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Effects of hybrid plyometric-ladder and plyometric-circuit training on sprint speed and maximum velocity development in male students

Efectos del entrenamiento híbrido de pliometría con escalera y pliometría en circuito sobre la velocidad de sprint y el desarrollo de la velocidad máxima en estudiantes masculinos

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Abstract

Sprint performance is a key determinant of success in many sports, relying on acceleration, maximum velocity, and neuromuscular efficiency. Although plyometric training enhances explosive power, evidence on hybrid training approaches remains limited. This study aimed to compare the effects of hybrid plyometric-ladder training (HPLT) and plyometric-circuit training (PCT) on sprint speed and maximum velocity in male students. A randomised allocation procedure was employed for the pre-test and post-test design. Sixty male participants (18-22 years) were randomly assigned to HPLT (n = 20), PCT (n = 20), and control (CG; n = 20) groups. The 12-week intervention was conducted three times per week. Sprint performance was assessed over 30 m, 40 m, and 50 m. Data were analysed using paired t-tests and ANCOVA ($p < 0.05$). Significant improvements were observed in both HPLT and PCT groups across all sprint distances ($p < 0.001$), whereas the control group showed no improvement. ANCOVA indicated significant group differences at 30 m ($F = 33.13$), 40 m ($F = 3.62$), and 50 m ($F = 4.64$). Post-hoc analysis confirmed that both experimental groups outperformed the control ($p < 0.001$). No difference was found between HPLT and PCT at 30 m; however, PCT showed greater improvements at 40 m and 50 m maximum velocity. Both training methods significantly enhance sprint performance, with PCT providing additional benefits for sustaining maximum velocity.

Keywords: plyometric training; sprint speed; hybrid training; circuit training; agility ladder; neuromuscular adaptation

Resumen

El rendimiento en sprint es un factor clave de éxito en muchos deportes, ya que depende de la aceleración, la velocidad máxima y la eficiencia neuromuscular. Aunque el entrenamiento pliométrico mejora la potencia explosiva, la evidencia sobre enfoques de entrenamiento híbrido sigue siendo limitada. Este estudio tuvo como objetivo comparar los efectos del entrenamiento híbrido de pliometría con escalera (HPLT) y del entrenamiento pliométrico en circuito (PCT) sobre la velocidad de sprint y la velocidad máxima en estudiantes masculinos. Se empleó un diseño experimental aleatorizado con pretest y posttest. Sesenta participantes masculinos (18-22 años) fueron asignados aleatoriamente a los grupos HPLT (n = 20), PCT (n = 20) y control (CG; n = 20). La intervención de 12 semanas se llevó a cabo tres veces por semana. El rendimiento en sprint se evaluó en distancias de 30 m, 40 m y 50 m. Los datos se analizaron mediante pruebas t pareadas y ANCOVA ($p < 0.05$). Se observaron mejoras significativas en los grupos HPLT y PCT en todas las distancias de sprint ($p < 0.001$), mientras que el grupo control no mostró mejoras. El análisis ANCOVA indicó diferencias significativas entre grupos en 30 m ($F = 33.13$), 40 m ($F = 3.62$) y 50 m ($F = 4.64$). El análisis post hoc confirmó que ambos grupos experimentales superaron al grupo control ($p < 0.001$). No se encontraron diferencias entre HPLT y PCT en 30 m; sin embargo, el PCT mostró mayores mejoras en 40 m y 50 m en la velocidad máxima. Ambos métodos de entrenamiento mejoran significativamente el rendimiento en sprint, siendo el PCT más beneficioso para mantener la velocidad máxima.

Keywords: entrenamiento pliométrico; velocidad de sprint; entrenamiento híbrido; entrenamiento en circuito; escalera de agilidad; adaptación neuromuscular



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Introduction

Speed development is a key factor in performance across many competitive sports, especially those that involve quick acceleration, high sprint speeds, and repeated explosive movements (Aff & Errete, 2015; Hicks et al., 2020). In both individual and team sports, athletes often perform short bursts of maximum effort running, combined with quick changes in direction and intense muscular contractions (Vigh-Larsen et al., 2024). Therefore, sprint speed and the capacity to reach and sustain near-maximum velocity are vital physical traits that significantly impact sports performance (Lhemus et al., 2025). These capabilities are mainly influenced by neuromuscular coordination, lower-limb power, stride rate, and efficient use of the stretch-shortening cycle (SSC) within the musculotendinous system (McGarrigal et al., 2025). Consequently, strength and conditioning experts continually seek training methods to enhance the physiological and biomechanical factors essential for sprinting (Brazil, 2018).

Among the various training methods used in athletic conditioning, plyometric training is widely recognised as an effective way to improve explosive muscular power and sprinting performance (Huang et al., 2023; Ramirez-delaCruz et al., 2022). Plyometric exercises are characterised by quick eccentric muscle contractions immediately followed by concentric actions, thus leveraging the stretch-shortening cycle to maximise force output and neuromuscular efficiency (Goodwin & Jeffreys, 2016; Vetrovsky et al., 2019). This process enhances motor unit recruitment, increases musculotendinous stiffness, and boosts reactive strength, all of which help improve sprint acceleration and top running speed (Crotty et al., 2024; Hicks et al., 2020). Previous research has shown that systematic plyometric training can significantly enhance sprint performance, vertical jump height, and change-of-direction ability in adolescent and adult athletes (Zheng et al., 2025). For example, research by Li et al., (2025) and colleagues reported notable improvements in sprint acceleration and jump performance following structured plyometric training programmes, emphasising the importance of SSC-based exercises for developing speed.

Despite the well-established benefits of plyometric training, contemporary sport conditioning increasingly emphasises integrating multiple training modalities to optimise athletic performance (Henjilito et al., 2025; Watkins et al., 2021). In this context, hybrid



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training approaches that combine plyometric exercises with complementary drills have gained growing attention among sport scientists and practitioners (Cao et al., 2024). One such modality frequently included in athletic training programmes is ladder training. Agility ladder drills involve rapid foot-placement patterns performed on a ladder grid, requiring high levels of coordination, balance, and neuromuscular control (Keskinis et al., 2025). These drills are commonly used to enhance stride frequency, foot speed, and movement rhythm, all of which directly contribute to improved sprint mechanics (Ravi & Kalimuthu, 2025). The rapid ground contacts characteristic of ladder drills promote neuromuscular activation and intermuscular coordination, enabling athletes to improve lower-limb movement efficiency and step frequency during high-speed running (Kırlangıç & Bozkurt, 2025; Short et al., 2022).

Although ladder drills are widely employed in athletic training settings, empirical evidence regarding their effectiveness in enhancing sprint performance remains limited and somewhat inconsistent (Keskinis et al., 2025). Some studies have observed improvements in agility and coordination following ladder training, while others indicate that the drills mainly improve movement rhythm and neuromuscular coordination rather than directly boosting power output or sprint velocity (Bassa et al., 2024). Nonetheless, when combined with plyometric training, ladder drills may offer complementary benefits by reinforcing rapid foot contact patterns and enhancing the neuromuscular timing necessary for effective sprint mechanics (Hansen & Kennelly, 2017; Mănescu, 2025). Therefore, integrating ladder drills with plyometric exercises could generate synergistic adaptations that improve both force production and movement efficiency during sprinting (Bassa et al., 2024).

Another commonly used method in athletic training is circuit training. Circuit training involves a series of strength, endurance, and conditioning exercises performed with minimal rest between stations (Ramos-Campo et al., 2021). Traditionally, it has been used to enhance cardiovascular fitness, muscular endurance, and overall work capacity (Ikenna et al., 2020). However, recent advances in high-intensity circuit training have incorporated explosive movements, resistance exercises, and plyometric elements to improve strength and power simultaneously (Sepriani et al., 2025). These protocols may boost neuromuscular endurance, metabolic efficiency, and the capacity to sustain



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repeated high-intensity efforts. In the context of sprint performance, circuit training can enhance muscular endurance and force production during repeated sprints, thereby aiding the maintenance of sprint velocity over longer distances (Bishop et al., 2011).

From a physiological standpoint, combining plyometric, ladder, and circuit training elements can lead to comprehensive neuromuscular adaptations that improve sprint performance (Markovic & Mikulic, 2010). Plyometric exercises primarily focus on explosive power by activating the stretch-shortening cycle, while ladder drills enhance stride frequency, coordination, and quick foot contact (Bassa et al., 2024). Circuit training, meanwhile, enhances muscular endurance and metabolic conditioning, enabling athletes to maintain high-intensity muscular contractions (Mahalingam et al., 2024). When integrated into a well-structured training programme, these methods may simultaneously activate multiple neuromuscular pathways, thereby improving motor unit recruitment, enhancing proprioceptive feedback, and increasing neuromuscular efficiency during sprinting (Winter et al., 2022).

