Physical Education Theory and Methodology
Теорія та методика фізичного виховання

ISSN 1993-7989 (print)
ISSN 1993-7997 (online)
ISSN-L 1993-7989

Original Scientific Article

The Effectiveness of Varying Plyometric Training Intensities in Improving Punching Force and Muscular Fitness in Adolescent Boxers

Shailendra Singh[1ABCD], Lata Apara Deori[1BCD], Purnima Chetry[2BD], Mohamed Prince Manamkandath[3BD], Yuni Astuti[4CD], Sohom Saha[1ABCD] and Awesh Khati[1ABD]

[1]Lakshmibai National Institute of Physical Education
[2]ITM University
[3]Tamil Nadu Physical Education and Sports University
[4]Universitas Negeri Padang

Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Corresponding Author: Yuni, Astuti, e-mail: yuniastuti@fik.unp.ac.id
Accepted for Publication: September 20, 2025
Published: September 30, 2025

DOI: 10.17309/tmfv.2025.5.19

Abstract

Background. The sport of boxing requires a great deal of explosive strength, particularly punching force and muscular fitness, which are crucial during adolescence due to the rapid development of neuromuscular systems. Plyometric training is known to enhance certain physical attributes. However, limited comparative research exists on the effectiveness of different plyometric training intensities in adolescent boxers.

Objectives. The study aimed to examine and assess the impact of high- and low-intensity plyometric training protocols on the punching force and muscle fitness of teenage male boxers.

Materials and Methods. Thirty adolescent male boxers, aged 13-17 years, each with at least three years of training experience, were chosen at random to be divided into three groups: Low-Intensity Plyometric Training (LIPT), High-Intensity Plyometric Training (HIPT), and an Active Control Group (ACG). The LIPT and HIPT groups engaged in an 8-week plyometric program conducted thrice weekly, with progressive overload, while the ACG continued with their standard boxing training routines. Pre- and post-intervention assessments included punching force, upper and lower body power, and muscular endurance, measured through validated sport-specific tests. Statistical analysis involved paired t-tests, ANOVA, and Bonferroni post-hoc tests.

Results. Both the LIPT and HIPT groups demonstrated statistically significant improvements ($p < .001$) across all measured variables, while the ACG exhibited no substantial changes. The HIPT group achieved the highest gains, with punching force increasing by 17.54 %, muscular endurance by 31.77 %, lower body power by 21.02 %, and upper body power by 9.96%. Effect sizes were large ($\eta^2_p \geq .65$), indicating strong treatment effects.

Conclusions. Plyometric training, especially at high intensities, significantly enhances punching force and muscular fitness in adolescent boxers. These findings support the integration of progressively overloaded plyometric exercises into youth boxing training programs, providing a scientifically grounded approach to improving performance during a critical developmental phase.

Keywords: plyometric training, punching force, muscular fitness, adolescent boxers, training intensity, explosive strength.

Introduction

Boxing is a high-intensity combat sport that demands the integration of speed, strength, endurance, coordination, and tactical decision-making. Among these, punching force and muscle fitness are important variables that have a big impact on sports performance, particularly throughout adolescence, a developmental period marked by continuous neurological and physiological changes. Improving these qualities is crucial for maximizing performance in a given activity as well as reducing the chance of injury, which is especially crucial for teenage athletes who are still going through biological maturation. As athletes enter adolescence, a time of rapid neuromuscular and hormonal development, the application of scientifically based training techniques becomes even more crucial (Lloyd & Oliver, 2012). The ability of plyometric training (PT), a training technique that uses rapid eccentric-concentric muscle contractions to capitalize on the stretch-shortening cycle (SSC), to enhance explosive power has garnered a lot of attention lately (Markovic & Mikulic, 2010; Ramírez-Campillo et al., 2014).

It is commonly known that plyometric training can enhance neuromuscular coordination, muscle power, and movement velocity, all essential elements of a successful punching performance (Moran et al., 2018). Punching is a biomechanical motion in boxing that requires a coordinated kinetic chain that begins with the lower body, travels through the trunk, and ends with the upper limbs extending explosively (Loturco et al., 2014). These chains are specifically stimulated by plyometric activities, including medicine ball tosses, depth leaps, and bounding, which enhance the rate of force development (RFD) and the effectiveness of energy transfer between joints and muscle groups (Suchomel et al., 2016). In boxing, where powerful, quick, and repetitive movements are necessary for both offensive and defensive success, these performance improvements are especially advantageous.

Due to their greater plasticity and potential for long-term athletic development, adolescents can benefit immensely from carefully thought-out and appropriately dosed plyometric therapies (Ford et al., 2010). To prevent maladaptive consequences, including overtraining, neuromuscular exhaustion, and injury, they also need strict supervision (Myer et al., 2011). While conventional strength training helps increase overall force generation, the quality that sets top boxers apart from their contemporaries is explosiveness, or the capacity to produce force rapidly. This demand is specifically satisfied by plyometric training, which emphasizes reactive movement patterns and quick contraction mechanics that are more functionally compatible with punching motions (Beato et al., 2020) Scopus, and Institute for Scientific Information Web of Knowledge. Results: In total, 7 eligible studies were identified based on the following results: First, practitioners can use different inertia intensities (eg, 0.03–0.11 kg·m2. Furthermore, boxing requires maintaining high-intensity efforts throughout several rounds rather than just putting up a single, powerful movement. Plyometric exercises that increase muscle strength and neuromuscular resilience can therefore have a substantial compounding impact on boxing performance as a whole (Slimani et al., 2016a).

