



## The effect of progressive plyometric training on sprint performance and flexibility in college baseball athletes

*Los efectos del entrenamiento pliométrico progresivo en el rendimiento de velocidad y la flexibilidad en el béisbol universitario*

### Authors

Taufik Rihatno <sup>1</sup>  
Sri Nuraini <sup>1</sup>  
Samsudin <sup>1</sup>  
Sujarwo <sup>1</sup>  
Oman Unju Subandi <sup>1</sup>  
Shela Ginajar <sup>1</sup>  
Dadan Resmana <sup>1</sup>  
Kevin Ramadhan <sup>2</sup>

<sup>1</sup>University Negeri Jakarta (Indonesia)

<sup>2</sup>Univeristas Pamulang (Indonesia)

Corresponding author:  
trihatno@unj.ac.id

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### Abstract

**Introduction:** Baseball performance relies on short sprint ability and lower-limb flexibility, yet evidence for structured plyometric training in collegiate players is limited.

**Objective:** This study examined an 8-week progressive plyometric program on linear sprint performance and flexibility in collegiate baseball athletes.

**Methodology:** Twenty-four collegiate baseball players, all regularly training, were randomly assigned to a Plyometric Training Group (PTG; n = 12) or Control Training Group (CTG; n = 12). The PTG completed an 8-week plyometric program, three sessions per week, including hurdle jumps, multi jumps, and drop jumps in 3–6 sets per exercise, while the CTG continued usual baseball and strength training without additional interventions.

**Results:** The PTG showed significant improvements in sprint performance, with 10-m time decreasing from  $1.987 \pm 0.125$  s to  $1.728 \pm 0.132$  s ( $p = 0.05$ ), 20-m from  $3.342 \pm 0.162$  s to  $3.146 \pm 0.143$  s ( $p = 0.05$ ), and 30-m from  $4.578 \pm 0.121$  s to  $4.120 \pm 0.1087$  s ( $p = 0.05$ ). Sit-and-reach flexibility increased from  $20.42 \pm 2.56$  cm to  $22.40 \pm 1.82$  cm ( $p = 0.05$ ). The CTG showed no statistically significant changes ( $p = 0.124-0.422$ ).

**Discussion:** These findings indicate that progressive plyometric training produces meaningful gains in acceleration and lower-limb flexibility beyond regular training alone.

**Conclusions:** An 8-week progressive plyometric program can be recommended as an effective conditioning strategy to enhance sprint performance and flexibility in university-level baseball athletes.

### Keywords

Plyometric, sprint, flexibility, baseball.

### Resumen

**Introducción:** El rendimiento en el béisbol depende de la capacidad de sprint corto y la flexibilidad de las extremidades inferiores; sin embargo, la evidencia del entrenamiento pliométrico estructurado en jugadores universitarios es limitada.

**Objetivo:** Este estudio examinó un programa pliométrico progresivo de 8 semanas sobre el rendimiento en sprint lineal y la flexibilidad en atletas universitarios de béisbol.

**Metodología:** Veinticuatro jugadores universitarios de béisbol, todos con entrenamiento regular, fueron asignados aleatoriamente a un Grupo de Entrenamiento Pliométrico (GTP; n = 12) o a un Grupo de Entrenamiento Control (GCT; n = 12). El GTP completó un programa pliométrico de 8 semanas, con tres sesiones semanales, que incluían saltos con vallas, saltos múltiples y saltos con caída en 3-6 series por ejercicio, mientras que el GCT continuó con su entrenamiento habitual de béisbol y fuerza sin intervenciones adicionales. **Resultados:** El PTG mostró mejoras significativas en el rendimiento del sprint, con una disminución del tiempo de 10 m de  $1,987 \pm 0,125$  s a  $1,728 \pm 0,132$  s ( $p = 0,05$ ), 20 m de  $3,342 \pm 0,162$  s a  $3,146 \pm 0,143$  s ( $p = 0,05$ ), y 30 m de  $4,578 \pm 0,121$  s a  $4,120 \pm 0,1087$  s ( $p = 0,05$ ). La flexibilidad de sentarse y alcanzar aumentó de  $20,42 \pm 2,56$  cm a  $22,40 \pm 1,82$  cm ( $p = 0,05$ ). El CTG no mostró cambios estadísticamente significativos ( $p = 0,124-0,422$ ). **Discusión:** Estos hallazgos indican que el entrenamiento pliométrico progresivo produce mejoras significativas en la aceleración y la flexibilidad de las extremidades inferiores, en comparación con el entrenamiento regular por sí solo.