Sprint performance is characterised by distinct biomechanical phases, including acceleration, transition, and maximum velocity phases (von Lieres und Wilkau et al., 2020). During the initial acceleration phase, athletes rely heavily on explosive force production and horizontal power output (Keller et al., 2020). As sprinting continues, stride frequency and neuromuscular coordination become increasingly important for reaching maximum running speed (Čoh et al., 2010). Therefore, training interventions that focus on both force production and movement efficiency may be particularly effective in enhancing overall sprint performance (Hicks et al., 2020). Hybrid training models that combine plyometric exercises with ladder drills or circuit routines can therefore provide an ideal training stimulus by simultaneously targeting these different aspects of sprint mechanics (Short et al., 2022). Although hybrid training approaches have potential benefits, scientific studies on their effectiveness are still limited. Most existing research has focused on individual training methods, such as plyometric training alone or resistance training combined with sprint drills. While these studies have offered useful insights into how speed develops, they do not fully reflect the diverse training strategies often used in real athletic environments. Therefore, more experimental research is needed

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to compare hybrid training models and assess their effectiveness in enhancing sprint performance and related physical abilities.

Many existing studies on plyometric or agility-based training face methodological limitations, such as small sample sizes, brief intervention durations, and limited performance assessments. Few studies have concurrently evaluated sprint speed across multiple distances to capture different phases of sprinting performance (Rumpf et al., 2016). Measuring sprint times at 30 m, 40 m, and 50 m provides valuable insights into both the acceleration and near-maximum-velocity phases of sprinting, enabling a more thorough assessment of speed development following training interventions. Therefore, the present study aims to investigate the effects of two hybrid training methods, namely hybrid plyometric-ladder training and plyometric-circuit training, on sprint performance in male students. Sprint performance will be evaluated using 30 m, 40 m, and 50 m sprint tests, representing various stages of sprint acceleration and speed development. By comparing these hybrid training models with a control condition, the study seeks to identify which training approach is more effective in improving sprint speed and maximum velocity.

Understanding the relative effectiveness of these hybrid training strategies has significant implications for sports training and physical education programmes. Coaches and strength-conditioning specialists need evidence-based training methods that maximise performance gains while preserving training efficiency and safety. By pinpointing the most effective hybrid training model to enhance sprint speed, the findings of this study may aid the development of more comprehensive and scientifically grounded athletic training programmes.

Methodology

Research Design

The present study adopted a randomised controlled experimental design with a pre-test and post-test parallel-group structure to investigate the effects of Hybrid plyometric-ladder training (HPLT) and plyometric-circuit training (PCT) on sprint performance and velocity among young adult males. The intervention period lasted 12 weeks, with training conducted three times per week, for a total of 36 sessions. A total of 60 male participants



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aged 18-22 years volunteered for the study. Participants were recreationally active and had prior exposure to general physical training but had not engaged in structured plyometric or high-intensity neuromuscular training during the six months preceding the study. Individuals with a history of musculoskeletal injury, cardiovascular disorders, or neurological impairments were excluded. Participants who missed more than 10% of the training sessions were also excluded from the final analysis

Participants

Participants were randomly assigned to three equal groups (n = 20 per group), the Hybrid Plyometric-Ladder Training group (HPLT), the Plyometric-Circuit Training group (PCT), and the Control Group (CG). Randomisation ensured equal distribution of baseline characteristics and minimised selection bias. Participants were randomly allocated to HPLT, PCT, or Control groups using a computer-generated random number sequence prepared by an investigator not involved in data collection. Allocation concealment was maintained using sealed opaque envelopes. To control external influences, participants were instructed to refrain from engaging in additional structured physical training during the intervention period. Weekly follow-ups were conducted to monitor adherence. The control group continued their regular physical activity routines without participating in any structured plyometric, ladder, or circuit-based training during the intervention period. The experimental intervention lasted 12 weeks and consisted of three training sessions per week. Each session lasted 60-90 minutes and included a standardised warm-up (10-15 minutes), the main training protocol (40-60 minutes), and a cool-down phase (10-15 minutes). The warm-up consisted of light jogging, dynamic stretching, mobility drills, and low-intensity skipping and bounding exercises to prepare the neuromuscular system for high-intensity activity. The cool-down included light aerobic activity, static stretching, and controlled breathing exercises to facilitate recovery.

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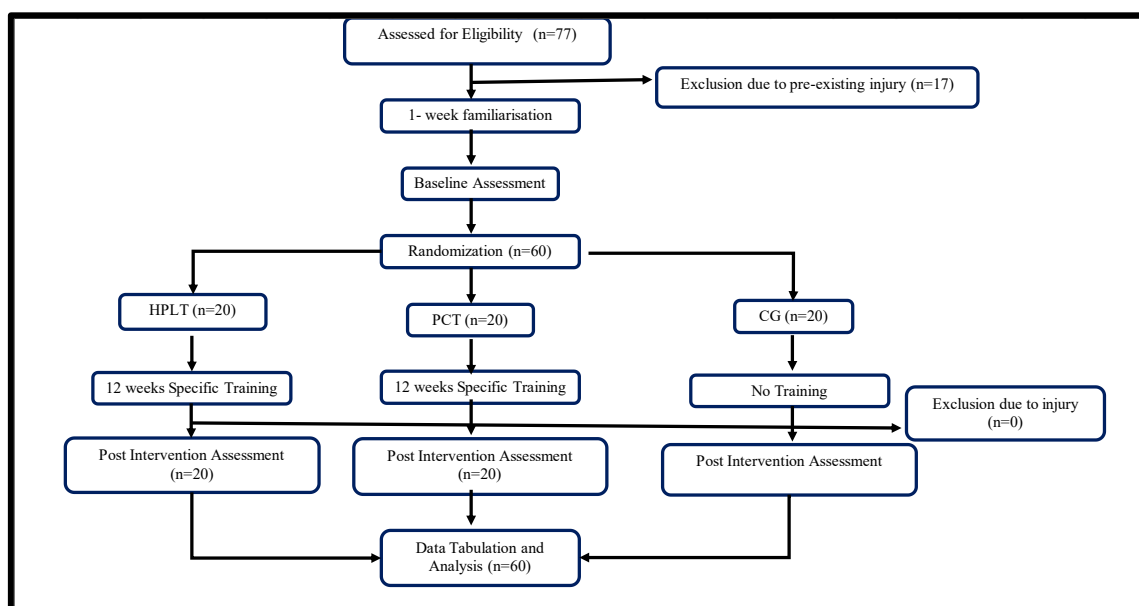


Figure 1: Flow chart of the research

The HPLT group performed a hybrid training protocol integrating plyometric exercises with agility ladder drills. Plyometric exercises included squat jumps, tuck jumps, bounding, lateral hops, and depth jumps, designed to enhance the stretch-shortening cycle and reactive strength. These were combined with ladder drills such as one-in and two-in steps, Ickey shuffle, lateral in-out drills, carioca steps, and high-knee quick steps to improve foot speed, coordination, and movement efficiency. Training intensity was progressively increased throughout the 12-week period following the principle of progressive overload. Participants initially trained at moderate intensity (approximately 60-70% of maximal perceived effort) during the first four weeks, gradually increasing to high intensity (80-90%) in the later stages. The number of sets ranged from three to five per exercise, with repetitions between eight and twelve and rest intervals of 60-120 seconds between sets. The PCT group performed plyometric exercises as part of a circuit-training structure. The circuit consisted of six to eight stations, including box jumps, medicine ball throws, jump lunges, burpees, standing broad jumps, and lateral bounds. Each station was performed for 45 seconds with 30 seconds of rest between stations and 2-3 minutes of rest between complete circuit rounds. Participants completed two to four circuits per session, depending on the training phase. The training



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intensity and volume were progressively increased across the intervention period by manipulating exercise duration, repetitions, number of circuits, and exercise complexity, in accordance with established principles of specificity, overload, progression, and recovery. To ensure internal validity, training sessions were supervised by qualified instructors. Environmental conditions, including testing surface, time of day, and warm-up procedures, were standardized across all testing sessions. Inter-trial recovery periods were controlled to minimise fatigue effects.

The Hybrid Plyometric-Ladder Training (HPLT) and Plyometric-Circuit Training (PCT) protocols were standardised throughout the intervention to ensure consistency across participants. In the HPLT programme, hurdle and vertical jump exercises were performed with an approximate jump height of 30 to 40 cm during the foundation phase, progressing to 40 to 60 cm during the development and peak phases according to the participants' technical proficiency. Box jumps and depth jumps utilised a box height of 30 cm during Weeks 1-4, 40 cm during Weeks 5-8, and 45-50 cm during Weeks 9-12. Agility ladder drills were performed using a flat ladder measuring approximately 8 m in length and 50 cm in width, with 40-cm spacing between rungs. In the PCT programme, medicine ball throws were executed using a 3-kg medicine ball throughout the intervention. The work-to-rest ratio was standardised, with 45 seconds of exercise followed by 30 seconds of recovery between stations and 2-3 minutes of passive recovery between complete circuit rounds. Rest intervals between plyometric exercises were maintained at 60-120 seconds, depending on exercise intensity. Training sessions were supervised by one qualified strength and conditioning instructor for every 10 participants (1:10 supervision ratio). The total plyometric ground contacts progressed from approximately 80-100 contacts per session during Weeks 1-4 to 100-120 contacts during Weeks 5-8 and 120-140 contacts during Weeks 9-12, following the principle of progressive overload while ensuring participant safety and adequate recovery.

