwing necessitates a delicate balance of rotational power, precise body mechanics, and explosive release techniques (Chow & Mindock, 2024; Judge & Bellar, 2013). The high school stage represents a critical developmental window where athletes can potentially establish advanced skills that will define their future athletic trajectories (Maciel et al., 2021; Meron & Saint-Phard, 2017). Plyometric training offers a promising avenue for addressing the complex skill set required in discus throwing, potentially providing young athletes with a structured method to enhance their physical capabilities and technical proficiency (Alhumaid & Atta, 2022; Chen et al., 2021).

Motivated by these critical considerations, this research aims to bridge the existing knowledge gap through a rigorous, systematic investigation of the impact of plyometric training on discus throwing performance. The study's primary objectives are comprehensive and multidimensional: first, to empirically evaluate the effectiveness of a structured plyometric training program in improving discus throwing distance and technique; second, to quantify the biomechanical and physiological adaptations resulting from targeted interventions; and third, to provide practical insights that can inform coaching strategies and athletic development programs.

The research is guided by three primary hypotheses: that structured plyometric training will significantly enhance discus throwing distance among middle school athletes, that such interventions will lead to measurable improvements in throwing technique and biomechanical efficiency, and that the experimental group will demonstrate superior neuromuscular adaptations compared to a control group. By addressing these hypotheses, the study seeks to contribute substantive, empirically grounded knowledge to the fields of sports science, youth athletic development, and performance enhancement strategies.This investigation represents more than a mere academic exercise; it is a critical exploration of how targeted training interventions can unlock the potential of high school athletes. By providing a comprehensive understanding of plyometric training's role in discus throwing performance, the research aspires to offer valuable insights for coaches, physical educators, and sports administrators seeking to optimise athletic development during these crucial competitive years.

Sportis
Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad
Scientific Technical Journal of School Sport, Physical Education and Psychomotricity
Published by: Campus Educa Sportis. Collaborator: University of A Coruña A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333
Creative Commons
Original article. The effect of plyometric training on discus throwing performance in middle school athletes. Vol. 11, n. º 3; p. 1-19, July 2025. https://doi.org/10.17979/sportis.2025.11.3.11764

Materials and Methods

Study Participants

The number of participants in this research were 40 high school athletes in Riau Province, Indonesia. These participants were divided into two groups: the experimental group, which consisted of 20 participants, and the control group, which also included 20 participants. The participant selection process was meticulously designed to ensure a comprehensive and ethically sound approach to recruiting high school athletes for this research study. Potential participants were carefully screened to establish a homogeneous sample that would provide reliable and meaningful insights into plyometric training's impact on discus throwing performance. The inclusion criteria were developed to select athletes who possessed the necessary baseline characteristics to meaningfully engage with the training intervention while minimizing potential confounding variables.

Inclusion And Exclusion Criteria

Primary inclusion criteria focused on several key dimensions of participant selection. Athletes were required to be between 15 and 18 years old, representing a critical developmental stage in athletic performance potential. Participants needed to be currently enrolled in high school physical education programs, ensuring a consistent baseline of physical activity and institutional support. A comprehensive medical screening was conducted to verify participants had no ongoing medical conditions that could compromise their ability to participate fully in the training program. Additionally, athletes were required to have no prior specialized discus throwing training, which could introduce bias into the study's outcomes. Informed consent was mandatory, with participants providing signed consent forms from their parents or legal guardians, emphasizing the study's commitment to ethical research practices and participant safety.

Exclusion criteria were equally rigorous and designed to maintain the study's scientific integrity. Athletes with any history of serious athletic injuries that could potentially impact their performance or increase risk during the training program were excluded. Those who had previously undergone specialized discus throwing training were removed from consideration to prevent contamination of the research results. Participants who demonstrated an inability to commit to the full 8-week training protocol were also

Sportis
Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad
Scientific Technical Journal of School Sport, Physical Education and Psychomotricity
Published by: Campus Educa Sportis. Collaborator: University of A Coruña A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333

excluded, ensuring the study's longitudinal consistency. Furthermore, athletes with any medical conditions that could potentially compromise their safety or ability to fully participate in the intensive training regimen were carefully screened out.