**Conclusiones:** Se puede recomendar un programa pliométrico progresivo de 8 semanas como una estrategia de acondicionamiento eficaz para mejorar el rendimiento en velocidad y la flexibilidad en atletas de béisbol universitarios.

### Palabras clave

Pliometría; sprint; flexibilidad; béisbol.

## Introduction

Baseball is a sport that integrates a variety of complex physical and technical elements including throwing, hitting, catching, and sprinting (Kim et al., 2024). The sequence of physical components involved in baseball not only demands advanced motor skills but also requires strategic understanding to effectively interpret game situations (Matsuda et al., 2022; Papadakis et al., 2021). As a competitive sports, baseball necessitates an optimal combination of strength, speed, flexibility, endurance, and coordination to achieve high-level performance (Aydin et al., 2015; Crotin et al., 2023; Matsuda et al., 2022).

Hitting the ball is a crucial element in baseball, as it significantly influences a team's chances of winning a game (Carboch et al., 2022). However, sprinting ability represents another key component that can directly impact the outcome of a baseball games (Magrini et al., 2018). Offensively, sprinting allows players to reach bases safely after hitting the ball, thereby avoiding elimination by the opposing team (Marquardt et al., 2018). While defensively, it enables players to chase down batted balls, make critical catches, or stop opposing runners from advancing to the next base (Sekine, 2016). Moreover, flexibility plays an essential role in enhancing movement efficiency and reducing the risk of injury, particularly during batting and fielding actions (Phrathep et al., 2023). Therefore, developing sprinting speed and flexibility should be considered a training priority for baseball players, alongside improving hitting skills.

Several training programs that aim to improve sprint performance and flexibility have been developed and documented in recent years including interval training (Lee et al., 2023; Wang et al., 2023), resistance training (Gao et al., 2024; Zhang et al., 2023), and mobility exercise (Cetin et al., 2020). Plyometric training is a widely adopted methods to enhance physical conditioning due to its its accessibility, time efficiency, and relatively low risk of injury (Ramirez-campillo et al., 2022; Ramirez-Campillo et al., 2023). Findings from previous studies have demonstrated that sport-specific plyometric training can significantly enhance physical performance in football players (Moran et al., 2024) and handball players (Jakšić et al., 2023). Recent research has shown that a systematically designed plyometric training program can lead to significant improvements in sprint performance among collegiate-level futsal athletes (Irawan et al., 2024). Additionally, structured plyometric training has been found effective in enhancing flexibility, particularly among athletes in sports such as badminton (Hassan et al., 2023), and volleyball athletes (Patel et al., 2022).

The effectiveness of specific plyometric training has been well-documented in enhancing physical performance across various sports disciplines, including football, futsal, badminton, volleyball, and handball. However, the effectiveness of specific plyometric training among baseball athletes particularly at the collegiate level remains limited and underexplored. Therefore, this study aims to examine the impact of structured plyometric exercises on sprint performance and flexibility in collegiate baseball players. By utilizing the findings of previous studies that show the effectiveness of plyometric training in improving physical performance, this study is expected to provide a significant contribution to specific training programs for student-level baseball athletes, which to date have rarely been explored.