Plyometric training's efficacy is not uniform and can vary significantly depending on the type, direction, intensity, and volume of exercises employed (De Villarreal et al., 2009). For example, plyometric activities that are vertical and those that are horizontal activate various neuromuscular pathways and can result in differing performance changes. Similarly, focusing on upper-body plyometric exercises like plyometric push-ups and overhead medicine ball throws can be very helpful for increasing hand speed and punching power in boxing, but these workouts are usually overlooked in youth training programs (Chelly et al., 2010). Similar benefits could be obtained by strategically combining upper- and lower-body plyometrics; however, the best ways to combine these techniques are still unknown, particularly when dealing with adolescent populations that differ in terms of physical maturity, experience, and training tolerance (Lloyd et al., 2011).

Despite the potential advantages and increasing use of plyometric training, there is a dearth of comparative empirical data assessing the precise effects of various plyometric regimens on the muscular fitness and punching force of teenage male boxers. There is a substantial study gap regarding youth training tailored to boxing because the majority of previous studies have concentrated on adult elite athletes or generic athletic populations. Furthermore, in younger age groups, differences in frequency, progression models, and training specificity have not been well examined (Harries et al., 2012). This makes it more difficult for coaches and sports scientists to create performance-enhancing programs for teenage boxers that are well-informed and supported by data.

Given this background, the current study's objective is to determine how well various plyometric training methods may improve the muscular strength and punching power of teenage male boxers. Through a controlled training session, this study compares several plyometric drill configurations in an effort to determine the best approach for enhancing sport-specific results in young boxers. The study is to further theoretical knowledge in the domains of youth fitness and sports science while also offering coaches, athletic trainers, and development specialists' useful advice. It is expected that the results of the study will help establish sport-specific training programs, developmentally appropriate, and performance-enhancing, specifically designed to meet the demands of adolescent combat athletes.

Materials and bethods

Purpose of the Study

The primary objective of the present investigation was to look into how various plyometric training regimens affected the muscular fitness and punching force of teenage male boxers. The research aimed to identify whether variations in plyometric training intensity (low vs high) would produce significant improvements in sport-specific performance variables relevant to boxing, particularly during adolescence, a period of critical neuromuscular development.

Participants

For the study, 30 adolescent male boxers, ages 13 to 17, were enlisted. All of the participants were actively engaged in regular practice sessions and had undergone at least three years of formal boxing instruction. Before the intervention, each participant underwent a medical screening and was cleared by a certified sports physician, ensuring they were fit for high-intensity physical activity. Based on a randomized allocation process, the participants were equally divided into three groups (n = 10 per group): Group A, which performed low-intensity plyometric training (LIPT); Group B, which engaged in high-intensity plyometric training (HIPT); and Group C, the active control group, which proceeded with standard boxing exercises without any extra plyometric exercises. Institutional permission was obtained before

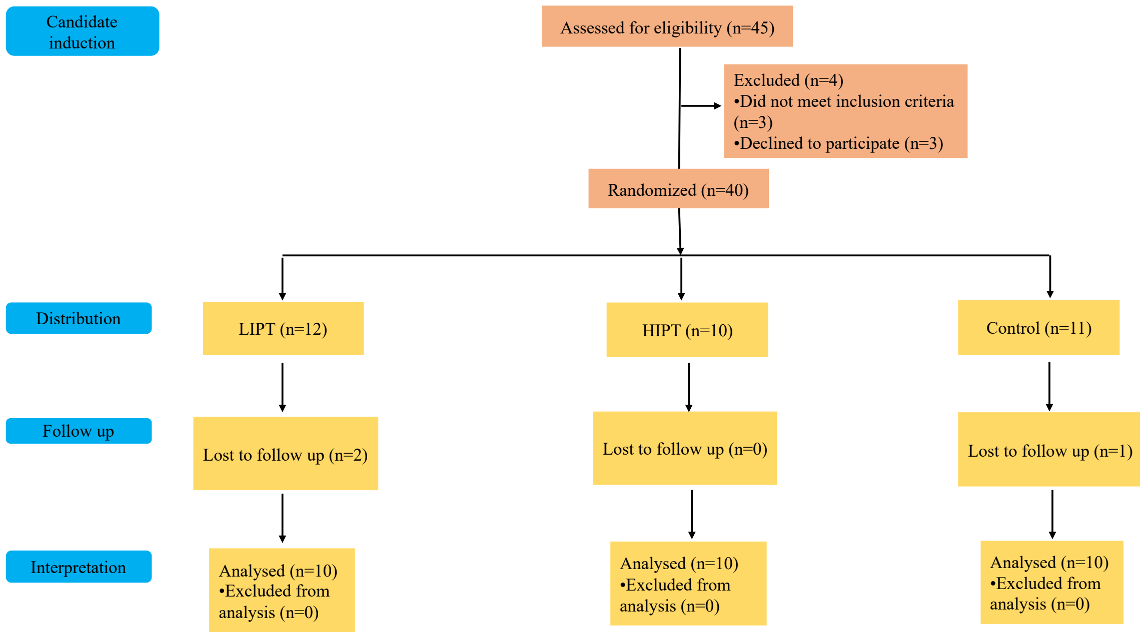

Fig. 1. Inclusion and Exclusion Criteria

initiating the research. All procedures involving human participants were reviewed and approved by the appropriate authority (Certificate No. 266/Kheuk/Esth/2025) and all procedures followed the Declaration of Helsinki's guidelines ("World Medical Association Declaration of Helsinki," 2013).