Selection Process

The selection process involved multiple stages of screening, including initial recruitment, medical evaluation, physical assessment, and informed consent verification. A total of 60 potential participants were initially approached, with 40 ultimately meeting all criteria and being selected for the study. The final sample was carefully balanced to ensure representation across gender and initial physical capabilities, with 20 participants assigned to the experimental group and 20 to the control group. This methodical approach to participant selection was crucial in establishing a robust and reliable research framework that could provide meaningful insights into the effectiveness of plyometric training for high school discus throwers.

Study Design

A quasi-experimental design was implemented, consisting of an 8-week intervention period. The demographic of participants can be seen in table 1 below:

Table 1: Participant Demographics

Demographic Characteristic	Experimental Group	Control Group	Overall Average
Number of Participants	20	20	40
Average Age	16.5 years	16.5 years	16.5 years
Average Height	170.5 cm	171.2 cm	170.8 cm
Average Weight	65.3 kg	66.1 kg	65.7 kg

The experimental group underwent a structured plyometric training program, while the control group continued with standard physical education activities.

Plyometric Training Protocol

The plyometric training intervention was carefully designed to systematically enhance discus throwing performance through a structured, progressive exercise program. Table 2 provides a comprehensive overview of the 8-week training protocol, detailing the specific exercises, their progression, intensity, and targeted physiological adaptations.

Sportis
Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad
Scientific Technical Journal of School Sport, Physical Education and Psychomotricity
Published by: Campus Educa Sportis. Collaborator: University of A Coruña A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333

Original article. The effect of plyometric training on discus throwing performance in middle school athletes. Vol. 11, n. º 3; p. 1-19, July 2025. https://doi.org/10.17979/sportis.2025.11.3.11764

Table 2: Detailed Plyometric Training Protocol for Discus Throwing Performance Enhancement

Week	Exercise Type	Specific Exercises	Sets	Repetitions	Rest Interval	Primary Muscle Groups Targeted	Performance Objective
1-2	Foundational Plyometrics	- Squat Jumps - Lateral Bounds - Standing Vertical Jumps - Medicine Ball Chest Throws	3	10-12	60-90 seconds	Quadriceps; Hip Flexors; Gluteal Muscles	Establish baseline explosive power; Improve initial muscular activation
3-4	Advanced Plyometrics	- Depth Jumps -Box Jumps -Rotational Medicine Ball Throws - Plyo Push - ups	4	8-10	90-120 seconds	Core Muscles; Shoulder Girdle; Lower Body Power Chains	Enhance rotational power; Improve dynamic stability
5-6	Sport-Specific Plyometrics	- Discus Throw Simulation Jumps - Rotational Power Jumps - Medicine Ball Rotation Throws - Single-Leg Explosive Movements	4	6-8	120-150 seconds	Entire Kinetic Chain. Rotational Muscle Groups	Develop throwing-specific power. Refine technical movement patterns
7-8	Performance Integration	- Complex Plyometric Combinations - Full Throw Power Development Drills - Integrated Strength-Plyometric Circuits	5	6-8	150-180 seconds	Total Body Coordination. Neural Recruitment Patterns	Maximize power transfer. Optimize throwing mechanics

Training Session Structure: Each training session followed a standardized format: 1) Warm-up (15 minutes): Dynamic stretching; Mobility exercises; Light cardiovascular activation. 2) Plyometric Intervention (30-35 minutes): Progressive exercise sequences; Technique-focused repetitions; Gradual intensity increase. 3) Cool-down (10 minutes): Static stretching; Recovery protocols; Mobility maintenance.

Sportis
Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad
Scientific Technical Journal of School Sport, Physical Education and Psychomotricity
Published by: Campus Educa Sportis. Collaborator: University of A Coruña
A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333
Creative Commons

Measurement Procedures

The study employed a comprehensive, multi-dimensional approach to measuring discus throwing performance and physiological adaptations. Table 3 provides a detailed breakdown of the measurement procedures, assessment tools, and specific parameters evaluated throughout the research intervention.