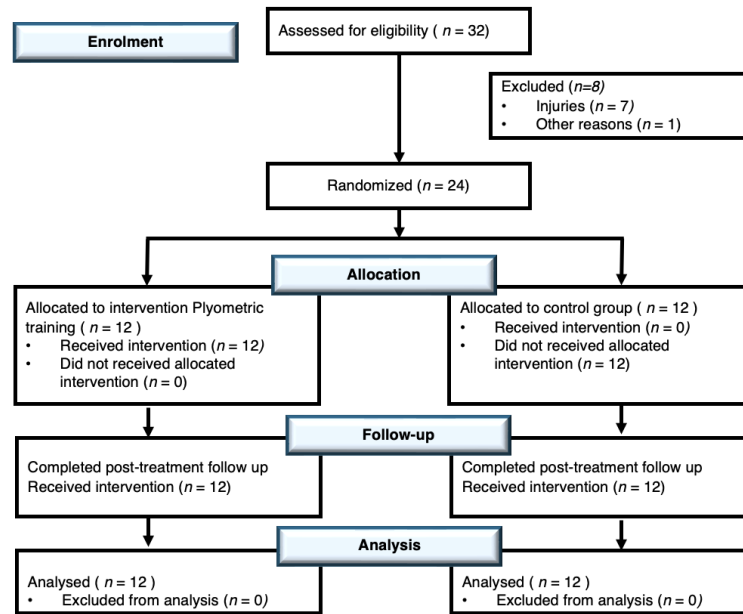
## Method

### *Participants*

This study employed an experimental design with a pre-test and post-test approach involving one intervention group with a control group. Thies approach was selected to evaluate changes in sprint performance at 10-meters, 20-meters, and 30-meters, and flexibility performances among collegiate-level baseball players before and after a progressive plyometric interventions. This study involved twenty four collegiate-level baseball players aged 19–22 years who actively trained and competed in national collegiate baseball tournaments. Sample selection was conducted using purposive sampling with inclusion criteria requiring participants to be actively engaged in baseball training at least three times per week for the past two years. Additionally, participants were required to have no history of injuries, particularly in the knee or ankle and to be willing to complete the entire intervention program and participate in all planned assessments. This research has been approved by the Ethics Committee of Jakarta State University with No. 616/UN39.14/PT.01.05/V/2025.



Figure 1. Participants flow chart



## Procedure

### Pre-test Procedures

Participants underwent anthropometric measurements, including body mass, stature, body mass index, and body fat percentage. A stadiometer was used to measure stature, while body mass, body mass index, and body fat percentage were assessed using the Omron KaradaScan Body Fat Monitor. Following the anthropometric measurements, participants performed a flexibility performance using sit and reach test, followed by sprint performance at 10-meters, 20-meters, and 30-meters measured with the Smartspeed system for precise timing. Pre-test assessments were conducted during week 0 to establish baseline data for subsequent analysis.

### Intervention Procedures

Participants were randomly assigned to two groups: Plyometric Training Group (PTG) and the Control Training Group (CTG). The intervention group underwent a specifically designed 8-week plyometric training program following their daily training program, progressing from the first to the eighth week. Before initiating the program, participants received a detailed explanation of the research procedures and were instructed on proper plyometric exercise techniques to minimize the risk of injury. Meanwhile the control group continued their daily training program as prescribed by the coach without additional plyometric training intervention. The detailed plyometric training program for the experimental group is presented in table 1.

Table 1. Progressive Training Program for Experimental Group

Week number	Exercise Type	Rest between series (s)	Repetitions of Set	Number of Sets	Total Volume (Reps x Sets)
1	Hurdle Jump	120 s	8	3	24
	Multi Jumps	120 s	8	3	24
	Drop Jump	120 s	8	3	24
2	Hurdle Jump	120 s	10	3	30
	Multi Jumps	120 s	10	3	30
	Drop Jump	120 s	10	3	30
3	Hurdle Jump	90 s	10	4	40
	Multi Jumps	90 s	10	4	40
	Drop Jump	90 s	10	4	40
4	Hurdle Jump	90 s	12	4	48
	Multi Jumps	90 s	12	4	48
	Drop Jump	90 s	12	4	48