Table 1. Demographic Characteristics for Participants

Characteristics	LIPT	HIPT	ACG
Age	15.10 ± 1.19	14.90 ± 1.44	14.60 ± 1.42
Experience	3.40 ± .51	3.10 ± .73	3.30 ± .67
Height	151.70 ± 5.55	152.40 ± 4.35	152.80 ± 5.09
Weight	52.90 ± 4.45	52.20 ± 4.73	51.40 ± 3.74
BMI	23.05 ± 2.38	22.50 ± 2.23	22.05 ± 1.79

Research Design

This study utilized an active control group in a pre-test-post-test experimental design. The total duration of the intervention was eight weeks, during which the experimental groups (Group A and Group B) participated in three plyometric training sessions per week. This design allowed for an evaluation of both within-group progress over time and between-group differences in outcomes related to punching force and muscular fitness following the specific training interventions.

Variables and Measurements

Punching Force: Punching force was measured using a force-measuring punching bag or force transducer system, calibrated to record impact in Newtons. Participants performed three maximal straight punches using their dominant hand, with sufficient rest between attempts to minimize fatigue. The highest force value obtained was used for analysis. This approach replicates the sport-specific punching action in boxing and aligns with protocols used in previous combat-sport research (Loturco et al., 2014).

Upper Body Power: The Medicine Ball Chest Throw Test, a popular field-based method for evaluating upper limb explosive strength, was employed to measure upper body power. Participants sat with their backs against a wall to restrict lower-body involvement and were instructed to forcefully throw a 3-kg medicine ball forward from chest level using both hands. The maximum horizontal distance reached during the attempts was recorded as the final score (Sayers & Lorenzetti, 2020a).

Lower Body Power: Using the Countermovement Jump (CMJ), a popular and proven test for determining lower limb explosive strength, lower body power was evaluated. The Countermovement Jump was used to quantify the height of vertical jumps (CMJ). The participants were instructed to stand erect, put their hands on their hips, descend rapidly, and then jump as high as they could. After two familiarization trials, three test trials were carried out. The CMJ has consistently demonstrated high reliability and sensitivity in evaluating lower-body power in adolescent athletes (Khati et al., 2025).

Muscular Endurance: Muscular endurance was used to assess core endurance with the Plank Hold Test, a valid technique. With their bodies in a straight line from head to heels, participants performed a prone plank on their forearms, and the duration held without losing form was recorded in seconds. Standardized protocols ensured consistency and safety (Tong, Wu, & Nie, 2014).

Statistical Analysis

All collected data were analyzed using SPSS software. For each variable, descriptive statistics including the mean

Table 2. Structured Eight-Week Training Program for Plyometric and Active Control Groups: Frequency, Intensity, Progression, and Training Objectives

Group A: Low-Intensity Plyometric Training (LIPT)						
Week(s)	**Frequency (Days/Week)**	**Session Duration**	**Intensity**	**Exercise Type**	**Progression Focus**	**Training Objective**
1-2	3	40 min	Low to Moderate	Jumping Jacks, Double-Leg Hops, Bounding	Basic technique, low reps and sets	Develop foundational plyometric skills and coordination
3-4	3	40-45 min	Moderate	Same exercises with slight variation	Increase repetitions and add simple variations	Improve neuromuscular control and movement efficiency
5-6	3	45 min	Moderate	Enhanced drills with moderate complexity	Add sets, increase Reps, raise complexity	Enhance agility and dynamic stability
7-8	3	45-50 min	Moderate to High	Combination drills from previous weeks	Progressive overload via reps, sets, and complexity	Optimize performance with improved movement economy
Group B: High-Intensity Plyometric Training (HIPT)						
Week(s)	**Frequency (Days/Week)**	**Session Duration**	**Intensity**	**Exercise Type**	**Progression Focus**	**Training Objective**
1-2	3	40 min	High	Depth Jumps, Single-Leg Hops, Med Ball Slams	Initial exposure to high-intensity loading	Develop explosive power and reactive strength
3-4	3	45 min	High	Increased volume of intense drills	Increase intensity and complexity	Improve stretch-shortening cycle efficiency
5-6	3	50 min	Very High	Complex drills combining power & balance	Increased load, challenging unilateral moves	Enhance muscular strength and acceleration capability
7-8	3	50-55 min	Very High	Advanced drills combining previous weeks	Maximize intensity and recovery optimization	Peak power output and movement precision
Group C: Active Control Group (Non-Plyometric)						
Week(s)	**Frequency (Days/Week)**	**Session Duration**	**Intensity**	**Exercise Type**	**Progression Focus**	**Training Objective**
1-8	3	40 min	Regular (Moderate)	Routine boxing drills	No progression applied	Maintain standard training without plyometric adaptation

and standard deviation (mean ± SD) were computed. To assess significant changes within each group from pre-test to post-test, paired sample t-tests were performed. Differences among the three groups were examined using a one-way ANOVA, followed by the Bonferroni post-hoc test to identify specific group comparisons. Effect sizes for ANOVA were categorized as small (less than 0.06), moderate (0.06 to 0.13), or large (0.14 or greater), based on partial eta-squared ($\eta^2 p$), following the criteria outlined by (Saha et al., 2025) optimizing training methodologies is crucial for improving players' repeated sprint ability, sustaining effort throughout matches, and enhancing overall performance. While hockey requires significant anaerobic power for explosive movements and sprints, the intermittent nature of the game also places considerable demands on aerobic systems for recovery between high-intensity efforts. \nObjectives. This study aimed to evaluate and compare the effectiveness of Small-Sided Games (SSG. All statistical analyses were carried out with a significance level set at $p < 0.05$, in order to determine whether the training interventions had any meaningful effects.

