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Contribution of Plyometric Exercises and Hamstring Curl Exercises in Explosive Power of Fast Bowler with Heart Rate Recovery

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ABSTRACT
The purpose of the research was to examine the contribution of plyometric exercises and hamstring curl exercises in explosive power and heart rate recovery of fast bowlers. Experimental research design with pre and post test was utilized. The n=24 sample size was allocated in two groups the experimental group and traditional training group with 12 participants in each group. The male professional club cricketers with age between 16-26 years old from Jawad Cricket Club and MS Cricket Academy were included after written informed consent. Explosive power was measured through 30 meter sprint test, 50m sprint test, and standing broad jump in both groups. Only experimental group heart rate responses were collected before the start of over, after over and heart rate recovery after 1-minute. Experimental group underwent 12 weeks combined plyometric and hamstring curl exercises and control group performed routine training. Paired sample t-test was used to analyze with-in group changes in both groups and independent t-test was use to compare the effects of training programs in both groups. The level significance was $p<0.05$. The mean age of fast bowlers were experimental group (19.33 ± 2.87) and control group (19.66±3.02). The playing experience of both groups was 4.83 ±1.90 and 4.75±2.01 respectively. While comparing both groups, experimental group significantly enhanced the explosive power after the intervention ($p<0.05$). Within group analysis showed that experimental group significantly improved the explosive power and heart rate recovery after the intervention ($p<0.05$). No significant changes were found in control group after training. The results indicated that both plyometric and hamstring curl training improved explosive power and heart rate recovery in fast bowlers at the end of study. The findings have shown that targeted training can improve the physical performance of cricketers. Cricket coaches and trainer should utilize structured and scientific based training program to enhance the performance of cricketers.

KEYWORDS
Nordic Hamstring Curl, Plyometric Training, Hamstring Curl, Prone Hamstring Curl, Heart Rate Recovery

1. Introduction

Over the past few years, Pakistani fast bowlers have faced difficulties in maintaining their peak performance at the international level frequently failing to maintain consistency and speed during long bowling spells. The decline in bowling performance is mainly due to physical fitness issues and the physical demands of prolong bowling sessions (Mahmood, 2023). To address these issues, it is necessary to implement a strategic approach at the domestic and club levels cricket including the development of structured, periodized, and scientific training programs to improve the fitness, speed, and endurance of fast bowlers. Strengthening these foundational characteristics is essential for enhancing performance on the international level.

Keeping in view the importance of physical fitness for enhancing fast bowling performance, it is crucial to integrate strength training, endurance development, and injury prevention strategies that directly target the specific physical requirements of fast bowlers to enable them to maintain speed, power, and consistency throughout their bowling spells. Plyometric training improves the speed of young cricketers (Ashraf et al., 2019). Incorporating high velocity elastic band for hamstring training in pre-season routine of football athletes are beneficial to increase knee extension-flexion maximal movement frequency with no evident effects on strength, jump and sprint running performance (Kamandulis et al., 2020).

According to Ghosh and Biswas (2020), plyometric training is very effective training program for speed improvement as compared to resistance training programs. It involved the stretch shortening cycle of muscles which improves the explosive power and is beneficial for speed enhancement for cricketers. Additionally, upper extremity plyometric exercises have been shown to improve shoulder strength in cricket players, which is critical for fast bowling. However, while plyometric exercises significantly enhance strength, there may not be as much improvement in power without a longer duration of training (Jhaveri & Patel, 2024).

The present study intends to examine the effects of plyometric exercises and hamstring curl exercises on explosive strength and heart rate recovery of fast bowlers. By focusing on these key physical attributes, the study aims to contribute to the development of optimized training programs for fast bowlers.

Research Objectives

The following objectives of the study are generated from the literature:

i. To examine the difference in explosive power between the experimental group and the control group before the implementation of intervention.

ii. To examine difference in explosive power between the experimental group and the control group after the implementation of intervention.

iii. To determine the difference in explosive power during pre and post intervention of experimental group.

iv. To examine difference in heart rate recovery between pre and post intervention of experimental group.

Research Hypotheses

The following hypotheses for the present research are proposed to answer the research questions:

Ho1: There is no significant difference in explosive power of experimental and control group before the intervention.

Ha1: There is a significant difference in explosive power of experimental and control group after the intervention.

Ha2: There is significant difference in explosive power during pre and post intervention of experimental group

Ha3: There is significant difference in heart rate recovery between pre and post intervention of experimental group.

2. Methodology

Research Design

A research design consists of structured framework which ensured the study is methodologically accurate, and maintains the reliability and validity (Creswell & Creswell, 2023). A scientific approach for examining cause-and-effect correlations between variables is an experimental study. In experimental research, the researcher manipulates one or more independent variables to evaluate their effect on a dependent variable while controlling for extraneous variables that could influence the results (Mattila et al., 2021).