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Table I: Twelve-Week Training Progression Plan for HPLT and PCT Groups

Weeks	HPLT	PCT	Intensity RPE*	Volume Progression	Training Characteristics
Phase I: Foundation Phase (Weeks 1-4)	3 sets × 8 reps (basic jumps + simple ladder drills)	2 circuits × 6 stations (20 sec work / 30 sec rest)	6/10	Technique emphasis	Focus: Technical mastery, neuromuscular adaptation, moderate intensity
	3×10 reps	2-6 stations (25 sec / 30 sec)	6-7/10	Slight repetition increase	
	4×8 reps	3×6 stations (25 sec / 25 sec)	7/10	Added circuit round	
	4×10 reps	3×6 stations (30 sec / 25 sec)	7/10	Increased work duration	
Phase II: Development Phase (Weeks 5-8)	4×10 reps (added depth jumps)	3×7 stations (30 sec / 20 sec)	7-8/10	Added exercise complexity	Focus: Increased intensity, improved reactive strength, reduced rest intervals
	4 × 12 reps	3×7 stations (35 sec / 20 sec)	8/10	Increased repetition & time	
	5×10 reps	4×7 stations (35 sec / 20 sec)	8/10	Added circuit round	
	5×12 reps	4×8 stations (35 sec / 15 sec)	8-9/10	Reduced rest interval	
Phase III: Peak Performance Phase (Weeks 9-12)	5×12 reps (maximal effort jumps)	4×8 stations (40 sec / 15 sec)	9/10	Increased work duration	Focus: High intensity, maximal power output, sport-specific explosiveness
	5×12 reps (reduced ground contact time focus)	4×8 stations (40 sec / 15 sec)	9/10	Maintain high load	
	5×10 reps (contrast sequencing drills)	4×8 stations (45 sec / 15 sec)	9/10	Increased intensity	
	4×8 reps (taper week, maximal quality)	3×8 stations (40 sec / 20 sec)	8/10	Slight taper for recovery	

***Intensity Monitoring:** Rating of Perceived Exertion (RPE 1-10 scale)

Training load and intensity were carefully controlled throughout the study to ensure consistency and adherence to sports training principles. Intensity was monitored using the Rating of Perceived Exertion (RPE) scale and regulated through work-to-rest ratios and exercise complexity. Training volume was progressively increased every four weeks by increasing repetitions, sets, and circuit rounds. Attendance was recorded for all participants, and only those completing at least 90% of the training sessions were included in the final statistical analysis. Performance assessments were conducted 2 days before and 2 days after the 12-week intervention period, under standardised environmental conditions. Sprint performance was assessed over a total distance of 50 meters. Each participant performed two maximal 50 m sprint trials, with a recovery interval of 45-



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minutes between trials. During each sprint, split times were recorded at 30 m and 40 m, in addition to the final 50 m time. Thus, sprint performances of 30 m, 40 m, and 50 m were obtained from a single continuous 50 m sprint effort. The best trial, based on the fastest 50 m time, was retained for statistical analysis, and the corresponding 30 m, 40 m, and 50 m split times from that trial were used for further evaluation. Sprint times were recorded using Brower Timing Gates (Brower Timing Systems, USA). To minimise the influence of extraneous variables, all testing sessions were conducted at the same time of day. Participants were instructed to avoid strenuous physical activity 24 hours prior to testing and to maintain their normal dietary habits throughout the study period. Environmental conditions were kept consistent during both pre- and post-testing sessions.

Data analysis

Descriptive statistics, including mean and standard deviation, were calculated for all variables. To determine the effectiveness of the interventions, Analysis of Covariance (ANCOVA) was applied to compare post-test scores among the three groups while controlling for pre-test differences. Pre-test scores were treated as covariates to adjust for baseline variability. The level of statistical significance was set at $p < 0.05$. F-ratios were calculated to examine between-group differences. When significant F-values were observed, appropriate post-hoc comparisons using Bonferroni adjustment were conducted. Assumptions of normality, homogeneity of variance, and a linear relationship between covariates and dependent variables were verified prior to conducting ANCOVA. All statistical analyses were performed using standard statistical software.

Potential ethical issues

All participants were informed about the purpose, procedures, risks, and benefits of the study, and written informed consent was obtained prior to participation. The study procedures were conducted in accordance with accepted ethical standards for research involving human participants.



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Results

Table II: Descriptive means and standard deviation of the anthropometric data of the experimental and control groups

Descriptive Statistics of Anthropometric Data							
	N	Minimum	Maximum	Mean	SD	Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error
Age (HPLT)	20	19	20	19.45	0.51	-2.18	0.99
Age (PCT)	20	18	21	19.45	0.94	-0.68	0.99
Age (CG)	20	18	20	19.35	0.58	-0.55	0.99
Height (HPLT)	20	169.00	173.00	171.25	1.06	-0.43	0.99
Height (PCT)	20	171.00	175.00	172.65	1.26	-0.69	0.99
Height (CG)	20	170.00	172.00	171.25	0.63	-0.43	0.99
Weight (HPLT)	20	55.00	78.00	66.60	6.43	-0.79	0.99
Weight (PCT)	20	50.00	74.00	62.25	7.26	-1.09	0.99
Weight (CG)	20	60.00	73.00	65.85	3.67	-0.623	0.99
Valid N (list-wise)	20						

*HPLT-Hybrid plyometric and ladder training

*PCT-Plyometric and circuit training

*CG- Control group

Table III: Descriptive Statistics of 30m, 40m, and 50m sprint of male students

Paired Samples Statistics					
	Training groups	Mean	N	SD	Std. Error Mean
Pair 1	Pre 30 HPLT	4.87	20	0.09	0.02
	Post 30 HPLT	4.58	20	0.12	0.02
Pair 2	Pre 30 PCT	4.85	20	0.11	0.02
	Post 30 PCT	4.56	20	0.12	0.02
Pair 3	Pre 30 CG	4.81	20	0.05	0.01
	Post 30 CG	4.81	20	0.06	0.01
Pair 4	Pre 40 HPLT	6.23	20	0.39	0.08
	Post 40 HPLT	5.94	20	0.34	0.07
Pair 5	Pre 40 PCT	6.23	20	0.34	0.07
	Post 40 PCT	5.85	20	0.33	0.07
Pair 6	Pre 40 CG	6.05	20	0.09	0.02
	Post 40 CG	6.09	20	0.07	0.01
Pair 7	Pre 50 HPLT	7.68	20	0.50	0.11
	Post 50 HPLT	7.33	20	0.40	0.09
Pair 8	Pre 50 PCT	7.60	20	0.31	0.07
	Post 50 PCT	7.20	20	0.29	0.06
Pair 9	Pre 50 CG	7.43	20	0.12	0.02
	Post 50 CG	7.49	20	0.12	0.02



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Table IIV: Pre-test and Post-test Mean, Standard Deviation, Standard Error, Mean Difference and t-ratio for the Experimental Group and the Control Group on Speed for Male Students

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		MD	SD	Std. Error Mean	95% CI of the Difference				
					Lower	Upper			
Pair 1	Pre 30 HPLT - Post 30 HPLT	0.28	0.04	0.009	0.26	0.30	31.765	19	0.001
Pair 2	Pre 30 PCT - Post 30 PCT	0.29	0.06	0.015	0.26	0.32	19.545	19	0.001
Pair 3	Pre 30 CG- Post 30 CG	-0.06	0.02	0.005	-0.05	0.04	-10.092	19	0.001
Pair 4	Pre 40 HPLT - Post 40 HPLT	0.29	0.06	0.015	0.25	0.32	18.892	19	0.001
Pair 5	Pre 40 PCT - Post 40 PCT	0.37	0.06	0.003	0.37	0.38	19.504	19	0.001
Pair 6	Pre 40 CG- Post 40 CG	-0.03	0.02	0.004	-0.04	-0.02	-8.028	19	0.001
Pair 7	Pre 50 HPLT - Post 50 HPLT	0.35	0.12	0.028	0.29	0.41	12.454	19	0.001
Pair 8	Pre 50 PCT -Post 50 PCT	0.40	0.11	0.026	0.34	0.45	15.348	19	0.001
Pair 9	Pre 50 CG- Post 50 CG	-0.05	0.02	0.004	-0.06	-0.04	-12.218	19	0.001

Table IIV shows that the paired-samples t-test was conducted to assess the effect of the training interventions on sprint performance over 30 m, 40 m, and 50 m among the three experimental groups. The results revealed statistically significant improvements in sprint times for both the Hybrid Plyometric and Ladder Training (HPLT) and Plyometric and Circuit Training (PCT) groups, whereas minimal or non-significant changes were observed in the Control Group (CG).

For the 30 m sprint, the HPLT group demonstrated a significant improvement between pre-test and post-test scores ($M = 0.28$, $SD = 0.04$, $t(19) = 31.765$, $p < 0.001$), with the 95% confidence interval ranging from 0.26 to 0.30. Similarly, the PCT group also showed a significant reduction in sprint time ($M = 0.29$, $SD = 0.06$, $t(19) = 19.545$, $p < 0.001$). In the 40 m sprint, significant improvements were again observed in both



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experimental groups. The HPLT group recorded a significant difference between pre- and post-tests ($M = 0.29$, $SD = 0.06$, $t(19) = 18.892$, $p < 0.001$). The PCT group showed an even improvement ($M = 0.37$, $SD = 0.06$, $t(19) = 19.504$, $p < 0.001$). Interestingly, the control group showed a slight decline in performance ($M = -0.03$, $SD = 0.02$, $t(19) = -8.028$, $p < 0.001$).