Results

Table 3 indicates the findings of a paired sample t-test used to evaluate the differences in punching force and muscle fitness variables (muscular endurance, lower body power, and upper body power) across the three groups (LIPT, HIPT, and ACG) both prior to and following the intervention. Across all variables, the LIPT and HIPT groups showed notable improvements. In punching force, both LIPT ($t = -22.53$, $p = .000$) and HIPT ($t = -19.96$, $p = .000$) showed highly significant gains, while the ACG showed no significant change ($t = -1.00$, $p = .343$). For upper body power, significant improvements were found in LIPT ($t = -8.33$, $p = .000$) and HIPT ($t = -6.87$, $p = .000$), but not in ACG ($t = -1.63$, $p = .137$). Lower body power increased markedly in both LIPT ($t = -63.94$, $p = .000$) and HIPT ($t = -29.05$,

Table 3. Paired Sample t-Test Results: Impact of Plyometric Training on Punch Power and Muscle Fitness in Adolescents

Variables	Group	SE	t	p
Punching Force	LIPT	.90	-22.53	.000
	HIPT	1.74	-19.96	.000
	ACG	.40	-1.00	.343
Upper Body Power	LIPT	.05	-8.33	.000
	HIPT	.08	-6.87	.000
	ACG	.01	-1.63	.137
Lower Body Power	LIPT	.06	-63.94	.000
	HIPT	.21	-29.05	.000
	ACG	.29	-2.19	.056
Muscular Endurance	LIPT	.47	-20.16	.000
	HIPT	.52	-35.33	.000
	ACG	.37	-1.07	.3.9

p = .000), with marginal change in ACG (t = -2.19, p = .056). Muscular endurance also improved significantly in LIPT (t = -20.16, p = .000) and HIPT (t = -35.33, p = .000), whereas ACG showed no significant improvement (t = -1.07, p = .39). While the active control group did not see any appreciable increases, these findings imply that both low- and high-intensity plyometric training regimens were successful in improving punching force and muscular fitness.

Table 4 presents the ANOVA results comparing the effects of LIPT, HIPT, and ACG on punching force and muscle fitness variables, including adolescents boxers' muscular endurance, lower body strength, and upper body power. In terms of punching force, LIPT showed a 10.17 % improvement (from 201.40 ± 3.40 to 221.90 ± 3.57), while HIPT exhibited a greater increase of 17.54 %, compared to a negligible change in the active control group (0.20 %). The ANOVA results for this variable revealed a strong influence attributed to group differences (F = 222.85, p = .000, η^2_p = .94), indicating a large effect size. Similarly, upper body power improved by 7.52 % in LIPT and 9.96 % in HIPT, while the active control group showed a minimal increase (0.33 %). The observed group differences were statistically significant (F = 25.71, p = .000, η^2_p = .65). For lower body power, LIPT and HIPT groups improved by 14.57 % and 21.02 %, respectively, with only a 2.19 % increase in ACG. This variable also showed significant between-group effects (F = 177.00, p = .000, η^2_p = .92). Lastly, muscular endurance increased substantially in LIPT (16.60 %) and HIPT (31.77 %), while ACG showed only a 0.67 % change. The statistical outcome for muscular endurance was also highly significant (F = 382.40, p = .000, η^2_p = .96). Overall, both plyometric training methods significantly enhanced all measured variables, with HIPT consistently producing the highest gains.

Table 5. Post Hoc Comparisons of Various Training Groups on Adolescent Boxers' Muscle Fitness and Punching Force

Variables	(I) Group	(J) Group	Mean Difference (I-J)	p
Punching Force	LIPT	HIPT	-4.70	.104
		ACG	14.75	.000
	HIPT	ACG	19.45	.000
Upper Body Power	LIPT	HIPT	-.11	1.000
		ACG	.23	.311
	HIPT	ACG	.35	.057
Lower Body Power	LIPT	HIPT	-1.86	.035
		ACG	1.51	.111
	HIPT	ACG	3.38	.000
Muscular Endurance	LIPT	HIPT	-4.50	.000
		ACG	3.30	.005
	HIPT	ACG	7.80	.000

Table 5 presents the Bonferroni post hoc comparisons among LIPT, HIPT, and ACG for punching force and muscle fitness variables. For punching force, HIPT showed a significantly greater improvement than ACG (mean difference = 19.45, p = .000), and LIPT also significantly

Table 4. Results of an ANOVA Comparing the Impact of Various Plyometric Training Methods on Adolescent Boxers' Punching Force and Muscle Fitness

