ISSN Print: 2664-7710
ISSN Online: 2664-7729
Impact Factor: RJIF 8.28
IJPSPE 2025; 7(2): 345-349
www.physicaleducationjournal.net
Received: 05-07-2025
Accepted: 08-08-2025

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Effect of 12-week plyometric training program on kinematic parameters in high school students

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DOI: https://www.doi.org/10.33545/26647710.2025.v7.i2e.174

Abstract
This study investigates the impact of 12-week plyometric training program on the kinematic parameters of high school students. This study includes thirty (30) students, who were split into two groups (the experimental group and the controlled group), each consisting of fifteen (15) students, using a random group design. Except for their regular activities, the controlled group (CG) was not permitted to take part in the training program. To develop kinematic parameters in high school students, a plyometric training program was given to the experimental group. The kinematic parameters are step frequency, stride length and velocity in 30-metre and 50-metre sprints. Data were collected in two parts: pre- and post-12-week training programs, using the Kinovea Software. Subjects were informed about the purpose of the study and how to execute the test by demonstration. To compare the mean differences between the pre- and post-test scores in each criterion measure, a paired 't'-test was applied by using SPSS. To test this hypothesis, the level of significance was set at 0.05. Based on the findings of this study, it is concluded that 12 weeks of plyometric training resulted in significant improvements in step frequency, stride length and velocity in both 30-metre and 50-metre sprints among high school students. However, no significant improvement was observed in either of the control groups.

Keywords: Kinematics, plyometric, step frequency, stride length, velocity

Introduction

Plyometric training, defined by rapid stretch-shortening cycle (SSC) movements that facilitate a swift transition from eccentric to concentric muscle contractions, has become an essential element of youth athletic development and performance improvement (Markovic & Mikulic, 2010; Turner & Jeffreys, 2010) [14, 25]. The process of the stretch-shortening cycle, which involves rapid stretching and contraction of muscle reinforces the effectiveness of plyometric training. The elastic energy that is generated during the stretching phase is used to enhance the force in the following concentric phase (Komi & Gollhofer, 1997) [9]. Systematic reviews and meta-analyses consistently show that well-designed plyometric training programs following proper supervision and progressive principles can safely and effectively improve physical parameters in children and adolescents with minimal risk of complications (Behm *et al*., 2017; Ramirez-Campillo *et al*., 2018; Stojanovic *et al*., 2017) [1, 19, 24]. Sprint performance is a complex athletic ability primarily influenced by the interaction of step frequency and stride length, which collectively dictate running velocity according to the biomechanical equation: velocity = stride length × step frequency (Brughelli *et al*., 2011; Morin *et al*., 2012) [2, 17]. Plyometric training causes a great variation in kinematic characteristics. The explosion characteristics of SSC workouts are connected to increasing the force applied to the ground in the stance phase of running and the limb adjustment in the flight phases (Jimenez-Reyes *et al*., 2014; Ramirez-Campillo *et al*., 2014) [8, 20].
Kinovea is an affordable and accurate tool for studying two-dimensional kinematic analysis. (Perez-Castilla *et al*., 2019) [18]. The present-day physical education curriculum gradually concerns on inclusive physical fitness development and encourages lifelong physical activity, making plyometric training a notable addition to the traditional program (Vaczi *et al*., 2013) [26]. The focus on short-distance sprint performance, particularly at 30-meter and 50-meter intervals, highlights the practical importance of this training for young athletic development

and sport-specific training programs (Grosset *et al*., 2009; Lloyd *et al*., 2012) [7, 12]. The focus on this short distance indicates essential stages of sprint performance, including the acceleration phase and the transition to maximum velocity growth, which are very important for success in many sports and physical activities (Chen *et al*., 2023) [3]. Various study into sprint kinematics over various distances shows that plyometric training can significantly improve step frequency, stride length, and overall velocity by improving neuromuscular function and movement mechanics (Chen *et al*., 2024; Kubo *et al*., 2007; Lloyd *et al*., 2016) [4, 10, 12]. The use of plyometric training in modern physical education programs has been proven both feasible and effective in improving athletes' physical fitness and sport performance (Zhang *et al*., 2025) [27].