For the 50 m sprint, both training groups again demonstrated statistically significant improvements. The HPLT group showed a mean improvement of 0.35 seconds ($SD = 0.12$, $t(19) = 12.454$, $p < 0.001$), while the PCT group improved by 0.40 seconds ($SD = 0.11$, $t(19) = 15.348$, $p < 0.001$). Conversely, the control group displayed a significant negative change ($M = -0.05$, $SD = 0.02$, $t(19) = -12.218$, $p < 0.001$), indicating a deterioration in sprint performance. Overall, the findings indicate that both Hybrid Plyometric and Ladder Training and Plyometric with Circuit Training significantly enhanced short-distance sprint performance across all measured distances (30 m, 40 m, and 50 m), while the control group showed either negligible or negative changes.

Table V: Paired Sample t-Test with Effect Size (Cohen's d) for Sprint Performance

Variable	Mean Difference	SD	t	df	p-value	Cohen's d	Interpretation
30 m HPLT	0.28	0.06	31.765	19	0.000	4.66	Very Large
30 m PCT	0.29	0.06	19.545	19	0.000	4.37	Very Large
30 m CG	0.06	0.02	-10.092	19	0.000	-2.24	Large (Negative)
40 m HPLT	0.29	0.06	18.892	19	0.000	4.23	Very Large
40 m PCT	0.37	0.06	19.504	19	0.000	2.62	Very Large
40 m CG	-0.03	0.02	-8.028	19	0.000	-1.82	Large (Negative)
50 m HPLT	0.35	0.12	12.454	19	0.000	2.78	Very Large
50 m PCT	0.40	0.11	15.348	19	0.000	3.43	Very Large
50 m CG	-0.05	0.02	-12.218	19	0.000	-2.75	Large (Negative)

Table VI: Analysis of Covariance for Speed on Hybrid Plyometric-Ladder Training, Plyometric- Circuit Training on 30M Sprint

Test	HPLT	PCT	CG	SOV	SS	df	M.Sq	'F' Ratio	'p' Value
Pre Test Mean	4.87	4.86	4.82	B W	0.033 0.466	2 57	0.016 0.008	1.986	0.477
Post-test Mean	4.58	4.56	4.81	B W	0.757 0.651	2 57	0.379 0.011	33.132*	0.000

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Adjusted Post-test Mean	4.56	4.55	4.84	B W	0.791 0.627	2 57	0.395 0.011	34.124*	0.000
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Table VI presents the analysis of covariance (ANCOVA) results examining the effects of Hybrid Plyometric-Ladder Training (HPLT) and Plyometric-Circuit Training (PCT) on 30 m sprint performance, with pre-test scores treated as the covariate to control for baseline differences among groups. The pre-test analysis revealed no statistically significant differences among the groups ($F(2,57) = 1.986$, $p = 0.477$), indicating that the participants had comparable sprint performance prior to the intervention. However, significant differences emerged in the post-test scores ($F(2,57) = 33.132$, $p < 0.001$), suggesting that the training interventions had a meaningful effect on sprint performance. After adjusting for the pre-test values, the adjusted post-test means further confirmed a statistically significant difference among the groups ($F(2,57) = 34.124$, $p < 0.001$). The adjusted mean values indicated superior improvement in the HPLT (4.56 s) and PCT (4.55 s) groups compared with the control group (4.84 s). These findings demonstrate that both training interventions were effective in enhancing short-distance sprint speed.

Table VII: Post-hoc test for mean difference between groups for 30 m sprint

Pairwise Comparisons						
Dependent Variable: Post-test 30 M Sprint						
(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	Sig. ^b	95% Confidence Interval for Difference ^b	
					Lower Bound	Upper Bound
HPLT	PCT	0.008	0.015	0.616	-0.023	0.038
	CG	-0.284*	0.016	0.000	-0.316	-0.253
PCT	HPLT	-0.008	0.015	0.616	-0.038	0.023
	CG	-0.292*	0.015	0.000	-0.323	-0.261
CONTROL	HPLT	0.284*	0.016	0.000	0.253	0.316
	PCT	0.292*	0.015	0.000	0.261	0.323

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Table VII presents the post-hoc pairwise comparisons using the Least Significant Difference (LSD) test to identify specific differences among the Hybrid Plyometric-Ladder Training (HPLT), Plyometric-Circuit Training (PCT), and Control Group (CG) in the post-test 30 m sprint performance. The results revealed no statistically significant difference between the two experimental groups, HPLT and PCT (Mean Difference = 0.008 s, $p = 0.616$), indicating that both training interventions produced comparable



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improvements in sprint performance. However, significant differences were observed between the experimental groups and the control group. The HPLT group demonstrated significantly faster sprint times compared with the control group (Mean Difference = -0.284 s, $p < 0.001$), while the PCT group also showed a significant improvement relative to the control group (Mean Difference = -0.292 s, $p < 0.001$). These findings suggest that both hybrid plyometric-ladder training and plyometric-circuit training significantly enhance short-distance sprint performance compared with no structured training intervention.

Table VIII: Analysis of Covariance for Speed on Hybrid Plyometric-Ladder Training, Plyometric- Circuit Training on 40 m Sprint

Test	HPLT	PCT	CG	SOV	SS	df	M.Sq	'F' Ratio	'p' Value
Pre Test Mean	6.23	6.23	6.06	B W	0.414 5.40	2 57	0.207 0.095	2.19	0.122
Post-test Mean	5.94	5.85	6.09	B W	0.580 4.56	2 57	0.290 0.080	3.62*	0.033
Adjusted Post-test Mean	5.89	5.80	6.20	B W	0.607 3.003	2 57	0.303 0.052	5.75*	0.000

¡Error! No se encuentra el origen de la referencia. presents the results of the analysis of covariance (ANCOVA) conducted to determine the effect of Hybrid Plyometric-Ladder Training (HPLT) and Plyometric-Circuit Training (PCT) on 40 m sprint performance, with pre-test scores used as the covariate to control for baseline differences. The pre-test analysis indicated no statistically significant differences among the groups ($F(2,57) = 2.19$, $p = 0.122$), confirming that the participants had comparable sprint performance prior to the intervention. However, significant differences were observed in the post-test scores ($F(2,57) = 3.62$, $p = 0.033$), suggesting that the training programs influenced sprint performance. After adjusting for the pre-test scores, the adjusted post-test means revealed a highly significant difference among the groups ($F(2,57) = 5.75$, $p < 0.001$). The adjusted means indicated superior improvements in the PCT group (5.80 s) followed by the HPLT group (5.89 s), whereas the control group (6.20 s) showed comparatively poorer performance. These findings demonstrate that both experimental training interventions effectively enhanced 40 m sprint speed.



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Table IX: Post-hoc test for mean difference between groups for 40 m sprints

Dependent Variable: Post-test 40 m Sprint						
(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	Sig. ^b	95% Confidence Interval for Difference ^b	
					Lower Bound	Upper Bound
HPLT	PCT	0.08*	0.010	0.000	0.064	0.106
	CG	-0.31*	0.011	0.000	-0.335	-0.292
PCT	HPLT	-0.08*	0.010	0.000	-0.106	-0.064
	CG	-0.39*	0.011	0.000	-0.419	-0.376
CG	HPLT	0.31*	0.011	0.000	0.292	0.335
	PCT	0.39*	0.011	0.000	0.376	0.419

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

¡Error! No se encuentra el origen de la referencia. presents the post-hoc pairwise comparisons using the Least Significant Difference (LSD) test to assess group differences in post-test 40 m sprint performance among the Hybrid Plyometric-Ladder Training (HPLT) group, the Plyometric-Circuit Training (PCT) group, and the Control Group (CG). The analysis revealed statistically significant differences between all groups ($p < 0.001$). The PCT group demonstrated significantly faster sprint performance than the HPLT group (Mean Difference = -0.085 s, $p < 0.001$), indicating a greater improvement following the plyometric-circuit training intervention. Furthermore, both experimental groups showed significantly better sprint performance compared with the control group. The HPLT group recorded a significant improvement over the control group (Mean Difference = -0.313 s, $p < 0.001$), while the PCT group exhibited an even larger difference (Mean Difference = -0.398 s, $p < 0.001$). These findings suggest that both training interventions significantly enhanced 40 m sprint speed, with plyometric-circuit training producing comparatively greater improvements.