Variables	Groups	Pre data	Post data	Δ (%)	SS	F	p	η²p
Punching Force	LIPT	201.40 ± 3.40	221.90 ± 3.57	10.17	3002.70	222.5	.000	.94
	HIPT	198.90 ± 5.44	233.80 ± 5.02	17.54				
	ACG	196.70 ± 5.81	197.10 ± 6.41	0.20				
Upper Body Power	LIPT	5.98 ± .29	6.43 ± .24	7.52	.90	25.71	.000	.65
	HIPT	6.02 ± .33	6.62 ± .32	9.96				
	ACG	5.96 ± .38	5.98 ± .37	0.33				
Lower Body Power	LIPT	28.88 ± 1.17	33.09 ± 1.17	14.57	80.49	177.00	.000	.92
	HIPT	29.73 ± 1.67	35.98 ± 1.40	21.				
	ACG	29.15 ± 1.82	29.79 ± 2.01	2.19				
Muscular Endurance	LIPT	57.80 ± 2.44	67.40 ± 1.71	16.60	810.13	382.40	.000	.96
	HIPT	57.90 ± 2.42	76.30 ± 2.58	31.77				
	ACG	59.10 ± 2.02	59.50 ± 2.01	0.67				

outperformed ACG (p = .000), though the LIPT and HIPT differences were not statistically significant. (p = .104). In upper body power, none of the pairwise comparisons reached statistical significance, though the HIPT vs ACG comparison approached it (p = .057), indicating a possible trend. For lower body power, There was a notable distinction discovered between HIPT and ACG (p = .000), while LIPT vs HIPT showed a modest but significant difference (p = .035), and LIPT vs ACG remained nonsignificant (p = .111). Regarding muscular endurance, all group comparisons were statistically significant: LIPT vs HIPT (p = .000), LIPT vs ACG (p = .005), and HIPT vs ACG (p = .000), with HIPT demonstrating the greatest gains. These Bonferroni-adjusted results confirm the greater effectiveness of plyometric interventions, particularly HIPT, in enhancing muscular performance variables among adolescent boxers.

Discussion

The present investigation examined how well various plyometric training methods may improve teenage boxers' punching force and muscular fitness. The findings demonstrate that both low-intensity and high-intensity plyometric training interventions produced significant improvements across all measured variables, with high-intensity plyometric training showing superior effects compared to low-intensity training and the active control group. Both plyometric training groups showed significant improvements in punching force, which is consistent with earlier studies showing the value of plyometric workouts in combat sports. The basic principles of plyometric training, which use the increased punching force caused by the stretch-shortening cycle, speed up force production and explosive power (Loturco et al., 2016). The stretch-shortening cycle pre-stretches the muscle-tendon complex, allowing muscles to produce more force. The concentric phase of movement allows for the rapid release of elastic energy that has been stored (Davies et al., 2015).

The superior performance of high-intensity plyometric training in enhancing punching force supports the principle of training specificity and intensity-dependent adaptations. High-intensity plyometric exercises likely provided a greater stimulus for neuromuscular adaptations, including higher motor neuron firing frequency, better intermuscular synchronization, and improved motor unit recruitment (Chelly et al., 2009). These adaptations are especially crucial to boxing, as the fast generation of peak force is essential for successful punching performance. The Medicine Ball Chest Throw Test shows that plyometric training is beneficial in increasing upper limb explosive strength because it enhances upper body power. This finding is consistent with research by Fernandez-Fernandez et al. (2013)comprising core strength, elastic resistance and medicine ball exercises. Both groups (control and training, who stated considerable progress in upper extremity power following plyometric training interventions. The medicine ball chest throw test specifically targets the kinetic chain involved in punching movements, making it a highly relevant assessment for boxing performance. Improved neuromuscular coordination and the upper body musculature's greater capacity to produce force are probably the factors behind these improvements. Plyometric training promotes adaptations in both the nervous system and musculoskeletal system, leading to improved synchronization of muscle fiber recruitment and enhanced power output (Sayers & Lorenzetti, 2020b). The larger progress seen in the high-intensity group indicates that how hard you train is key to getting the best results.

The Countermovement Jump test, which measures the significant gains in lower body power, confirms the proven value of plyometric training in building explosive strength in the lower limbs. These results are consistent with a wealth of research showing that plyometric training improves jump performance among various athletic populations (Slimani et al., 2016b). The countermovement jump is particularly relevant for boxing, as lower body power contributes significantly to punch force generation through the kinetic chain. The mechanisms responsible for these improvements include enhanced stretch-shortening cycle function, improved muscle-tendon unit stiffness, as well as enhanced neuronal activity in the working muscles. Plyometric training has been shown to optimize the storage and utilization of elastic energy, leading to more efficient force production during explosive movements (Lloyd et al., 2012). The findings from the group that trained at higher intensity clearly show that how hard you push yourself plays a key role in boosting power in the lower body. The significant enhancements in muscular endurance, as measured by the Plank Hold Test, demonstrate the multifaceted benefits of plyometric training beyond power development. Core endurance is fundamental to boxing performance, as it provides the stability and force transmission necessary for effective punching technique and sustained performance during competition (Tong, Wu, Nie, et al., 2014)would contribute to core muscle fatigue. Nine male recreational runners were recruited for two reasons; (1. The improvements in muscular endurance following plyometric training can be attributed to several physiological adaptations, including enhanced neuromuscular efficiency, improved muscle fiber recruitment patterns, and increased metabolic capacity of the working muscles. While plyometric training is primarily associated with power development, the repetitive nature of the exercises and the demands placed on stabilizing muscles contribute to endurance improvements.

High-intensity plyometric training's superior performance on every variable examined offers crucial information on plyometric training's dose-response relationship in adolescent athletes. High-intensity plyometric exercises likely provide a greater stimulus for both neural and morphological adaptations, leading to more pronounced improvements in performance measures. This finding is consistent with the principle of progressive overload, which implies that training adaptations are maximized when the training stimulus surpasses the system's current capacity. It is crucial to remember that adolescent populations require careful consideration of training load management and injury prevention strategies when implementing high-intensity plyometric training. While the current study demonstrated the safety and effectiveness of high-intensity plyometric training, proper progression, adequate recovery, and appropriate supervision are essential for maximizing benefits while minimizing injury risk.