Plyometric training programs prepare sports persons to improve explosivity and speed that enhance sport performance (Deng *et al*., 2024; Lloyd *et al*., 2013) [6, 13]. Using video to analyse how your body is moving is a valid way to check for changes in your training programme. According to Perez-Castilla *et al*. (2019) [18] plyometric training can improve step frequency, stride length, and velocity in 6 weeks. It was hypothesised that the experimental group would see significant improvements in all kinematic parameters and there would be no significant improvement in any of the kinematic variables of the control group, which was consistent with principles of training and adaptation (Chen *et al*., 2024; Moran *et al*., 2019; Ramirez-Campillo *et al*., 2014) [4, 16, 20]. This study addresses this gap by investigating the effect of a 12-week plyometric training program on step frequency, stride length and velocity in 30 metre and 50 metre sprints among high school students. The purpose of this study is to contribute evidence-based insights into an adolescent-specific training programme. The findings of this study may inform coaches and physical educators on optimising training schedules to enhance sprint performance during critical developmental stages.

Statement of the problem

The objective of the study is to investigate the effect of 12-week plyometric training program on kinematic parameters in high school students.

Methods and procedure

This is a true experimental design conducted to investigate the effect of 12-week plyometric training program on the kinematic parameters in high school students. The study included thirty (30) students between the ages of 14-16 years and students who had medical problems were excluded from the study. A random group design was adopted to divide the thirty (30) students into two groups (experimental group and control group) of fifteen (15) students in each training group. The controlled group (CG) was excluded from the training program, except as part of their daily routine. The experimental group was given a plyometric training program to develop kinematic parameters. The kinematic variables are step frequency, stride length, and velocity in 30-metre and 50-metre sprints. Data were collected in two parts, as pre- and post-training of a 12-week program using the Kinovea Software. Students were informed about the purpose of the study and how to execute the test by demonstration. To compare the mean differences between the pre-test and post-test scores in each criterion measure, a paired 't'-test was applied by using SPSS. To test the hypothesis, the level of significance was set at 0.05.

Results and Findings

The Analysis of all the collected data, their results and discussion are systematically presented as follows.

A comparative analysis of pre-test and post-test of plyometric training group on kinematic variables (step frequency, stride length, and velocity) in 30-metre and 50-metre sprints is presented in Table 1.

Table 1: Comparison of pre-test and post-test of plyometric training group on kinematic parameters (step frequency, stride length, and velocity) in 30-metre and 50-metre sprints

Variable	Testing Condition	Mean	SD	SEM	't'	Sig.
Step Frequency in 30M Sprint	Pre-Test	3.55	0.32	0.08	5.20	0.00*
	Post-Test	3.99	0.46	0.12		
Step Frequency in 50M Sprint	Pre-Test	4.10	0.32	0.08	1.98	0.00*
	Post-Test	4.56	0.56	0.14		
Stride Length in 30M Sprint	Pre-Test	1.45	0.10	0.03	10.72	0.00*
	Post-Test	1.53	0.12	0.03		
Stride Length in 50M Sprint	Pre-Test	1.52	0.09	0.02	8.79	0.00*
	Post-Test	1.58	0.09	0.02		
Velocity in 30M Sprint	Pre-Test	5.17	0.42	0.11	8.33	0.00*
	Post-Test	6.06	0.46	0.12		
Velocity in 50M Sprint	Pre-Test	6.23	0.52	0.13	6.67	0.00*
	Post-Test	7.13	0.65	0.17		

*Significant at 0.05

Table-1 shows the Mean ±SD of pre-test and post-test of plyometric training on step frequency in 30m sprint as 3.55±0.32 & 3.99±0.46 and step frequency in 50M Sprint as 4.10±0.32 & 4.56±0.56. The p-values were found to be statistically significant as the values obtained were **0.00*** and 0.00*, which were less than the 0.05 level of significance.

The Mean±SD of pre-test and post-test of plyometric training on stride length in 30m sprint as 1.45±0.10 & 1.53±0.12 and stride length in 50M Sprint as 1.52±0.09 & 1.58±0.09. The p-values were found to be statistically significant as the values obtained were 0.00* and 0.00*, which were less than the 0.05 level of significance.

Further, Table-1 shows the Mean±SD of pre-test and post-test of plyometric training on velocity in 30m sprint as 5.17±0.42 & 6.06±0.46 and velocity in 50m sprint as 6.23±0.52 & 7.13±0.65. The p-values were found to be statistically significant as the values obtained were **0.00*** and 0.00*, which were less than the 0.05 level of significance.

A comparative analysis of pre-test and post-test of the control group on kinematic variables (step frequency, stride length, and velocity) of high school students is shown in table 2.