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Table X: Analysis of Covariance for Speed on Hybrid Plyometric-Ladder Training, Plyometric- Circuit Training on 50 m Sprint

Test	HPLT	PCT	CG	SOV	SS	df	M.Sq	'F' Ratio	'p' Value
Pre Test Mean	7.69	7.61	7.44	B W	0.647 7.077	2 57	0.324 0.124	2.61	0.083
Post-test Mean	7.33	7.21	7.49	B W	0.818 5.022	2 57	0.409 0.088	4.64*	0.014
Adjusted Post-test Mean	7.24	7.18	7.61	B W	0.968 4.392	2 57	0.484 0.077	6.28*	0.000

¡Error! No se encuentra el origen de la referencia. presents the results of the analysis of covariance (ANCOVA) conducted to examine the effect of Hybrid Plyometric-Ladder Training (HPLT) and Plyometric-Circuit Training (PCT) on 50 m sprint performance, with the pre-test scores treated as a covariate to control for initial group differences. The analysis of the pre-test scores revealed no statistically significant difference among the groups ($F(2,57) = 2.61$, $p = 0.083$), indicating that the participants had comparable sprint performance prior to the intervention. However, significant differences emerged in the post-test scores ($F(2,57) = 4.64$, $p = 0.014$), suggesting that the training interventions influenced sprint speed. After adjusting for the pre-test values, the adjusted post-test means demonstrated a highly significant difference among the groups ($F(2,57) = 6.28$, $p < 0.001$). The adjusted mean values showed greater improvements in the PCT group (7.18 s) followed by the HPLT group (7.24 s), whereas the control group (7.61 s) exhibited comparatively lower performance. These findings indicate that both experimental training interventions were effective in enhancing 50 m sprint speed.

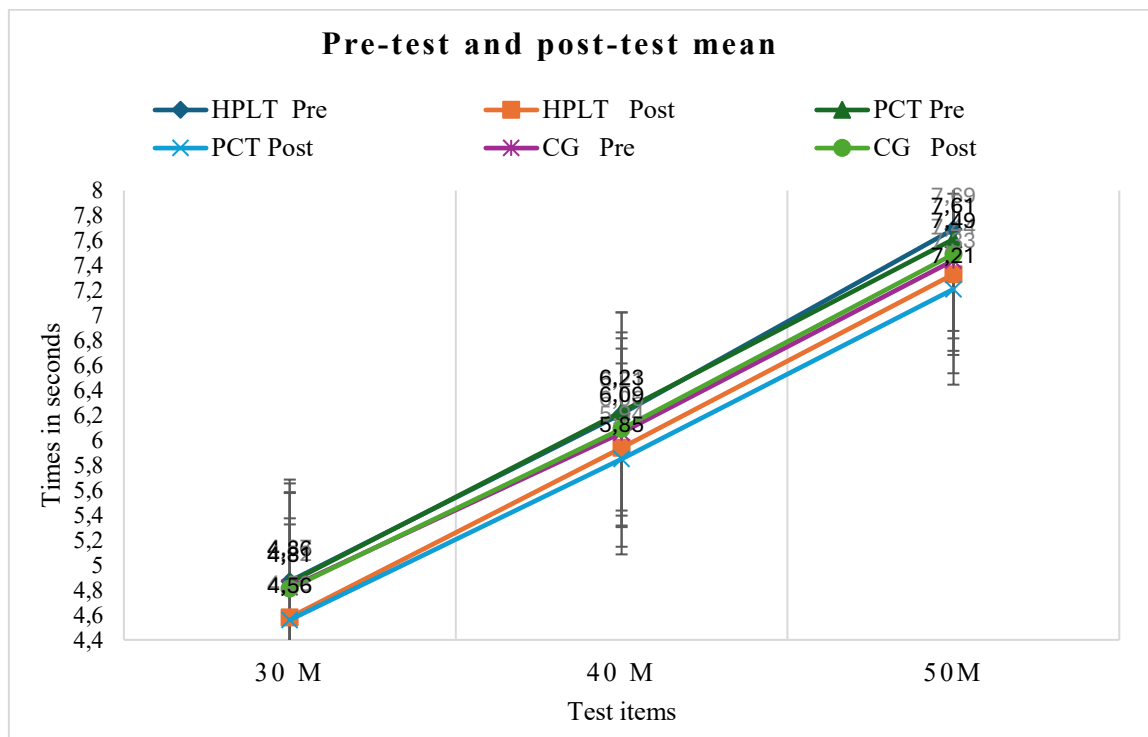
Table XI: Post-hoc test for mean difference between groups for 50 m sprints

Pairwise Comparisons						
Dependent Variable: Post-test 50 m Sprint						
(I) Groups	(J) Groups	M D(I-J)	Std. Error	Sig. ^b	95% Confidence Interval for Difference ^b	
					Lower Bound	Upper Bound
HPLT	PCT	0.060*	0.024	0.018	0.011	0.109
	CG	-0.365*	0.025	0.000	-0.416	-0.314
PCT	HPLT	-0.060*	0.024	0.018	-0.109	-0.011
	CG	-0.425*	0.025	0.000	-0.474	-0.375
CG	HPLT	0.365*	0.025	0.000	0.314	0.416
	PCT	0.425*	0.025	0.000	0.375	0.474

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Table XI presents the post-hoc pairwise comparisons using the Least Significant Difference (LSD) test to identify group differences in post-test 50 m sprint performance among the Hybrid Plyometric-Ladder Training (HPLT) group, the Plyometric-Circuit Training (PCT) group, and the Control Group (CG). The analysis revealed statistically significant differences among all groups. The PCT group demonstrated significantly faster sprint performance than the HPLT group (Mean Difference = -0.060 s, $p = 0.018$), indicating comparatively greater improvement following the plyometric circuit training intervention. Moreover, both experimental groups showed significantly superior sprint performance compared with the control group. The HPLT group exhibited a significant improvement over the control group (Mean Difference = -0.365 s, $p < 0.001$), while the PCT group displayed a larger difference (Mean Difference = -0.425 s, $p < 0.001$). These findings indicate that both training interventions significantly enhanced 50 m sprint speed, with plyometric-circuit training producing slightly greater performance gains than hybrid plyometric-ladder training. Although statistical significance was observed, effect sizes were not calculated, which limits the interpretation of the magnitude of differences.





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Graph I: Pre-test and Post-test Mean for the Experimental Group and the Control Group on Speed for Male Students of 30m, 40m and 50m.

Discussion

The present study investigated the effects of Hybrid Plyometric-Ladder Training (HPLT) and Plyometric-Circuit Training (PCT) on maximum sprint velocity in male students, using a 50 m sprint with split times at 30 m and 40 m. This approach enabled a thorough assessment of both the acceleration phase (0-30 m) and the maximum-velocity phase (30-50 m) of sprint performance. Although the results showed statistically significant improvements in sprint performance for both experimental groups compared to the control group, the broader significance of these findings lies in the physiological, neuromuscular, and pedagogical implications of the training interventions. Instead of simply indicating performance gains, the findings suggest that integrated neuromuscular training programmes that combine explosive power, coordination, and metabolic conditioning can may contribute to improvements in sprint mechanics and athlete development. The marginally greater improvements observed in the PCT group during the later sprint phases offer valuable insights into how different training modalities influence sprint performance through various physiological and motor learning mechanisms.

One of the primary theoretical explanations for the improvements seen in both training groups is the enhancement of neuromuscular efficiency and motor unit recruitment. Plyometric training is widely recognised for its ability to stimulate the stretch-shortening cycle (SSC), which enables muscles and tendons to store and release elastic energy during rapid eccentric-concentric actions (Goodwin & Jeffreys, 2021). Improvements in SSC efficiency allow athletes to generate greater force in shorter time frames, which is a key factor in sprint acceleration and maximum velocity (Hicks et al., 2020).

Previous studies have consistently shown that plyometric training enhances the rate of force development (RFD), motor unit synchronisation, and neural drive to the working musculature (Markovic & Mikulic, 2010). These neural adaptations reduce ground contact time during sprinting and facilitate higher stride frequencies, both of

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which contribute to improved sprint speed (Haugen et al., 2019). The significant reductions in sprint time observed in the experimental groups are therefore likely linked to improved neuromuscular activation patterns and enhanced explosive strength in the lower extremities (Ross et al., 2001).

The neural mechanisms underlying plyometric training and ladder drills in the HPLT protocol likely contributed to improvements in coordination, rhythm, and foot speed (Bassa et al., 2024). Ladder training requires athletes to perform quick foot placements with high precision, thereby stimulating the central nervous system to optimise motor control patterns (Dave & Singh, 2024). Enhanced coordination between the hip flexors, knee extensors, and ankle plantar flexors is essential for efficient sprint mechanics (Crotty et al., 2024). Research on agility ladder training suggests that such drills improve proprioceptive awareness and movement efficiency, which can translate into more effective stride patterns during sprinting (Keskinis et al., 2025; Short et al., 2022). The current findings, therefore, support the idea that ladder drills, when combined with plyometric exercises, may enhance sprint performance by improving the technical and neuromuscular aspects of sprinting (Bassa et al., 2024; Keskinis et al., 2025).

Although both interventions yielded meaningful improvements, the slightly greater enhancement observed in the PCT group at the 40 m and 50 m splits suggests that circuit training may provide additional physiological benefits, particularly during the later stages of a sprint (Taskin, 2009). Circuit training usually involves resistance exercises, plyometric movements, and conditioning drills performed with minimal recovery periods (Ramos-Campo et al., 2021). This structure imposes combined demands on the muscular, cardiovascular, and metabolic systems, resulting in improvements in muscular endurance, anaerobic capacity, and fatigue resistance (Saghiv & Sagiv, 2020). Sprint performance, especially beyond the initial acceleration phase, depends not only on explosive power but also on the ability to sustain high levels of force across repeated strides (Pandy et al., 2021). Athletes who fatigue rapidly may show increased ground contact times and a lower stride frequency, ultimately reducing running velocity (Apte et al., 2021). The extra metabolic conditioning from circuit training may therefore help athletes maintain optimal neuromuscular output during the latter stages of a sprint (Ross et al., 2001).