Coaches, strength and conditioning experts, and boxing athletes themselves stand to gain a lot from these findings. The study clearly shows that plyometric training helps improve both punching power and muscle fitness, giving solid proof that these exercises should be part of training routines for young boxers. The superior results observed with high-intensity plyometric training suggest that appropriately progressed, high-intensity exercises may be more effective for developing boxing-specific performance attributes. The sport-specific nature of the improvements observed in this study, particularly in punching force, highlights the importance of training specificity in athletic development. The integration of plyometric exercises that target the movement patterns and energy systems relevant to boxing can contribute to more effective training programs and improved competitive performance. Although the current study offers insightful information about how well plyometric training works for teenage boxers, it should be noted that there are a number of limitations. The findings may not be as applicable to longer-term training adaptations due to the comparatively brief intervention time. To maximize performance gains while avoiding overtraining, future studies should look into the effects of plyometric training over time and evaluate the most effective training periodization techniques. Furthermore, the results may not be as applicable to other age groups due to the emphasis on adolescent athletes. The best training regimen for boxing performance would be better understood with more study looking at the impacts of varying plyometric training intensities across age groups and skill levels.

Conclusions

The present study demonstrates that plyometric training, particularly high-intensity approaches, effectively enhances punching force and muscle fitness in adolescent boxers. The significant improvements observed across all measured variables support the inclusion of plyometric exercises in training programs for young combat sport athletes. The superior performance of high-intensity plyometric training suggests that appropriately progressed, high-intensity exercises may provide optimal stimulus for developing boxing-specific performance attributes. These results offer useful advice for coaches and athletes looking to maximize training efficacy alongside adding more evidence that highlights the benefits of plyometric training for athletes in combat sports.

Acknowledgment

The authors extend their heartfelt gratitude to all the athlete participants for their dedication and involvement in this research. They also wish to acknowledge the invaluable support of their colleagues, research team, and mentors, whose guidance and assistance were instrumental throughout the study.

Conflict of Interest

The authors affirm that there are no conflicts of interest associated with this study.

References

Lloyd, R. S., & Oliver, J. L. (2012). The Youth Physical Development Model: A New Approach to Long-Term Athletic Development. *Strength & Conditioning Journal, 34*(3), 61-72. https://doi.org/10.1519/ssc.0b013e31825760ea

Markovic, G., & Mikulic, P. (2010). Neuro-Musculoskeletal and Performance Adaptations to Lower-Extremity Plyometric Training. *Sports Medicine, 40*(10), 859-895. https://doi.org/10.2165/11318370-000000000-00000

Ramírez-Campillo, R., Meylan, C., Álvarez, C., Henríquez-Olguín, C., Martínez, C., Cañas-Jamett, R., Andrade, D. C., & Izquierdo, M. (2014). Effects of In-Season Low-Volume High-Intensity Plyometric Training on Explosive Actions and Endurance of Young Soccer Players. *Journal of Strength and Conditioning Research, 28*(5), 1335-1342. https://doi.org/10.1519/jsc.0000000000000284

Moran, J., Sandercock, G. R. H., Ramírez-Campillo, R., Wooller, J.-J., Logothetis, S., Schoenmakers, P. P. J. M., & Parry, D. A. (2018). Maturation-Related Differences in Adaptations to Resistance Training in Young Male Swimmers. *Journal of Strength and Conditioning Research, 32*(1), 139-149. https://doi.org/10.1519/jsc.0000000000001780

Loturco, I., Artioli, G. G., Kobal, R., Gil, S., & Franchini, E. (2014). Predicting Punching Acceleration From Selected Strength and Power Variables in Elite Karate Athletes: A Multiple Regression Analysis. *Journal of Strength and Conditioning Research, 28*(7), 1826-1832. https://doi.org/10.1519/jsc.0000000000000329

Suchomel, T. J., Nimphius, S., & Stone, M. H. (2016). The Importance of Muscular Strength in Athletic Performance. *Sports Medicine, 46*(10), 1419-1449. https://doi.org/10.1007/s40279-016-0486-0

Ford, K. R., Myer, G. D., & Hewett, T. E. (2010). Longitudinal effects of maturation on lower extremity joint stiffness in adolescent athletes. *The American Journal of Sports Medicine, 38*(9), 1829-1837. https://doi.org/10.1177/0363546510367425

Myer, G. D., Faigenbaum, A. D., Ford, K. R., Best, T. M., Bergeron, M. F., & Hewett, T. E. (2011). When to Initiate Integrative Neuromuscular Training to Reduce Sports-Related Injuries and Enhance Health in Youth? *Current Sports Medicine Reports, 10*(3), 155-166. https://doi.org/10.1249/jsr.0b013e31821b1442

Beato, M., McErlain-Naylor, S. A., Halperin, I., & Dello Iacono, A. (2020). Current Evidence and Practical Applications of Flywheel Eccentric Overload Exercises as Postactivation Potentiation Protocols: A Brief Review. *International Journal of Sports Physiology and Performance, 15*(2), 154-161. https://doi.org/10.1123/ijspp.2019-0476

Slimani, M., Chamari, K., Miarka, B., Del Vecchio, F. B., & Chéour, F. (2016a). Effects of Plyometric Training on Physical Fitness in Team Sport Athletes: A Systematic Review. *Journal of Human Kinetics,* 53, 231-247. https://doi.org/10.1515/hukin-2016-0026