Table 2: Comparison of pre-test and post-test of control group on kinematic parameters (step frequency, stride length, and velocity) in 30-metre and 50-metre sprints

Variable	Testing Condition	Mean	SD	SEM	't'	Sig.
Step Frequency in 30M Sprint	Pre-Test	3.83	0.28	0.07	0.18	0.86
	Post-Test	3.83	0.30	0.08		
Step Frequency in 50M Sprint	Pre-Test	4.00	0.42	0.11	0.97	0.35
	Post-Test	4.03	0.45	0.11		
Stride Length in 30M Sprint	Pre-Test	1.42	0.10	0.03	1.633	0.12
	Post-Test	1.43	0.11	0.03		
Stride Length in 50M Sprint	Pre-Test	1.51	0.06	0.01	0.408	0.69
	Post-Test	1.51	0.06	0.01		
Velocity in 30M Sprint	Pre-Test	5.43	0.21	0.05	1.63	0.12
	Post-Test	5.46	0.25	0.06		
Velocity in 50M Sprint	Pre-Test	6.02	0.55	0.14	1.59	0.13
	Post-Test	6.06	0.59	0.15		

*Significant at 0.05

Table-2 shows the Mean ± SD of pre-test and post-test of the control group on step frequency in 30m sprint as 3.83±0.28 & 3.83±0.30 and step frequency in 50m sprint as 4.00±0.42 & 4.03±0.45. The p-values were found to be statistically insignificant as the values obtained were 0.86 and 0.35, which were more than the 0.05 level of significance.

The Mean ± SD of pre-test and post-test of the control group on stride length in 30m sprint as 1.42±0.10 & 1.43±0.11 and stride length in 50m sprint as 1.51±0.06 & 1.51±0.06. The p-values were found to be statistically insignificant as the values obtained were 0.12 and 0.69, which were more than the 0.05 level of significance.

Further, table-2 shows the Mean ± SD of pre-test and post-test of the control group on velocity in 30m sprint as 5.43±0.21 & 5.46±0.25 and velocity in 50m sprint as 6.02±0.55 & 6.06±0.59. The p-values were found to be statistically insignificant as the values obtained were 0.12 and 0.13, which were more than the 0.05 level of significance.

The graphical representation of pre-test and post-test of the plyometric training group (PTG) and the control group (CG) on kinematic parameters (step frequency) is depicted in fig.1.

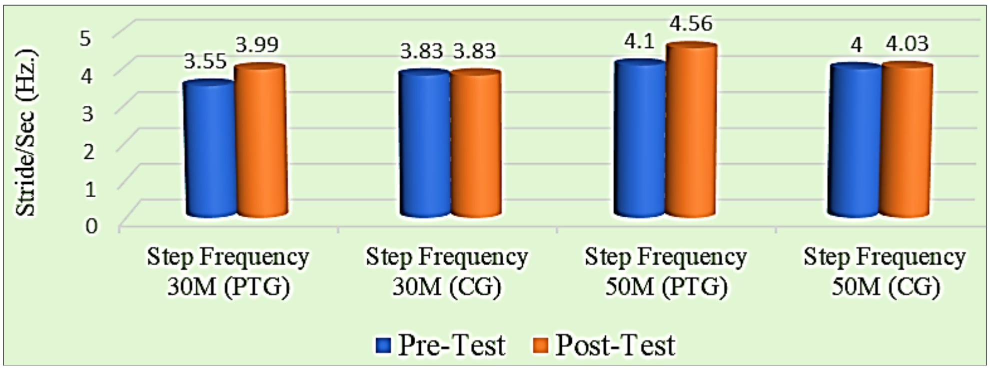

Fig 1: Graphical Presentation of Pre-Test and Post-Test Of Plyometric Training Group and Control Group on Kinematic Parameters (Step Frequency)

The graphical representation of pre-test and post-test of the plyometric training group (PTG) and the control group (CG) on kinematic parameters (stride length) is depicted in fig.2.