Experimental research design with pre and post-test was used in the present study. Before the treatment experimental group, and control group underwent a pre-test with reference to all independent variable at 0 week and score of each subject were recorded. After the pre-test, the treatment of plyometric exercises and hamstring curl exercises were given to experimental group for 12 weeks consisting 2 days in a week (Tuesday and Thursday).

Proposed Location and Facility

The testing and training were conducted at Jawad Cultural Sports Complex facility, and control group testing was conducted at MS cricket academy Eden Garden Faisalabad. All the facilities such as dumbbells, elastic bands, stopwatch, and heart rate monitor were provided by the researcher during testing and training sessions.

Participants of the Study

In experimental research, participants refer to all subjects, objects, or members directly involved in data gathering relating to the problem that is being investigated (Ullah et al., 2023). The participants from Jawad cultural sports complex Faisalabad and MS academy Faisalabad were chosen for the study. All fast bowlers (16-26 years) were chosen as participants in the study.

Sample Size

Total twenty-four fast bowlers were selected from two different club such as Jawad cricket club (n=12) and MS cricket academy (n=12). Jawad cricket club fast bowlers who met the inclusion criteria were divided into the experimental group and MS cricket academy fast bowlers were assigned to the control group.

Procedure of Data Collection

Demographic information of all participants such as age, and playing experience were recorded in pre-test for both experimental group and control group. Speed was measured through 30m and 50m standing sprints. Participants were instructed to stand behind the starting line and run in a straight lane on whistle. Each participant performed three sprints, and average time was noted for both 30m and 50m sprints. Explosive strength was measured via standing long jump, which is reliable test (Fernandez-Santos et al., 2015) to measure the lower body explosive strength. Participants were informed to stand behind the line and jump as far as possible. Heart Rate recovery was assessed through polar H-10 heart rate monitor. It is a reliable tool to measure the heart rate responses during different physical activities (Schaffarczyk et al., 2022). After the explanation about the test, a Polar H-10 heart rate monitor connected via Bluetooth to a smartphone containing Polar Beat (v.3.5.10) was attached to participants. Participants were instructed to start their warm-up and after completion of warm up participant wore the polar heart rate monitor. Heart rate was recorded before the start of the first over, after completion of the over and after one minute of first over. After that, 3-minute rest was given to fast bowler and same procedure was followed for second over. Perrett et al. (2021) used a same procedure to record the heart rate responses of fast bowlers. Fast bowlers used 70-80% percent of their maximum heart rate during the both over. Maximum heart rate of each participant was calculated according to formula 220-age developed by Dr. William Haskell and Dr. Samuel Fox in 1970.

All fast bowlers followed a standardized warm-up routine consisting of five minutes of jogging and dynamic stretching exercises targeting different muscles and joints. Participants were instructed to avoid vigorous physical activity for 24 hours before testing. A familiarization session was conducted to ensure the participants were fully aware of the testing and training procedures before the study began. The pre-test was conducted in week 0 and post-test was conducted in week 13 after the completion of 12 weeks intervention. Fast bowlers underwent speed and lower limb strength testing on the first day, followed by heart rate recovery testing on the second day of week zero. For the post-test the same procedure followed as pre-test.

Equipment Used

Stopwatch, Measuring tape, Cones, and Polar H-10 heart rate monitor as equipment were used during the pre and post test.

Development of Training Protocol

The training protocols of the present study were self-administrated and adapted from previous studies. Plyometric training was adopted from (Ashraf et al., 2019) and nordic hamstring curl training was adapted from (Moran et al., 2022). Originally, plyometric and nordic hamstring training intervention were eight weeks long and volume of these two exercises were adjusted according to needs of the present study with the permission of the original authors. The training protocols of prone hamstring curl with elastic band and lying hamstring curl with dumbbells were self-administrated.

Training Intervention

The training protocol of this study was a 12-weeks plyometric and hamstring exercises of Nordic hamstring curl, prone hamstring curl with elastic band, and lying hamstring curl with dumbbells. The written informed consent was obtained from the fast bowlers before the start of testing and training.

Procedure of Training Protocol

The experimental group performed a 12 weeks training protocol for two days per week and the control group continued the regular training program. The treatment group performed plyometric training on the first day and hamstring curl exercises on the second day for weeks 1 and 2. For the remaining ten weeks, the experimental group performed both plyometric and hamstring exercises on the same day. The training protocol was conducted on Tuesday and Thursday for every week. Athletes followed a standardized warm-up routine consisting of 5-10 minutes of jogging and dynamic stretching exercises targeting different muscles and joints.