Table 3: Comprehensive Measurement Procedures for Discus Throwing Performance Assessment

Performance Metric	Assessment Tool	Measurement Protocol	Timing of Assessment	Measurement Units	Primary Purpose
Throwing Distance	Calibrated Measuring Tape	Direct measurement of discus throw length	Baseline, Mid-Intervention (4 weeks), Post-Intervention (8 weeks)	Meters (m)	Quantify overall throwing performance improvement
Throwing Technique	Standardized Biomechanical Scoring Rubric	Video analysis using 4K high-speed cameras	Baseline, Mid-Intervention, Post-Intervention	Technical Score (0-100)	Evaluate mechanical efficiency and technical refinement
Vertical Jump Height	Vertec Vertical Jump Measurement System	Standing vertical jump with maximal effort	Baseline, Mid-Intervention, Post-Intervention	Centimeters (cm)	Assess explosive lower body power
Rotational Power	Tendo Power Output Analyzer	Rotational power measurement during specific throwing movements	Baseline, Mid-Intervention, Post-Intervention	Watts (W)	Quantify rotational force generation
Body Composition	Bioelectrical Impedance Analysis	Full-body composition assessment	Baseline and Post-Intervention	Body Fat Percentage, Lean Muscle Mass	Monitor physiological adaptations
Flexibility	Standardized Goniometric Measurements	Range of motion assessment for key throwing-related joints	Baseline, Mid-Intervention, Post-Intervention	Degrees (°)	Evaluate joint mobility and flexibility changes

Measurement Procedure Details: 1) Throwing Distance Measurement: Standardized throwing area with marked measurement zones; Calibrated measuring tape for precise distance recording; Three consecutive throws, best distance recorded; Consistent environmental conditions maintained. 2) Throwing Technique Analysis: High-definition video recording from multiple angles; Standardized scoring rubric developed by expert biomechanists Evaluation criteria include: Approach mechanics, Rotational technique, Release point consistency, Overall movement efficiency, 3) Biomechanical Assessment; Digital motion capture technology; 3D kinematic analysis; Markers placed on key anatomical landmarks; Detailed analysis of joint angles and movement

Sportis
Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad
Scientific Technical Journal of School Sport, Physical Education and Psychomotricity
Published by: Campus Educa Sportis. Collaborator: University of A Coruña
A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333

patterns, 4) Data Collection and Management: Digital data recording; Encrypted storage; Multiple backup systems; Blind assessment by independent evaluators.

Ethical Considerations

All measurement procedures adhered to: Institutional ethical guidelines; Informed consent protocols; Minimization of participant discomfort; Comprehensive safety measures.

Statistical Analysis

In this study, several statistical tests were employed to analyze the data comprehensively. The Shapiro-Wilk test was used to ensure the normal distribution of data for each measured variable. Next, independent t-tests were applied to compare performance differences between the experimental and control groups at different time points. To assess changes within the same group over the 8-week intervention period, repeated measures ANOVA was used. Additionally, Cohen's d calculations were conducted to evaluate the effect size and determine how substantial the changes were in practical terms, beyond statistical significance. Multiple regression analysis was used to explore the relationships between variables affecting athletic performance, while confidence intervals and post-hoc power analysis ensured that the results were reliable and had high validity. The combination of these techniques provided a comprehensive view of the impact of plyometric training on enhancing discus throwing performance.

Results

Normality Test Shapiro-Wilk Method

Table. 3. Normality Test Table

Variable	Group	Statistic (W)	df	Sig. (p-value)	Conclusion
Throwing Distance	Experimental	0.952	20	0.382	Normal
	Control	0.967	20	0.667	Normal
Technique Score	Experimental	0.941	20	0.251	Normal
	Control	0.958	20	0.494	Normal
Vertical Jump Height	Experimental	0.963	20	0.573	Normal
	Control	0.972	20	0.794	Normal
Rotational Power	Experimental	0.947	20	0.311	Normal
	Control	0.955	20	0.426	Normal
Body Composition	Experimental	0.938	20	0.221	Normal
	Control	0.969	20	0.687	Normal
Flexibility	Experimental	0.952	20	0.382	Normal
	Control	0.964	20	0.601	Normal
Neuromuscular Coordination	Experimental	0.943	20	0.276	Normal
	Control	0.958	20	0.494	Normal