5	Hurdle Jump	75 s	12	5	60
	Multi Jumps	75 s	12	5	60
	Drop Jump	75 s	12	5	60
6	Hurdle Jump	75 s	14	5	70
	Multi Jumps	75 s	14	5	70
	Drop Jump	75 s	14	5	70
7	Hurdle Jump	60 s	14	6	84
	Multi Jumps	60 s	14	6	84
	Drop Jump	60 s	14	6	84
8	Hurdle Jump	60 s	16	6	96
	Multi Jumps	60 s	16	6	96
	Drop Jump	60 s	16	6	96

### Post-test Procedures

Participants completed post-test assessments for 10-meters, 20-meters, and 30-meters sprint performance, along with flexibility testing in the ninth week without further anthropometric measurements. Sprint performance was measured using Smartspeed system, while flexibility performance was assessed with the sit and reach test. This post-test evaluation aimed to compare performance with baseline data and determine the effectiveness of the intervention.

### Data analysis

The data analysis was performed using SPSS version 24. All variables were presented using descriptive statistics, expressed as mean  $\pm$  standard deviation (SD). The Shapiro-Wilk test was utilized to assess the normality of the data. To examine differences between group over time, a Two-Way Repeated Measures ANOVA was conducted, enabling the evaluation of interaction effects between group assignment and time (pre-test and post-test). A significance level of  $P < 0.05$  was set to determine statistically significant differences between groups. Changes in sprint performance and flexibility within each group from pre-test to post-test were analyzed using paired sample t-tests.

## Results

Table 2 presents the baseline characteristics of the plyometric group (PTG) and the control group (CTG). At baseline, the two groups were comparable across all measured variables. Mean age was  $19.49 \pm 1.91$  years in PTG and  $18.90 \pm 2.62$  years in CTG ( $p = 0.53$ ; Cohen's  $d = 0.26$ ), while body mass was  $68.30 \pm 11.40$  kg and  $69.50 \pm 12.30$  kg, respectively ( $p = 0.81$ ;  $d = -0.10$ ). Stature was also similar between groups ( $170.10 \pm 8.50$  cm vs.  $169.80 \pm 9.30$  cm for PTG and CTG;  $p = 0.94$ ;  $d = 0.03$ ), as were BMI values ( $23.50 \pm 3.30$  vs.  $24.20 \pm 2.80$   $\text{kg}\cdot\text{m}^{-2}$ ;  $p = 0.58$ ;  $d = -0.23$ ) and body fat percentage ( $14.80 \pm 3.50\%$  vs.  $15.30 \pm 4.10\%$ ;  $p = 0.75$ ;  $d = -0.13$ ). All  $p$ -values were non-significant, and all effect sizes were small ( $|d| < 0.30$ ), indicating no meaningful baseline differences between the plyometric and control groups.

Table 2. Anthropometric and Training Characteristic of Participants

Variables	Groups		P-value	Levene p
	PTG	CTG		
Age (years)	$19.5 \pm 1.9$	$18.9 \pm 2.6$	0.534	0.347
Body Mass (kg)	$68.3 \pm 11.4$	$69.5 \pm 12.3$	0.807	0.561
Body Height (cm)	$170.1 \pm 8.5$	$169.8 \pm 9.3$	0.935	0.654
Body Mass Index ( $\text{kg}/\text{m}^2$ )	$23.5 \pm 5.3$	$24.4 \pm 6.8$	0.581	0.504
Body Fat Percentage (%)	$14.8 \pm 3.5$	$15.3 \pm 4.1$	0.751	0.986

Table 2 summarizes the changes in sprint performance and flexibility from pretest to posttest for the plyometric training group (PTG) and the control group (CTG). Within groups, the PTG showed statistically significant improvements in all sprint tests. For the 10-m sprint, mean time decreased from  $1.99 \pm 0.43$  s to  $1.58 \pm 0.44$  s ( $p = 0.034$ ; Cohen's  $d = -0.70$ ). A similar pattern was observed for the 20-m sprint, where time decreased from  $3.34 \pm 0.42$  s to  $2.95 \pm 0.42$  s ( $p = 0.042$ ;  $d = -0.67$ ). The largest improvement was found in the 30-m sprint, with times improving from  $4.58 \pm 0.51$  s to  $4.12 \pm 0.48$  s ( $p = 0.003$ ;  $d = -1.09$ ). The PTG also demonstrated a significant increase in flexibility, as indicated by the sit-and-reach