De Villarreal, E. S.-S., Kellis, E., Kraemer, W. J., & Izquierdo, M. (2009). Determining Variables of Plyometric Training for Improving Vertical Jump Height Performance: A Meta-Analysis. *Journal of Strength and Conditioning Research, 23*(2), 495-506. https://doi.org/10.1519/jsc.0b013e318196b7c6

Chelly, M. S., Ghenem, M. A., Abid, K., Hermassi, S., Tabka, Z., & Shephard, R. J. (2010). Effects of in-Season Short-Term Plyometric Training Program on Leg Power, Jump- and Sprint Performance of Soccer Players. *Journal of Strength and Conditioning Research, 24*(10), 2670-2676. https://doi.org/10.1519/jsc.0b013e3181e2728f

Lloyd, R. S., Meyers, R. W., & Oliver, J. L. (2011). The natural development and trainability of plyometric ability during childhood. *Strength & Conditioning Journal, 33*(2), 23-32.

Harries, S. K., Lubans, D. R., & Callister, R. (2012). Resistance training to improve power and sports performance in adolescent athletes: A systematic review and meta-analysis. *Journal of Science and Medicine in Sport, 15*(6), 532–540. https://doi.org/10.1016/j.jsams.2012.02.005

World Medical Association Declaration of Helsinki: Ethical Principles for Medical Research Involving Human Subjects (2013). *JAMA, 310*(20), 2191. https://doi.org/10.1001/jama.2013.281053

Sayers, M. G., & Lorenzetti, S. (2020a). Influence of technique on upper body force and power production during medicine ball throws. *Journal of Sports Sciences, 38*(4), 470-475. https://doi.org/10.1080/02640414.2019.1706871

Khati, A., Saibya, R., Bhutia, N. N., Khatun, J., Mohit, Singh, H., & Saha, S. (2025). Exploring the Acute Benefits of Manual Soft Tissue Mobilization and Myofascial Release on Dynamic Athletic Performance in National Level Soccer Players. *Physical Education Theory and Methodology, 25*(4), 800-807. https://doi.org/10.17309/tmfv.2025.4.07

Tong, T. K., Wu, S., & Nie, J. (2014). Sport-specific endurance plank test for evaluation of global core muscle function. *Physical Therapy in Sport, 15*(1), 58-63. https://doi.org/10.1016/j.ptsp.2013.03.003

Saha, S., Obhrai, S., Vishwakarma, R., Mondal, P., Nagesh, Prasad, B., Upadhyay, K., & Singh, D. K. (2025). Clarifying the Impact of Small-Sided Games and HIIT on Anaerobic Endurance in Adolescent Hockey Players. *Physical Education Theory and Methodology, 25*(3), 660-667. https://doi.org/10.17309/tmfv.2025.3.23

Loturco, I., Nakamura, F. Y., Artioli, G. G., Kobal, R., Kitamura, K., Cal Abad, C. C., Cruz, I. F., Romano, F., Pereira, L. A., & Franchini, E. (2016). Strength and Power Qualities Are Highly Associated With Punching Impact in Elite Amateur Boxers. *Journal of Strength and Conditioning Research, 30*(1), 109-116. https://doi.org/10.1519/JSC.0000000000001075

Davies, G., Riemann, B. L., & Manske, R. (2015). Current Concepts of Plyometric Exercise. *International Journal of Sports Physical Therapy, 10*(6), 760-786.

Chelly, M. S., Fathloun, M., Cherif, N., Ben Amar, M., Tabka, Z., & Van Praagh, E. (2009). Effects of a back squat training program on leg power, jump, and sprint performances in junior soccer players. *Journal of Strength and Conditioning Research, 23*(8), 2241-2249. https://doi.org/10.1519/JSC.0b013e3181b86c40

Fernandez-Fernandez, J., Ellenbecker, T., Sanz-Rivas, D., Ulbricht, A., & Ferrautia, A. (2013). Effects of a 6-week junior tennis conditioning program on service velocity. *Journal of Sports Science & Medicine, 12*(2), 232-239.

Sayers, M. G., & Lorenzetti, S. (2020b). Influence of technique on upper body force and power production during medicine ball throws. *Journal of Sports Sciences, 38*(4), 470-475. https://doi.org/10.1080/02640414.2019.1706871

Slimani, M., Chamari, K., Miarka, B., Del Vecchio, F. B., & Chéour, F. (2016b). Effects of Plyometric Training on Physical Fitness in Team Sport Athletes: A Systematic Review. *Journal of Human Kinetics,* 53, 231-247. https://doi.org/10.1515/hukin-2016-0026

Lloyd, R. S., Oliver, J. L., Hughes, M. G., & Williams, C. A. (2012). The effects of 4-weeks of plyometric training on reactive strength index and leg stiffness in male youths. *Journal of Strength and Conditioning Research, 26*(10), 2812-2819. https://doi.org/10.1519/JSC.0b013e318242d2ec

Tong, T. K., Wu, S., Nie, J., Baker, J. S., & Lin, H. (2014). The occurrence of core muscle fatigue during high-intensity running exercise and its limitation to performance: The role of respiratory work. *Journal of Sports Science & Medicine, 13*(2), 244-251.