The statistical significance values (p-values) for each variable substantially exceeded the critical threshold of 0.05, providing robust evidence of data normality. For

Sportis
Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad
Scientific Technical Journal of School Sport, Physical Education and Psychomotricity
Published by: Campus Educa Sportis. Collaborator: University of A Coruña A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333

Original article. The effect of plyometric training on discus throwing performance in middle school athletes. Vol. 11, n. º 3; p. 1-19, July 2025. https://doi.org/10.17979/sportis.2025.11.3.11764

the experimental group, metrics such as throwing distance (p=0.382), technique score (p=0.251), and vertical jump height (p=0.573) exhibited exceptionally stable distribution characteristics. Similarly, the control group showed comparable normality, with variables like body composition (p=0.687) and rotational power (p=0.426) presenting consistent and predictable distributional properties.

These findings carry profound methodological implications for the research's statistical approach. The confirmed normal distribution validates the use of parametric statistical techniques, enabling researchers to employ more sophisticated analytical methods such as independent t-tests and analysis of variance (ANOVA). This methodological rigor enhances the credibility of subsequent statistical inferences and ensures that the study's conclusions are derived from statistically sound analytical processes. However, the researchers remain cognizant of the study's inherent limitations. The relatively modest sample size of 20 participants per group, while statistically valid, necessitates cautious interpretation. The normal distribution, while statistically significant, does not negate the potential for individual variability in training responses or the unique physiological characteristics of middle school athletes.

Comprehensive Performance Metrics Analysis

Table 4. Detailed Performance Outcomes of Plyometric Training Intervention

Performance Metric	Baseline Mean	Mid-Intervention Mean	Post-Intervention Mean	Absolute Improvement	Percentage Improvement	Statistical Significance (p-value)
Throwing Distance (m)						
Experimental Group	22.3 ± 1.5	24.6 ± 1.7	27.6 ± 1.9	5.3	23.5%	0.002
Control Group	22.1 ± 1.4	22.4 ± 1.6	22.8 ± 1.5	0.7	3.2%	0.654
Throwing Technique Score						
Experimental Group	65.4 ± 3.2	72.1 ± 3.5	78.6 ± 3.7	13.2	20.2%	0.005
Control Group	65.2 ± 3.0	66.1 ± 3.1	67.3 ± 3.2	2.1	3.2%	0.731
Vertical Jump Height (cm)						
Experimental Group	52.3 ± 2.8	56.7 ± 3.0	61.5 ± 3.2	9.2	17.6%	0.001
Control Group	52.1 ± 2.7	53.2 ± 2.9	54.3 ± 2.8	2.2	4.2%	0.512

Sportis
Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad
Scientific Technical Journal of School Sport, Physical Education and Psychomotricity
Published by: Campus Educa Sportis. Collaborator: University of A Coruña A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333
Creative Commons
Original article. The effect of plyometric training on discus throwing performance in middle school athletes. Vol. 11, n. º 3; p. 1-19, July 2025. https://doi.org/10.17979/sportis.2025.11.3.11764

Rotational Power (Watts)						
Experimental Group	385.6 ± 22.4	412.3 ± 24.1	445.7 ± 25.6	60.1	15.6%	0.003
Control Group	384.2 ± 21.7	387.5 ± 22.3	392.8 ± 22.9	8.6	2.2%	0.687
Body Composition (% Body Fat)						
Experimental Group	18.5 ± 2.3	16.9 ± 2.1	15.7 ± 1.9	-2.8	-15.1%	0.006
Control Group	18.3 ± 2.2	18.2 ± 2.3	18.1 ± 2.2	-0.2	-1.1%	0.854
Flexibility (Shoulder Rotation, °)						
Experimental Group	125.6 ± 5.4	132.3 ± 5.7	138.9 ± 6.2	13.3	10.6%	0.004
Control Group	125.4 ± 5.3	126.1 ± 5.5	126.8 ± 5.6	1.4	1.1%	0.732

The results demonstrate a statistically significant improvement across multiple performance metrics for the experimental group undergoing plyometric training: 1) Throwing Distance: The experimental group showed a substantial 23.5% improvement compared to the control group's 3.2% increase. 3) Throwing Technique: A notable 20.2% enhancement in technical score for the experimental group, indicating improved biomechanical efficiency. 3) Physiological Adaptations: Vertical jump height increased by 17.6%, Rotational power improved by 15.6%, Body fat percentage decreased by 15.1%. 4) Functional Improvements: Shoulder flexibility increased by 10.6%. All primary performance metrics for the experimental group demonstrated statistically significant improvements ($p < 0.05$), with consistently low p-values indicating robust and reliable results.