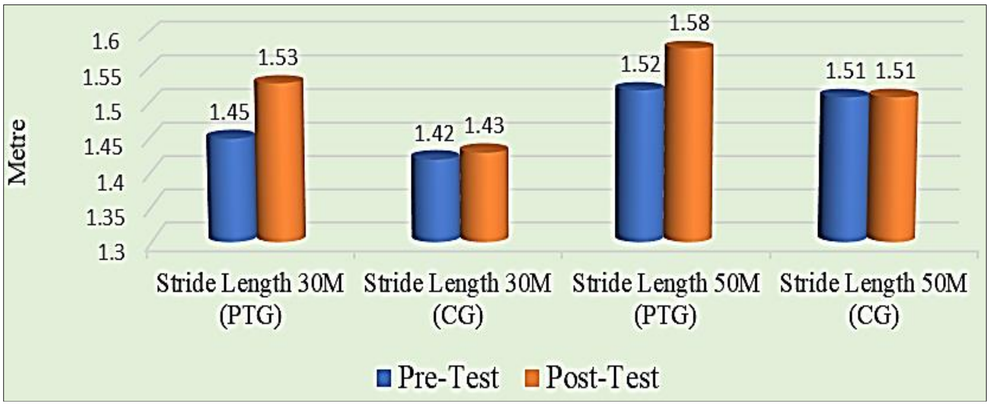

Fig 2: Graphical Presentation of Pre-Test and Post-Test Of Plyometric Training Group and Control Group on Kinematic Parameters (Stride Length)

The graphical representation of pre-test and post-test of the plyometric training group (PTG) and the control group (CG) on kinematic parameters (velocity) is depicted in fig.3.

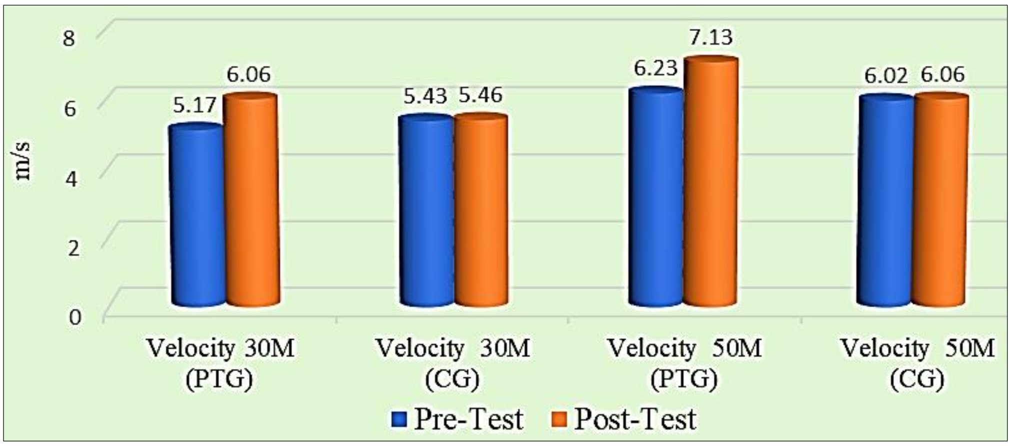

Fig 3: Graphical Presentation of Pre-Test and Post-Test Plometric Training Group and Control Group on Kinematic Parameters (Velocity)

Discussion of Findings

This study found that after 12 weeks of plyometric training step frequency, stride length and velocity significantly improved in both 30m and 50m sprints. This agrees with the literature, which states plyometric training can improve the sprint kinematics of youth (Markovic & Mikulic, 2010; Ramirez-Campillo *et al*., 2018) [14, 19]. In line with the kinematic improvements shown in the high school students, Miller *et al*. (2006) [15] found that 6 weeks of plyometric training increased 40M sprint velocity by 2.5% in physically active guys while also causing substantial increases in stride length and step frequency. The observed kinematic alterations were also supported by Saez-Saez de Villarreal *et al*. (2012) [23], who discovered that 7 weeks of plyometric training increased young athletes' 20M sprint velocity by 2.8% due to better stride efficiency and step rate. Furthermore, Rimmer and Sleivert (2000) [21] showed that teenage athletes who received 8 weeks of plyometric training enhanced their explosive power by 3.0% in 30M sprints by increasing stride length and step frequency. Together, these investigations support the idea that plyometric exercise can improve kinematic variables, which is in line with the findings of the high school students. The limited changes in the control group suggest that the improvements in the experimental group were due to specific changes in the neuromuscular system. These changes were brought about through participation in plyometric activities, rather than the passage of time or other external events. This supports the idea of training specificity and the effectiveness of targeted treatments to enhance sprint performance (Lloyd *et al*. 2016 Stojanovic *et al*. 2017). The results show that plyometric training should be added to juvenile sport activities to improve sprint mechanics and athletic development generally.

Conclusion

Based on the findings of this study, the following conclusions were drawn:

1. It was concluded from the findings that twelve weeks of plyometric training showed significant improvement in the step frequency, stride length and velocity in 30 metre sprints of high school students. However, an insignificant improvement was observed in the control group.
2. The findings of the study proved that twelve weeks of plyometric training showed significant improvement in step frequency, stride length and velocity in 50 metre sprints of high school students. However, no significant improvement was observed in the control group.

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