Ефективність застосування пліометричного тренування різної інтенсивності у покращенні сили удару кулаком та м’язової підготовленості підлітків-боксерів

Сінгх Шайлендра[1ABCD], Деорі Лата Апара[1BCD], Четрі Пурніма[2BD], Манамкандат Мохамед Прінс[3BD], Астуті Юні[4CD], Саха Сохом[1ABCD], Кхаті Авеш[1ABD]

[1]Національний інститут фізичного виховання імені Лакшмібай
[2]Університет ITM
[3]Університет фізичного виховання та спорту Таміл-Наду
[4]Державний університет Паданг

Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 9 с., 5 табл., 1 рис., 28 джерел.

Історія питання. Бокс як вид спорту вимагає значної вибухової сили, зокрема сили удару кулаком і м’язової підготовленості, що є ключовими чинниками в підлітковому віці через швидкий розвиток нервово-м’язової системи. Пліометричні тренування, як відомо, сприяють розвитку певних фізичних якостей. Однак існує обмежена кількість порівняльних досліджень щодо ефективності застосування пліометричних тренувань різної інтенсивності у підлітків-боксерів.

Мета дослідження. Мета дослідження полягала у вивченні та оцінці впливу протоколів пліометричного тренування високої та низької інтенсивності на силу удару кулаком та м'язову підготовленість боксерів підліткового віку чоловічої статі.

Матеріали та методи. Тридцять підлітків-боксерів чоловічої статі віком 13-17 років, кожен з яких мав щонайменше три роки тренувального досвіду, було відібрано за методом рандомізації та розділено на три групи: група пліометричного тренування низької інтенсивності (НІПТ), група пліометричного тренування високої інтенсивності (ВІПТ) та група активного контролю (АКГ). Групи НІПТ та ВІПТ брали участь у 8-тижневій пліометричній програмі, яка проводилася тричі на тиждень з прогресивним перевантаженням, тоді як АКГ продовжувала стандартний режим тренувань з боксу. Оцінювання показників на перед- та постінтервенційному етапах включало силу удару кулаком, потужність верхньої та нижньої частин тіла, а також м'язову витривалість, які вимірювалися за допомогою валідованих тестів, специфічних для даного виду спорту. Статистичний аналіз передбачав застосування t-критеріїв для парних вибірок, дисперсійного аналізу та post hoc тестів Бонферроні.

Результати. Групи НІПТ і ВІПТ продемонстрували статистично значущі поліпшення ($p < .001$) за всіма вимірюваними змінними, тоді як в АКГ істотних змін не спостерігалося. Група ВІПТ досягла найвищих результатів: сила удару кулаком збільшилася на 17.54%, м'язова витривалість — на 31.77%, потужність нижньої частини тіла — на 21.02%, а потужність верхньої частини тіла — на 9.96%. Розміри ефекту були великими ($\eta^2 p \geq .65$), що вказує на сильний ефект курсу тренувань.

Висновки. Пліометричне тренування, зокрема високої інтенсивності, сприяє значному підвищенню сили удару кулаком та м'язової підготовленості у підлітків-боксерів. Отримані результати підтверджують доцільність включення пліометричних вправ з прогресивним перевантаженням до програм тренувань юних боксерів, що забезпечує науково обґрунтований підхід до покращення результативності впродовж критичного етапу розвитку.

Ключові слова: пліометричне тренування, сила удару кулаком, м'язова підготовленість, підлітки-боксери, інтенсивність тренувань, вибухова сила.

Information about the authors:

Singh, Shailendra: shailendras670@gmail.com; https://orcid.org/0009-0003-1399-2387; Department of Sports Psychology, Lakshmibai National Institute of Physical Education, Gwalior, Madhya Pradesh, India.

Deori, Lata Apara: aparadeorilata96@gmail.com; https://orcid.org/0009-0001-2599-3294; Department of Yogic Sciences, Lakshmibai National Institute of Physical Education, Gwalior, Madhya Pradesh, India.

Chetry, Purnima: purnimachetry29@gmail.com; https://orcid.org/0009-0000-5888-3449; School of Sports Education, ITM University, Gwalior, Madhya Pradesh, India.

Manamkandath, Mohamed Prince: benignprince@gmail.com; https://orcid.org/0009-0003-0551-2056; Department of Physical Education, Tamilnadu physical Education and Sports University, Chennai, India.

Astuti, Yuni: yuniastuti@fik.unp.ac.id; https://orcid.org/0000-0001-6430-2938; Faculty of Sports Sciences, Universitas Negeri Padang, Jl. Prof. Dr. Hamka No.1, Air Tawar Bar., Kec. Padang Utara, Kota Padang, Sumatera Barat 25173, Indonesia.

Saha, Sohom: sohomsaha77@gmail.com; https://orcid.org/0009-0006-9438-1554; Department of Sports Psychology, Lakshmibai National Institute of Physical Education, Gwalior, Madhya Pradesh, India.

Khati, Awesh: awesh19@gmail.com; https://orcid.org/0009-0009-9090-1593; Department of Physical Education Pedagogy, Lakshmibai National Institute of Physical Education, Gwalior, Madhya Pradesh, India.

Cite this article as: Singh, S., Deori, L. A., Chetry, P., Manamkandath, M. P., Astuti, Y., Saha, S., & Khati, A. (2025). The Effectiveness of Varying Plyometric Training Intensities in Improving Punching Force and Muscular Fitness in Adolescent Boxers. *Physical Education Theory and Methodology, 25*(5), 1193-1201. https://doi.org/10.17309/tmfv.2025.5.19

Received: 10.08.2025. Accepted: 20.09.2025. Published: 30.09.2025