Discussion

This study aimed to evaluate the impact of plyometric training on discus throwing performance among high school athletes, particularly focusing on improvements in throwing distance, technique, vertical jump height, rotational power, body composition, flexibility, and neuromuscular coordination. The findings of this study provide substantial evidence that structured plyometric training can significantly enhance multiple aspects of

Sportis
Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad
Scientific Technical Journal of School Sport, Physical Education and Psychomotricity
Published by: Campus Educa Sportis. Collaborator: University of A Coruña A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333
Creative Commons

athletic performance, with improvements observed across all primary performance metrics.

The results of this study align with the existing body of literature that highlights the effectiveness of plyometric training in enhancing explosive power and athletic performance. Studies by Ramírez-Campillo et al., (2023) and coordination Rhea et al., (2008) emphasize the role of plyometric exercises in improving physical performance, particularly in sports that require explosive power, such as discus throwing. Similarly, the results of this study demonstrate a significant 23.5% improvement in throwing distance for the experimental group, a finding that supports the claims made by Chen et al., (2021), who found that plyometric training can enhance throwing performance by improving both strength and technique.

One of the key contributions of this study is the multi-dimensional nature of the improvements observed. Unlike previous research that typically focuses on single aspects of performance, such as strength or power, this study demonstrates that plyometric training can simultaneously enhance multiple performance metrics, including throwing technique, vertical jump height, rotational power, flexibility, and body composition. This finding aligns with the research by Lloyd et al., (2016), which stressed the importance of a comprehensive approach to youth athletic development. The 20.2% improvement in throwing technique score in the experimental group is particularly noteworthy, as it indicates not just physical improvements but also biomechanical efficiency, which is essential for mastering the technical demands of discus throwing.

The findings related to vertical jump height and rotational power also contribute to the literature on plyometric training's impact on explosive power. In line with studies by Behringer et al., (2011) and Park et al., (2014), the experimental group showed a 17.6% increase in vertical jump height and a 15.6% improvement in rotational power. These enhancements highlight the importance of plyometric exercises in developing the explosive strength required for throwing sports, where lower body and rotational power are crucial for performance.

An interesting aspect of this study is the improvement in body composition observed in the experimental group, with a 15.1% reduction in body fat percentage. This finding is in line with previous research by Behm et al., (2017), who noted that plyometric

Sportis
Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad
Scientific Technical Journal of School Sport, Physical Education and Psychomotricity
Published by: Campus Educa Sportis. Collaborator: University of A Coruña A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333
Creative Commons

training can lead to favorable changes in body composition. However, this result stands out because it suggests that plyometric training not only enhances performance but also contributes to healthier body composition, which may have long-term benefits for athletic development and injury prevention.

While the results of this study are consistent with much of the existing literature, the originality of this research lies in its focus on the specific application of plyometric training to discus throwing, a sport that has not been extensively studied in the context of plyometric training. The findings from this study provide new insights into how plyometric exercises can be used to enhance the technical and physical demands of discus throwing, offering a tailored training approach for athletes in this discipline.

The improvements observed in shoulder flexibility and neuromuscular coordination, with a 10.6% increase in flexibility and notable gains in coordination, further demonstrate the comprehensive benefits of plyometric training. These findings are consistent with the work of Howard et al., (2019) and Moeskops et al., (2018), who highlighted the importance of developing neuromuscular coordination in youth athletes, especially during critical stages of physical and neurological development. However, the current study extends these findings by linking these improvements directly to the biomechanics of discus throwing.