test, improving from  $20.42 \pm 3.37$  cm to  $23.42 \pm 3.84$  cm ( $p = 0.044$ ;  $d = 0.65$ ). In contrast, the CTG did not show significant changes over time in any variable. Sprint 10-m performance changed only slightly from  $1.95 \pm 0.48$  s to  $1.91 \pm 0.51$  s ( $p = 0.801$ ), and 20-m sprint times changed from  $3.46 \pm 0.56$  s to  $3.37 \pm 0.45$  s ( $p = 0.760$ ). The 30-m sprint improved minimally from  $4.62 \pm 0.40$  s to  $4.53 \pm 0.43$  s ( $p = 0.889$ ). Sit-and-reach scores increased from  $20.82 \pm 4.27$  cm to  $21.02 \pm 4.06$  cm but remained non-significant ( $p = 0.862$ ).

Table 3. Performance variables of pretest and posttests for PTG (n = 12) and CTG (n = 12).

Variables	Groups	Pretest	Posttest	Within group, p	Between Group, p	Effect Size
Sprint 10-meters (s)	PTG	$1.99 \pm 0.43$	$1.58 \pm 0.44$	0.034*	0.236	-0.48
	CTGI	$1.95 \pm 0.48$	$1.91 \pm 0.51$	0.801		
Sprint 20-meters (s)	PTG	$3.34 \pm 0.42$	$2.95 \pm 0.42$	0.042*	0.260	-0.46
	CTGI	$3.46 \pm 0.56$	$3.37 \pm 0.45$	0.760		
Sprint 30-meters (s)	PTG	$4.58 \pm 0.51$	$4.12 \pm 0.48$	0.031*	0.067	-0.76
	CTGI	$4.62 \pm 0.40$	$4.53 \pm 0.43$	0.889		
Sit and Reach (cm)	PTG	$20.42 \pm 3.37$	$23.42 \pm 3.84$	0.041*	0.122	0.63
	CTGI	$20.82 \pm 4.27$	$21.02 \pm 4.06$	0.862		

Note.  $p < 0.05$  indicates a significant within-group difference between pretest and posttest.

## Discussion

The primary objective of this study was to evaluate the effectiveness of an eight-week progressive plyometric training on sprint performance and flexibility in collegiate-level baseball athletes. This study highlights that a progressive plyometric training consisting of 3–6 sets of exercises over eight weeks can significantly enhance 10-meter, 20-meter, and 30-meter sprint performance as well as flexibility in collegiate-level baseball athletes.

Compared with previous research, the present study focused on collegiate-level athlete and an intervention period of eight weeks, whereas previous studies has mostly examined elite athletes and used longer training durations (Branquinho et al., 2022; Matuszczyk et al., 2025). The results of this study suggest that progressive plyometric training can significantly improve several key physical components that are important for optimal performance in collegiate -level baseball players. In particular, this study indicates that progressive plyometric training effectively enhances sprint performance across various distances, suggesting that plyometric exercises contribute not only to the initial acceleration phase but also to the attainment of maximal running speed (Matuszczyk et al., 2025). Our results are consistent with previous research reporting improvements in sprint performance over both short and longer distances following supplementary plyometric training interventions (Ferley et al., 2020). Similarly, the improvements in flexibility observed in the intervention group align with prior studies demonstrating the effectiveness of plyometric training in enhancing flexibility among elite-level athletes (Hassan et al., 2023; Patel et al., 2022).

The neurophysiological mechanisms underlying sprint performance improvements resulting from plyometric training remain a subject of ongoing investigation. However, several studies have provided a comprehensive understanding of these processes (Andrade et al., 2018; Sánchez et al., 2020). Previous studies suggest that enhanced sprint performance is associated with adaptations in the Parallel Elastic Component (PEC) and the Contractile Component (CC), which are key biomechanical structures involved in force production (Matuszczyk et al., 2025). During the muscle stretching phase, potential energy is stored within the muscle's elastic tissues and subsequently released during the concentric contraction, leading to a significant increase in concentric force output (Matuszczyk et al., 2025).