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Empirical studies have shown that circuit-based training programmes can significantly enhance speed, agility, and muscular endurance in young athletes (Annasai et al., 2023). These adaptations are especially useful during the maximum-velocity phase of sprinting, where preserving stride efficiency is vital (Wild et al., 2011). The findings of the current study align with this literature, indicating that incorporating circuit training elements may improve an athlete's capacity to sustain high sprint velocities (Hicks et al., 2026; Liu et al., 2025).

A complex interaction of biomechanical variables, including stride length, stride frequency, ground contact time, and vertical force production, influences sprint performance (Fletcher, 2009; Kale & Acikada, 2016). Improvements in sprint speed usually occur when athletes can generate greater propulsive forces while minimising braking forces during ground contact (Haugen et al., 2019; Hicks et al., 2020). Plyometric training has been shown to enhance lower-limb stiffness and tendon elasticity, enabling athletes to apply force more efficiently during each stride (Brazier et al., 2019; Markovic & Mikulic, 2010). In the present study, the improvements observed in the experimental groups likely reflect enhanced force transmission through the kinetic chain, enabling more powerful push-offs and reducing energy loss during ground contact. Ladder drills may also have contributed to improved stride rhythm and step timing, thereby optimising the interaction between stride length and stride frequency (Keskinis et al., 2025; Short et al., 2022).

The slightly greater improvements observed in the PCT group during the 50 m sprint may suggest that circuit training better supports the maintenance of optimal biomechanics under fatigue (Boccia et al., 2017; Lin et al., 2025). As fatigue increases, athletes often exhibit altered movement patterns that reduce sprint efficiency (Bishop et al., 2011). Training programmes that enhance both power and endurance could therefore help athletes sustain proper sprint mechanics throughout the entire distance (Haugen et al., 2019). The results of this study align with an increasing body of research emphasising the effectiveness of combined training methods for boosting sprint performance. For example, a study by Asadi (2018) and Ramirez-Campillo (2020) reported that plyometric training significantly enhances sprint acceleration and jumping ability in young athletes. Similarly, de Villarreal (2013) and Kargarfard (2020) demonstrated that sprint training

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combined with plyometric exercises resulted in greater improvements in sprint speed than traditional training alone.

Recent research has also highlighted the importance of multimodal training interventions that combine strength, power, and coordination elements. Belete (2025) reported that neuromuscular training programmes that incorporate plyometric exercises with coordination drills improved sprint speed and agility in youth athletes. The authors suggested that blending technical and physical training components can enhance the transfer of training effects to sport-specific movements (Issurin, 2013). The marginally superior performance seen in the PCT group in the present study aligns with research indicating that combined resistance and conditioning training can boost sprint performance by increasing both muscular power and metabolic efficiency (Pareja-Blanco et al., 2021). Collectively, these studies support the idea that training programmes targeting multiple physiological systems may lead to greater improvements in sprint performance than single-modality approaches.

The 30 m split indicates the acceleration phase, during which rapid force development and the ability to generate high power are vital (Lockie et al., 2011). Improvements in this phase suggest athletes' enhanced capacity to quickly produce force against the ground, aligning with documented neuromuscular adaptations from plyometric and circuit training (Mănescu, 2025). The 40 m and 50 m splits represent transitional and near-maximum-velocity phases, where efficient stride mechanics, reduced ground contact time, and elastic recoil efficiency become increasingly significant (Moura et al., 2024). The superior performance of PCT in these later stages may stem from its broader range of training stimuli, which boost both anaerobic power and muscular endurance (Sandford et al., 2021).

These results also align with systematic reviews indicating that longer or more varied training programmes tend to produce greater improvements in sprint performance, likely because they provide sufficient time for physiological mechanisms such as tendon stiffness adaptation and neural optimisation to take place (Van Hooren et al., 2024). The present study, therefore, contributes not only to the field of sport science but also to educational practice within physical education contexts. By demonstrating the effectiveness of structured training interventions in improving sprint performance



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(Nicholson et al., 2021), the findings emphasise the potential for physical education programmes to incorporate evidence-based training methods that simultaneously enhance physical fitness and support broader developmental outcomes (Timperio et al., 2004).

From a practical perspective, the findings indicate that both HPLT and PCT can be effectively implemented within school-based athletic programmes to improve sprint performance in adolescent students. Coaches and physical educators might consider incorporating a combination of plyometric, ladder, and circuit training exercises to target multiple aspects of athletic performance simultaneously. For example, ladder drills can be employed during warm-up sessions to enhance coordination and neuromuscular activation, while plyometric exercises such as bounding, hopping, and jump squats can boost explosive power. Circuit training sessions can then be integrated to develop muscular endurance and metabolic conditioning. This integrated training approach may assist students in developing not only speed and power but also overall physical competence and confidence in movement.

Limitations and Future Directions

The present study provides valuable insights into the effectiveness of hybrid plyometric training methods; however, several limitations should be acknowledged. First, the sample size was relatively small ($n = 60$), with only 20 participants in each group, which may limit the statistical power and generalisability of the findings. Future studies should consider larger, more diverse samples, including female participants and athletes across different competitive levels. Second, the study primarily relied on sprint time measurements (30 m, 40 m, and 50 m) as performance indicators, without incorporating detailed biomechanical or physiological assessments, such as stride length, ground contact time, electromyography, or force-plate analysis. Including such variables would provide deeper insight into the mechanisms underlying performance improvements. Finally, although the intervention lasted 12 weeks, no long-term follow-up was conducted to determine the retention or sustainability of training adaptations. Future studies are encouraged to use more precise measurement tools to enhance data accuracy.

Conclusion of the Discussion

Overall, the findings of this study demonstrate that both Hybrid Plyometric-Ladder Training and Plyometric-Circuit Training are effective methods for improving



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sprint performance in male students. The improvements observed across the 30 m, 40 m, and 50 m sprint splits indicate that these training programmes enhance both the acceleration and maximum velocity phases of sprinting. The slightly greater improvements seen in the PCT group suggest that incorporating circuit training elements may provide additional benefits by boosting muscular endurance and metabolic efficiency, allowing athletes to maintain higher running speeds. These results align with the existing literature on neuromuscular training and emphasise the importance of integrated training approaches that combine strength, power, coordination, and conditioning.

From both a sport science and sport pedagogy perspective, the findings highlight the importance of structured training programmes in enhancing athletic performance, physical literacy, and the development of life skills among youth athletes.

Ethics approval

The study protocol was reviewed and approved by the Institutional Ethics Committee of Alagappa University College of Physical Education, Alagappa University, Karaikudi, Tamil Nadu, and India. Approval No.: AUCPE/R20161803/2025. The WMA Declaration of Helsinki -Ethical Guidelines for Medical Research Involving Human Subjects was followed in the creation of this paper. Also, all procedures were carried out in accordance with the applicable rules and laws.

References

- Annasai, F., Nugroho, S., Hartanto, A., & Arianto, A. C. (2023). Circuit training based physical condition training model to increase speed, agility, arm power, and limb muscle power of basketball athletes. *Pedagogy of Physical Culture and Sports*, 27(4), 282–288. <https://doi.org/10.15561/26649837.2023.0403>
- Apte, S., Prigent, G., Stöggel, T., Martínez, A., Snyder, C., Gremeaux-Bader, V., & Aminian, K. (2021). Biomechanical response of the lower extremity to running-induced acute fatigue: a systematic review. *Frontiers in Physiology*, 12, 646042. <https://doi.org/10.3389/fphys.2021.646042>
- Asadi, A., Ramirez-Campillo, R., Arazi, H., & Sáez de Villarreal, E. (2018). The effects of maturation on jumping ability and sprint adaptations to plyometric training in



Original article. Effects of hybrid plyometric-ladder and plyometric-circuit training on sprint speed and maximum velocity development in male students. Vol. 12, n. ° 4; p. 1-33, July 2026.

<https://doi.org/10.55040/smw7tj44>

youth soccer players. Journal of Sports Sciences, 36(21), 2405–2411.

<https://doi.org/10.1080/02640414.2018.1459151>

Bassa, E., Lola, A. C., Melliou, A., Prassa, M., Stavropoulou, G., & Ziogas, N. (2024).

Agility ladder training combined with plyometric or multidirectional speed drills: short-term adaptations on jump, speed, and change of direction performance in young female volleyball players. Pediatric Exercise Science, 36(4), 248–257.

<https://doi.org/10.1123/pes.2024-0024>

Belete, H. B. (2025). Plyometric Training and Its Effects on Neuromuscular Performance among Bahir Dar City U-20 Football Athletes. ETHIOPIAN JOURNAL OF SPORT SCIENCE, 6, 160–179.

Bishop, D., Girard, O., & Mendez-Villanueva, A. (2011). Repeated-sprint ability—part II: recommendations for training. Sports Medicine, 41(9), 741–756.