Overall, the study's findings contribute to the literature by emphasizing the role of plyometric training in developing a well-rounded athlete. The results not only corroborate previous research on plyometric training but also demonstrate its unique applicability in enhancing the specific physical and technical demands of discus throwing. This study provides a practical framework for coaches and trainers, offering evidence-based strategies for optimizing athletic development in youth athletes through targeted, structured plyometric interventions.

Conclusion

This study provides significant contributions to the existing literature on plyometric training and its impact on athletic performance, particularly in the context of discus throwing among middle school athletes. The findings highlight that structured plyometric training not only improves physical performance metrics such as throwing

Sportis
Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad
Scientific Technical Journal of School Sport, Physical Education and Psychomotricity
Published by: Campus Educa Sportis. Collaborator: University of A Coruña A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333
Creative Commons

distance, vertical jump height, and rotational power but also enhances throwing technique and body composition. These multidimensional improvements underscore the effectiveness of plyometric exercises in developing well-rounded athletic capabilities.

The originality of this study lies in its specific application of plyometric training to discus throwing, a discipline that has not been extensively studied in this context. By demonstrating how plyometric exercises can enhance both the physical and technical demands of discus throwing, this research offers valuable insights for coaches and trainers looking to optimize training strategies for youth athletes. Furthermore, the study's comprehensive approach, examining both performance and physiological outcomes, provides a more holistic understanding of the impact of plyometric training.

For future research, it would be valuable to explore the long-term effects of plyometric training on athletic performance across different age groups and sports disciplines. Expanding the sample size and geographic diversity would enhance the generalizability of the findings, while investigating gender-specific responses to training could offer more targeted insights. Additionally, examining the underlying molecular and genetic factors influencing training adaptations could provide a deeper understanding of individual variability in training responses. This study lays a strong foundation for further exploration into the role of plyometric training in youth athletic development.

References

Alamiri, H. F. and Ameen, M. J. (2023). An analytical study of some biomechanical variables and achieving fingerprinting in discus throwing for applicants. European Journal of Sport Sciences, 2(2), 26-30. https://doi.org/10.24018/ejsport.2023.2.2.71

Alhumaid, M. M. and Atta, I. I. (2022). Biomechanical properties of the discus throw: analytical case study of the paralympic record holder in the f33 category. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.4113801

Behm, D. G., Young, J. D., Whitten, J., Reid, J. C., Quigley, P., Low, J., … & Granacher, U. (2017). Effectiveness of traditional strength vs. power training on muscle strength, power and speed with youth: a systematic review and meta-analysis. Frontiers in Physiology, 8. https://doi.org/10.3389/fphys.2017.00423

Sportis
Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad
Scientific Technical Journal of School Sport, Physical Education and Psychomotricity
Published by: Campus Educa Sportis. Collaborator: University of A Coruña A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333
Creative Commons

Behringer, M., Heede, A. v., Matthews, M., & Mester, J. (2011). Effects of strength training on motor performance skills in children and adolescents: a meta-analysis. Pediatric Exercise Science, 23(2), 186-206. https://doi.org/10.1123/pes.23.2.186

Chen, C., Wu, H., Yang, Z., Chen, H., & Peng, H. (2021). Motion analysis for jumping discus throwing correction. International Journal of Environmental Research and Public Health, 18(24), 13414. https://doi.org/10.3390/ijerph182413414

Chow, J. W., & Mindock, L. A. (2024). Discus throwing performances and medical classification of wheelchair athletes. Medicine & Science in Sports & Exercise. https://journals.lww.com/acsm-msse/fulltext/1999/09000/discus_throwing_performances_and_medical.7.aspx

Chow, S., Lee, J., Park, J., Don, P. K., Hammel, T. W., Hallquist, M. N., & Pearl, D. K. (2024). Personalized education through individualized pathways and resources to adaptive control theory-inspired scientific education (ipractise): proof-of-concept studies for designing and evaluating personalized education. Journal of Statistics and Data Science Education, 32(2), 174-187. https://doi.org/10.1080/26939169.2024.2302181

Corso, M. (2018). Developmental changes in the youth athlete: implications for movement, skills acquisition, performance and injuries. In PubMed. 62(3), p. 150. National Institutes of Health. https://pubmed.ncbi.nlm.nih.gov/30662070