The types of plyometric exercises implemented in this study represent varied neuromuscular stimuli with distinct force directions, each contributing uniquely to biomechanical adaptations and sprint performance. Drop jumps, for instance, primarily emphasize vertical force production and the development of upward explosive power, yet their contribution to horizontal speed enhancement tends to be relatively limited (Loturco et al., 2023). Conversely, hurdle jumps and multi jumps involve more complex horizontal and lateral movement patterns, making them more effective in enhancing acceleration capacity and maintaining sprinting speed (Elnaggar, 2022). In line with previous findings, the combination of vertical and horizontal elements in plyometric training activates a broader range of muscle groups,



thereby contributing to a more comprehensive improvement in sprint performance (Loturco et al., 2018; Moran et al., 2024).

Flexibility performance in this study exhibited a similar trend to sprint performance, with the intervention group undergoing progressive plyometric training demonstrating more substantial improvements compared to the control group. These findings suggest that progressive plyometric training not only enhances explosive capacity and running speed but also contributes to improved mobility and muscular elasticity, particularly in the lower-body muscle groups. The improvement in flexibility performance is associated with the activation of the stretch-shortening cycle (SSC) mechanism, which sequentially integrates the eccentric and concentric phases (Barrio et al., 2023; Thapa et al., 2021). This mechanism allows elastic energy to be stored during muscle stretch and subsequently released during contraction, thereby enhancing movement efficiency and functionally increasing joint range of motion (Ramirez-Campillo et al., 2023; Sánchez et al., 2020).

These findings reinforce the functional value of progressive plyometric training in baseball, a sport that demands rapid acceleration, agility, and explosive movements when sprinting to bases or fielding the ball (Lee et al., 2023; Magrini et al., 2018). The application of progressive overload and gradual intensity increases has been shown to yield significant improvements in athletes' physical performance. The absence of significant performance improvements in the control group suggests that regular training alone, without the inclusion of specific exercise modalities, is insufficient to enhance key physical components. This finding underscores the importance of integrating plyometric training into the physical conditioning programs of collegiate-level baseball athletes.

However, several limitations should be acknowledged. The eight-week intervention period may not fully capture the long-term effects or the sustainability of the physiological adaptations induced by the training program. Moreover, the limited sample size and the homogeneity of participants restrict the generalizability of the findings to athletes of different ages, skill levels, and sporting disciplines. This study also did not assess other important performance variables such as muscular strength, explosive power, or neuromuscular responses, which play a critical role in overall athletic performance. Therefore, future research involving a broader participant base, longer intervention periods, and more comprehensive performance assessments is highly recommended to enhance external validity and provide a more holistic understanding of the effects of progressive plyometric training.

## Conclusions

The results of this study indicate that a 8-week progressive plyometric training program significantly enhances sprint performance and flexibility in collegiate-level baseball athletes. These improvements reflect neuromuscular and biomechanical adaptations resulting from the progressive overload and explosive nature of the exercises. Plyometric drills such as hurdle jumps, multi jumps, and drop jumps not only strengthen the muscle's elastic and contractile components but also improve range of motion and movement efficiency. These findings highlight the effectiveness of incorporating progressive plyometric training into physical conditioning programs to optimize explosive power, speed, and mobility key components of athletic performance in sports like baseball.

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### Authors' and translators' details:

Taufik Rihatno	trihatno@unj.ac.id	Author
Sri Nuraini	srinuraini@unj.ac.id	Author
Samsudin	samsudin@unj.ac.id	Author
Sujarwo	sujarwo@unj.ac.id	Author
Oman Unju Sobandi	oman@unj.ac.id	Author
Shela Ginanjar	shelaginanjar@unj.ac.id	Author
Dadan Resmana	dadanresmana@unj.ac.id	Author
Kevin Ramadhan	dosen03068@unpam.ac.id	Author