<https://doi.org/10.2165/11590560-000000000-00000>

Boccia, G., Fornasiero, A., Savoldelli, A., Bortolan, L., Rainoldi, A., Schena, F., & Pellegrini, B. (2017). Oxygen consumption and muscle fatigue induced by whole-body electromyostimulation compared to equal-duration body weight circuit training. Sport Sciences for Health, 13(1), 121–130.

<https://doi.org/10.1007/s11332-016-0335-4>

Brazier, J., Maloney, S., Bishop, C., Read, P. J., & Turner, A. N. (2019). Lower extremity stiffness: considerations for testing, performance enhancement, and injury risk. The Journal of Strength & Conditioning Research, 33(4), 1156–1166.

<https://doi.org/10.1519/JSC.0000000000002283>

Brazil, A. (2018). A biomechanical framework of the training principles to inform exercise selection within strength and conditioning for sprinting. Cardiff Metropolitan University.

Cao, J., Xun, S., Zhang, R., & Zhang, Z. (2024). Effects of unilateral, bilateral and combined plyometric jump training on asymmetry of muscular strength and power, and change-of-direction in youth male basketball players. Journal of Sports Science & Medicine, 23(4), 754. <https://doi.org/10.52082/jssm.2024.754>



Original article. Effects of hybrid plyometric-ladder and plyometric-circuit training on sprint speed and maximum velocity development in male students. Vol. 12, n.º 4; p. 1-33, July 2026.

<https://doi.org/10.55040/smw7tj44>

- Čoh, M., Babić, V., & Maćkała, K. (2010). Biomechanical, neuro-muscular and methodical aspects of running speed development. *Journal of Human Kinetics*, 26, 73–81. <https://doi.org/10.2478/v10078-010-0051-0>
- Crotty, E. D., Furlong, L.-A. M., & Harrison, A. J. (2024). Ankle and plantar flexor muscle–tendon unit function in sprinters: a narrative review. *Sports Medicine*, 54(3), 585–606. <https://doi.org/10.1007/s40279-023-01967-1>
- Dave, V. R., & Singh, A. K. (2024). Comparison of Ladder Training Versus Plyometric Training on Agility & Speed among Vadodara Cricket Players: An Experimental Study. *Indian Journal of Physiotherapy & Occupational Therapy*, 18(2). <https://doi.org/10.37506/2k9fk365>
- de Villarreal, E. S., Requena, B., Izquierdo, M., & Gonzalez-Badillo, J. J. (2013). Enhancing sprint and strength performance: combined versus maximal power, traditional heavy-resistance and plyometric training. *Journal of Science and Medicine in Sport*, 16(2), 146–150. <https://doi.org/10.1016/j.jsams.2012.05.007>
- Fletcher, I. (2009). Biomechanical aspects of sprint running. *UK Strength and Conditioning Association*, 16(16), 20–23.
- Goodwin, J. E., & Jeffreys, I. (2016). Plyometric training: Theory and practice. In *Strength and Conditioning for Sports Performance* (pp. 346–382). Routledge.
- Goodwin, J. E., & Jeffreys, I. (2021). Plyometric Training. *Strength and Conditioning for Sports*. <https://doi.org/10.4324/9780429330988-19>
- Hansen, D., & Kennelly, S. (2017). Plyometric anatomy. *Human Kinetics*. <https://doi.org/10.5040/9781718225442>
- Haugen, T., McGhie, D., & Ettema, G. (2019). Sprint running: from fundamental mechanics to practice—a review. *European Journal of Applied Physiology*, 119(6), 1273–1287. <https://doi.org/10.1007/s00421-019-04139-0>
- Henjilito, R., bin Abdullah, N. M., Yani, A., Setiawan, B. A., & Amran, Z. (2025). The effect of plyometric training on discus throwing performance in middle school athletes. *Sportis. Scientific Journal of School Sport, Physical Education and Psychomotricity*, 11(3), 1–19. <https://doi.org/10.17979/sportis.2025.11.3.11764>



Original article. Effects of hybrid plyometric-ladder and plyometric-circuit training on sprint speed and maximum velocity development in male students. Vol. 12, n. ° 4; p. 1-33, July 2026.

<https://doi.org/10.55040/smw7tj44>

Hicks, D. S., McMillan, S., Schöllhorn, W., & Van Den Tillaar, R. (2026). Sprint Running Coordination: A Dynamical Systems Perspective. *Sports Medicine*, 1–25.

<https://doi.org/10.1007/s40279-025-02380-6>

Hicks, D. S., Schuster, J. G., Samozino, P., & Morin, J.-B. (2020). Improving mechanical effectiveness during sprint acceleration: practical recommendations and guidelines. *Strength & Conditioning Journal*, 42(2), 45–62.

<https://doi.org/10.1519/SSC.0000000000000519>

Huang, H., Huang, W.-Y., & Wu, C.-E. (2023). The effect of plyometric training on the speed, agility, and explosive strength performance in elite athletes. *Applied Sciences*, 13(6), 3605. <https://doi.org/10.3390/app13063605>

Ikenna, U. C., Ngozichi, O. G., Ijeoma, I., Ijeoma, N., Ifeanyichukwu, N., & Martin, O. C. (2020). Effect of circuit training on the cardiovascular endurance and quality of life: Findings from an apparently healthy female adult population. *Journal of Applied Life Sciences International*, 23(3), 1–8.

<https://doi.org/10.9734/jalsi/2020/v23i330148>

Issurin, V. B. (2013). Training transfer: scientific background and insights for practical application. *Sports Medicine*, 43(8), 675–694. <https://doi.org/10.1007/s40279-013-0049-6>

[013-0049-6](https://doi.org/10.1007/s40279-013-0049-6)

Kale, M., & Acikada, C. (2016). Effects of stride length and frequency training on acceleration kinematic, and jumping performances. *Sport Science Review*, 25(3–4), 243–260. <https://doi.org/10.1515/ssr-2016-0013>

Kargarfard, M., Tajvand, S., Rabbani, A., Clemente, F. M., & Jalilvand, F. (2020). Effects of combined plyometric and speed training on change of direction, maximal speed, and repeated sprint ability in young soccer players. *Kinesiology*, 52(01), 85–93.

<https://doi.org/10.26582/k.52.1.11>

Keller, S., Koob, A., Corak, D., von Schöning, V., & Born, D.-P. (2020). How to improve change-of-direction speed in junior team sport athletes—horizontal, vertical, maximal, or explosive strength training? *The Journal of Strength & Conditioning Research*, 34(2), 473–482.

<https://doi.org/10.1519/JSC.0000000000002814>

Keskinis, I., Bassa, E., Merkou, E., Lazaridis, S., & Panoutsakopoulos, V. (2025). The effect of ladder training on performance and kinematic parameters of sprinting in



Original article. Effects of hybrid plyometric-ladder and plyometric-circuit training on sprint speed and maximum velocity development in male students. Vol. 12, n. ° 4; p. 1-33, July 2026.

<https://doi.org/10.55040/smw7tj44>

prepubertal track and field athletes. International Journal of Sports Science & Coaching, 17479541251384100. <https://doi.org/10.1177/17479541251384101>

Kırlangıç, S., & Bozkurt, S. (2025). The effect of fundamental movement skills on the gross motor skills of third-grade primary school students. Sportis. Scientific Journal of School Sport, Physical Education and Psychomotricity, 11(4), 1–24.

<https://doi.org/10.17979/sportis.2025.11.4.11881>

Lhemus, H. A., Jayan, E. H., & Al-Lami, G. A. H. (2025). The Ability to Repeat Maximum Speeds and Their Impact on Some Functional and Skill Indicators for Futsal Players. Revista de Psicología Del Deporte, 34(1).

Li, A., Zhang, H., Peng, C., Wu, Y., & He, J. (2025). Can weekly frequency of plyometric training impair strength and power? A short-term comparison in regional-level jump athletes. Frontiers in Physiology, 16, 1671750.

<https://doi.org/10.3389/fphys.2025.1671750>

Lin, H., Wang, H., & Ke, Y. (2025). Research on optimization and improvement of sports fatigue training based on biomechanical principles. Molecular & Cellular Biomechanics, 22(5). <https://doi.org/10.62617/mcb1561>

Liu, X., Shao, Y., Saha, S., Zhao, Z., & Karmakar, D. (2025). Maximizing sprint performance among adolescent sprinters: a controlled evaluation of functional, traditional, and combined training approaches. Frontiers in Public Health, 13, 1596381. <https://doi.org/10.3389/fpubh.2025.1596381>

Lockie, R. G., Murphy, A. J., Knight, T. J., & De Jonge, X. A. K. J. (2011). Factors that differentiate acceleration ability in field sport athletes. The Journal of Strength & Conditioning Research, 25(10), 2704–2714.

<https://doi.org/10.1519/JSC.0b013e31820d9f17>

Mahalingam, M., Saibya, S., Pandey, G., Karmakar, D., Rajpoot, Y. S., Elayaraja, M., Prasad, S., Lachungpa, P. K., Govindasamy, K., & Gogoi, H. (2024). Effectiveness of High-Intensity Circuit Training on Physical Fitness Among Athletes: A Systematic Review of Randomized-Controlled and Non-Controlled Trials. Fizjoterapia Polska, 24(3), 145–157.