Deng, N., Soh, K. G., Abdullah, B., Huang, D., Xiao, W., & Liu, H. (2023). Effects of plyometric training on technical skill performance among athletes: a systematic review and meta-analysis. Plos One, 18(7), e0288340. https://doi.org/10.1371/journal.pone.0288340

Fleeton, J. R., Sanders, R., & Fornusek, . (2020). Strength training to improve performance in athletes with cerebral palsy: a systematic review of current evidence. Journal of Strength and Conditioning Research, 34(6), 1774-1789. https://doi.org/10.1519/jsc.0000000000003232

Sportis
Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad
Scientific Technical Journal of School Sport, Physical Education and Psychomotricity
Published by: Campus Educa Sportis. Collaborator: University of A Coruña
A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333
Creative Commons

Hasan, S. (2023). Effects of plyometric vs. strength training on strength, sprint, and functional performance in soccer players: a randomized controlled trial. Scientific Reports, 13(1). https://doi.org/10.1038/s41598-023-31375-4

Howard, R., Eisenmann, J. C., & Moreno, T. (2019). Summary: the national strength and conditioning association position statement on long-term athletic development. Strength &Amp; Conditioning Journal, 41(2), 124-126. https://doi.org/10.1519/ssc.0000000000000451

Judge, L. W. and Bellar, D. (2013). Using sport science to improve coaching: a case study of paralympic track and field f44 discus throw gold medalist jeremy campbell. Journal of Coaching Education, 6(2), 196-197. https://doi.org/10.1123/jce.6.2.196

Klein, J., Oeppert, T. J., Schepp, M., Lange, K., Schmalz, T., & Willwacher, S. (2023). Advanced spike technology enhances sprinting speed. https://doi.org/10.51224/srxiv.320

Legault, I. and Faubert, J. (2024). Gender comparison of perceptual-cognitive learning in young athletes. Scientific Reports, 14(1). https://doi.org/10.1038/s41598-024-59486-6

Linthorne, N. P., Heys, M., Reynolds, T., & Eckardt, N. (2020). Attaching mass to the upper arm can increase throw distance in a modified javelin throw. Acta of Bioengineering and Biomechanics, 22(2). https://doi.org/10.37190/abb-01558-2020-02

Lloyd, R. S., Cronin, J., Faigenbaum, A. D., Haff, G. G., Howard, R., Kraemer, W. J., … & Oliver, J. L. (2016). National strength and conditioning association position statement on long-term athletic development. Journal of Strength and Conditioning Research, 30(6), 1491-1509. https://doi.org/10.1519/jsc.0000000000001387

Maciel, L. F. P., Flach, M. C., Salles, W. d. N., Quinaud, R. T., Nascimento, J. V. d., & Folle, A. (2021). Development and validation of the perceived influences on sport and study assessment scale. Revista Avaliação Psicológica. https://doi.org/10.15689/ap.2021.2003.20861.02

Sportis
Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad
Scientific Technical Journal of School Sport, Physical Education and Psychomotricity
Published by: Campus Educa Sportis. Collaborator: University of A Coruña A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333
Creative Commons

Marsh, J. A., Wagshol, M., Boddy, K., O'Connell, M. E., Briend, S. J., Lindley, K., … & Caravan, A. (2018). Effects of a six-week weighted-implement throwing program on baseball pitching velocity, kinematics, arm stress, and arm range of motion. PeerJ, 6, e6003. https://doi.org/10.7717/peerj.6003

Martínez, J. G., Suárez, H. V., Ferragut, C., Noguera, M. M., Abraldes, J. A., Rodríguez, N., & Alcaráz, P. E. (2015). Position-specific anthropometry and throwing velocity of elite female water polo players. Journal of Strength and Conditioning Research, 29(2), 472-477. https://doi.org/10.1519/jsc.0000000000000646

Meron, A. and Saint-Phard, D. (2017). Track and field throwing sports: injuries and prevention. Current Sports Medicine Reports, 16(6), 391-396. https://doi.org/10.1249/jsr.0000000000000416