<https://doi.org/10.56984/8ZG020AWUR>



Original article. Effects of hybrid plyometric-ladder and plyometric-circuit training on sprint speed and maximum velocity development in male students. Vol. 12, n.º 4; p. 1-33, July 2026.

<https://doi.org/10.55040/smw7tj44>

Mănescu, D. C. (2025). Computational analysis of neuromuscular adaptations to strength and plyometric training: an integrated modeling study. *Sports*, 13(9), 298.
<https://doi.org/10.3390/sports13090298>

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>

McGarrigal, L. D., Morse, C. I., Sims, D. T., & Stebbings, G. K. (2025). Development of stretch-shortening cycle function in girls during maturation and in response to training: a narrative review. *The Journal of Strength & Conditioning Research*, 39(8), e1043–e1051. <https://doi.org/10.1519/JSC.00000000000005191>

Moura, T. B. M. A., Leme, J. C., Nakamura, F. Y., Cardoso, J. R., & Moura, F. A. (2024). Determinant biomechanical variables for each sprint phase performance in track and field: A systematic review. *International Journal of Sports Science & Coaching*, 19(1), 488–509. <https://doi.org/10.1177/17479541231200526>

Nicholson, B., Dinsdale, A., Jones, B., & Till, K. (2021). The training of short distance sprint performance in football code athletes: a systematic review and meta-analysis. *Sports Medicine*, 51(6), 1179–1207. <https://doi.org/10.1007/s40279-021-01447-4>

Pandy, M. G., Lai, A. K. M., Schache, A. G., & Lin, Y. (2021). How muscles maximize performance in accelerated sprinting. *Scandinavian Journal of Medicine & Science in Sports*, 31(10), 1882–1896. <https://doi.org/10.1111/sms.14021>

Pareja-Blanco, F., Asián-Clemente, J. A., & de Villarreal, E. S. (2021). Combined squat and light-load resisted sprint training for improving athletic performance. *The Journal of Strength & Conditioning Research*, 35(9), 2457–2463.
<https://doi.org/10.1519/JSC.00000000000003171>

Ramirez-Campillo, R., Castillo, D., Raya-Gonzalez, J., Moran, J., de Villarreal, E. S., & Lloyd, R. S. (2020). Effects of plyometric jump training on jump and sprint performance in young male soccer players: a systematic review and meta-analysis. *Sports Medicine*, 50(12), 2125–2143. <https://doi.org/10.1007/s40279-020-01337-1>



Original article. Effects of hybrid plyometric-ladder and plyometric-circuit training on sprint speed and maximum velocity development in male students. Vol. 12, n. ° 4; p. 1-33, July 2026.

<https://doi.org/10.55040/smw7tj44>

- Ramirez-delaCruz, M., Bravo-Sanchez, A., Esteban-Garcia, P., Jiménez, F., & Abian-Vicen, J. (2022). Effects of plyometric training on lower body muscle architecture, tendon structure, stiffness and physical performance: a systematic review and meta-analysis. *Sports Medicine-Open*, 8(1), 40. <https://doi.org/10.1186/s40798-022-00431-0>
- Ramos-Campo, D. J., Andreu Caravaca, L., Martinez-Rodriguez, A., & Rubio-Arias, J. Á. (2021). Effects of resistance circuit-based training on body composition, strength and cardiorespiratory fitness: a systematic review and meta-analysis. *Biology*, 10(5), 377. <https://doi.org/10.3390/biology10050377>
- Ravi, P., & Kalimuthu, D. (2025). Effectiveness of plyometrics vs. circuit training in core conditioning: an empirical study. *Sportis. Scientific Journal of School Sport, Physical Education and Psychomotricity*, 11(3), 1–22. <https://doi.org/10.17979/sportis.2025.11.3.11906>
- Ross, A., Leveritt, M., & Riek, S. (2001). Neural influences on sprint running: training adaptations and acute responses. *Sports Medicine*, 31(6), 409–425. <https://doi.org/10.2165/00007256-200131060-00002>
- Rumpf, M. C., Lockie, R. G., Cronin, J. B., & Jalilvand, F. (2016). Effect of different sprint training methods on sprint performance over various distances: a brief review. *The Journal of Strength & Conditioning Research*, 30(6), 1767–1785. <https://doi.org/10.1519/JSC.0000000000001245>
- Saghiv, M. S., & Sagiv, M. S. (2020). Oxygen uptake and anaerobic performances. In *Basic Exercise Physiology: Clinical and Laboratory Perspectives* (pp. 149–205). Springer. https://doi.org/10.1007/978-3-030-48806-2_3
- Sandford, G. N., Laursen, P. B., & Buchheit, M. (2021). Anaerobic speed/power reserve and sport performance: scientific basis, current applications and future directions. *Sports Medicine*, 51(10), 2017–2028. <https://doi.org/10.1007/s40279-021-01523-9>
- Sepriani, R., Pratiwi, M. D., Resmana, R., Amra, F., & Angelia, L. (2025). The effectiveness of plyometric training using set and circuit system on leg muscle explosive power. *Journal of Physical Education and Sport*, 25(10), 2145–2151.



Original article. Effects of hybrid plyometric-ladder and plyometric-circuit training on sprint speed and maximum velocity development in male students. Vol. 12, n. ° 4; p. 1-33, July 2026.

<https://doi.org/10.55040/smw7tj44>

Short, T., Manos, T., Ortega, J., Peterson, A., & Kwon, Y. S. (2022). The effects of ladder training on sprint and change of direction performance. *Topics in Exercise Science and Kinesiology*, 3(1), 7.

Taskin, H. (2009). Effect of Circuit Training on the Sprint-Agility and Anaerobic Endurance. *The Journal of Strength & Conditioning Research*, 23(6).
https://journals.lww.com/nscajscr/Fulltext/2009/09000/Effect_of_Circuit_Training_on_the_Sprint_Agility.25.aspx.

<https://doi.org/10.1519/JSC.0b013e3181b3dfc0>

Timperio, A., Salmon, J., & Ball, K. (2004). Evidence-based strategies to promote physical activity among children, adolescents and young adults: review and update. *Journal of Science and Medicine in Sport*, 7(1), 20–29.

[https://doi.org/10.1016/S1440-2440\(04\)80274-3](https://doi.org/10.1016/S1440-2440(04)80274-3)

Van Hooren, B., Aagaard, P., & Blazevich, A. J. (2024). Optimizing resistance training for sprint and endurance athletes: balancing positive and negative adaptations. *Sports Medicine*, 54(12), 3019–3050. <https://doi.org/10.1007/s40279-024-02110-4>

Vetrovsky, T., Steffl, M., Stastny, P., & Tufano, J. J. (2019). The efficacy and safety of lower-limb plyometric training in older adults: a systematic review. *Sports Medicine*, 49(1), 113–131. <https://doi.org/10.1007/s40279-018-1018-x>

Vigh-Larsen, J. F., Junge, N., Cialdella-Kam, L., Tomas, R., Young, L., Krstrup, P., Mohr, M., & Nybo, L. (2024). Testing in Intermittent Sports—Importance for Training and Performance Optimization in Adult Athletes. *Medicine & Science in Sports & Exercise*, 56(8), 1505–1537.
<https://doi.org/10.1249/MSS.00000000000003442>

von Lieres und Wilkau, H. C., Irwin, G., Bezodis, N. E., Simpson, S., & Bezodis, I. N. (2020). Phase analysis in maximal sprinting: an investigation of step-to-step technical changes between the initial acceleration, transition and maximal velocity phases. *Sports Biomechanics*, 19(2), 141–156.

<https://doi.org/10.1080/14763141.2018.1473479>

Watkins, C. M., Storey, A. G., McGuigan, M. R., & Gill, N. D. (2021). Implementation and efficacy of plyometric training: Bridging the gap between practice and



Original article. Effects of hybrid plyometric-ladder and plyometric-circuit training on sprint speed and maximum velocity development in male students. Vol. 12, n. ° 4; p. 1-33, July 2026.

<https://doi.org/10.55040/smw7tj44>

research. The Journal of Strength & Conditioning Research, 35(5), 1244–1255.

<https://doi.org/10.1519/JSC.0000000000003985>

Wild, J., Bezodis, N. E., Blagrove, R. C., & Bezodis, I. N. (2011). A biomechanical comparison of accelerative and maximum velocity sprinting: Specific strength training considerations. Professional Strength and Conditioning, 21, 23–37.

Winter, L., Huang, Q., Sertic, J. V. L., & Konczak, J. (2022). The effectiveness of proprioceptive training for improving motor performance and motor dysfunction: a systematic review. Frontiers in Rehabilitation Sciences, 3, 830166.

<https://doi.org/10.3389/freesc.2022.830166>

Zheng, T., Kong, R., Liang, X., Huang, Z., Luo, X., Zhang, X., & Xiao, Y. (2025). Effects of plyometric training on jump, sprint, and change of direction performance in adolescent soccer player: A systematic review with meta-analysis. PloS One, 20(4), e0319548. <https://doi.org/10.1371/journal.pone.0319548>