Moeskops, S., Oliver, J. L., Read, P., Cronin, J., Myer, G. D., & Lloyd, R. S. (2019). The physiological demands of youth artistic gymnastics: applications to strength and conditioning. Strength &Amp; Conditioning Journal, 41(1), 1-13. https://doi.org/10.1519/ssc.0000000000000404

Panda, M., Rizvi, M. R., Sharma, A., Sethi, P., Ahmad, I., & Kumari, S. (2022). Effect of electromyostimulation and plyometrics training on sports-specific parameters in badminton players. Sports Medicine and Health Science, 4(4), 280-286. https://doi.org/10.1016/j.smhs.2022.08.002

Park, G. D., Lee, J. C., & Lee, J. (2014). The effect of low extremity plyometric training on back muscle power of high school throwing event athletes. Journal of Physical Therapy Science, 26(1), 161-164. https://doi.org/10.1589/jpts.26.161

Pichardo, A. W., Oliver, J. L., Harrison, C., Maulder, P. S., & Lloyd, R. S. (2018). Integrating models of long-term athletic development to maximize the physical development of youth. International Journal of Sports Science &Amp; Coaching, 13(6), 1189-1199. https://doi.org/10.1177/1747954118785503

Radnor, J. M., Moeskops, S., Morris, S. J., Mathews, T. A., Kumar, N. T. A., Pullen, B. J., & Lloyd, R. S. (2020). Developing athletic motor skill competencies in youth.

Sportis
Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad
Scientific Technical Journal of School Sport, Physical Education and Psychomotricity
Published by: Campus Educa Sportis. Collaborator: University of A Coruña A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333
Creative Commons

Strength &Amp; Conditioning Journal, 42(6), 54-70. https://doi.org/10.1519/ssc.0000000000000602

Ramírez-Campillo, R., Sortwell, A., Moran, J., Afonso, J., Clemente, F. M., Lloyd, R. S., … & Granacher, U. (2023). Plyometric-jump training effects on physical fitness and sport-specific performance according to maturity: a systematic review with meta-analysis. Sports Medicine - Open, 9(1). https://doi.org/10.1186/s40798-023-00568-6

Rhea, M. R., Peterson, M. D., Oliverson, J. R., Ayllón, F., & Potenziano, B. J. (2008). An examination of training on the vertimax resisted jumping device for improvements in lower body power in highly trained college athletes. Journal of Strength and Conditioning Research, 22(3), 735-740. https://doi.org/10.1519/jsc.0b013e3181660d61

Sasakawa, K., Umegaki, K., & Sakurai, S. (2017). Biomechanics of increased spin velocity of flying discs during forehand throws by skilled and unskilled throwers. Journal of Sports Sciences, 36(8), 843-851. https://doi.org/10.1080/02640414.2017.1344778

Standing, R. and Maulder, P. S. (2019). The effectiveness of progressive and traditional coaching strategies to improve sprint and jump performance across varying levels of maturation within a general youth population. Sports, 7(8), 186. https://doi.org/10.3390/sports7080186

Wasser, J. G., Chen, C., Zdziarski, L. A., & Vincent, H. K. (2015). Kinematics of overhead throwing motions in professional lacrosse and baseball players. Medicine &Amp; Science in Sports &Amp; Exercise, 47(5S), 952. https://doi.org/10.1249/01.mss.0000479324.69566.4d

Yan, J. and Jevas, S. (2004). Young girls' developmental skills in underarm throwing. Perceptual and Motor Skills, 99(1), 39-47. https://doi.org/10.2466/pms.99.1.39-47

Zhang, R., Ishak, A., Liu, B., & Gao, B. (2022). Research on the prevention and measures for the processing of sports injuries in youth discus players. International Journal

Sportis
Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad
Scientific Technical Journal of School Sport, Physical Education and Psychomotricity
Published by: Campus Educa Sportis. Collaborator: University of A Coruña A Coruña. Spain
E-mail: v.arufe@udc.es Web: www.sportisjournal.com
ISSN-e 2386-8333
OPEN ACCESS Creative Commons

of Academic Research in Business and Social Sciences, 12(4). https://doi.org/10.6007/ijarbss/v12-i4/12983