Table 1. Protocol of plyometric training

Weeks	Plyometric exercises	Repetitions and sets	Intensity
Week 1	Ankle hop	16 x2	Low
(80 foot contacts)	Box jump	8 x3	
	Jump squats	8 x3	
Week 2	Ankle hop	15 x2	Low
(90 foot contacts)	Box jump	10 x3	Medium
	Jump squats	10 x2	
Week 3	Ankle hop	15x2	Low/Medium
(100 foot contacts)	Box jump	10x3	Medium
	Jump squats	10x3	
	Plyometric step ups	10x2	
Week 4	Ankle hop	15x2	Low/Medium
(110 foot contacts)	Box jump	10x3	Medium
	Jump squats	8x3	
	Plyometric step ups	8x3	
	Depth jumps	6x2	
Week 5	Ankle hop	15x2	Low/Medium
(120 foot contacts)	Box jump	10x3	Medium
	Jump squats	8x3	
	Depth jumps	8x2	
	Alternate lunge jumps	10x2	
Week 6	Ankle hop	15x2	Medium/High
(130 foot contacts)	Box jump	10x2	
	Jump squats	10x3	High
	Depth jumps	8x3	
	Alternate lunge jumps	13x2	
Week 7	Ankle hop	15x2	Medium/High
(140 foot contacts)	Box jump	10x2	
	Jump squats	10x3	High
Table 3.2: Continue			
	Depth jumps	8x2	
	Alternate lunge jumps	15x2	
Week 8	Ankle hop	15x2	Low/Medium
(150 foot contacts)	Box jump	10x3	Medium
	Jump squats	10x3	
	Depth jumps	8x2	
Week 9	Alternate lunge jumps	15x2	High
(160 foot contacts)	Ankle hop	20x2	Medium
	Box jump	10x3	Medium
	Jump squats	10x3	
	Depth jumps	8x2	
	Alternate lunge jumps	15x2	High
Week 10	Ankle hop	20x2	Medium
(170 foot contacts)	Box jump	10x3	Medium
	Jump squats	10x3	
	Depth jumps	8x2	
	Alternate lunge jumps	15x2	High
	Standing broad jumps	5x2	
Week 11	Ankle hop	20x2	Medium/High
(180 foot contacts)	Box jump	10x3	Medium
	Jump squats	10x3	
	Depth jumps	8x2	
	Alternate lunge jumps	15x2	High
	Standing broad jumps	10x2	

Week 12 (140 foot contacts)	Ankle hop Box jump Jump squats Depth jumps Alternate lunge jumps Standing broad jumps	15x2 10x3 10x3 10x2 10x2 5x2	Medium/High Medium High

Nordic hamstring curl exercise is a partner-assisted exercise in which the participant tries to resist a forward-falling movement by engaging the hamstrings in order to increase loading during the eccentric phase as shown in figure 3.3. The participants were instructed to maintain a slightly flexed hip position during the whole range of motion, to use their hamstrings to break the forward fall for the longest duration possible, and to maintain tension in their hamstrings even after they were told to "let go." In order to reduce loading during the concentric phase, they were instructed to utilize their hands and arms for support during the fall, bring their chest to contact the ground, and then quickly return to the starting position by pushing strongly with the hands.

Figure 1. Illustration of Nordic hamstring exercise

Table 2. Training protocol of Nordic hamstring exercise

Weeks	Session per Week	Sets and Repetitions
1 Week	1	2x5
2 Week	1	2x5
3 Week	1	2x5
4 Week	2	3x5
5 Week	2	3x5
6 Week	2	3x5
7 Week	2	3x6
8 Week	2	3x6
9 Week	2	3x6
10 Week	2	3x8
11 Week	2	3x8
12 Week	2	3x8

Prone Hamstring Curl with Elastic Band

The second hamstring curl exercise for the intervention group was performed using an elastic band. All subjects started the program using elastic band with an elastic band of 1m in length. According to (Januševičius et al., 2020) elastic bands provide 4.6 kg of resistance at 100% elongation with a 1m distance. Each participant was required lying face down on ground with their legs straight. Participants were divided into pairs, where one of them held the elastic band of 1 m in length fastened (nylon webbing and reinforced steel D-rings) with a special strap to the ankles while standing behind, and the other performed the exercise. After each set the participants of the pairs changed their roles. Then, knee flexion and extension at the full range of motion from the ground to the buttocks were performed, alternating the legs as quickly as possible at maximum velocity. The distance of the band was increased progressively over the weeks.

Figure 2. Position of prone hamstring curl with elastic band

Table 3. Training protocol of prone hamstring curl with elastic band

Weeks	Session Per Week	Sets and Repetitions	Elastic Band Distance
1	1	2x12 reps each leg	1 meter
2	1	2x12 reps each leg	1 meter
3	2	3x12 reps each leg	1 meter
4	2	3x10 reps each leg	1.5 meters
5	2	3x10 reps each leg	1.5 meters
6	2	3x10 reps each leg	1.5 meters
7	2	3x8 reps each leg	2 meters
8	2	3x8 reps each leg	2 meters
9	2	3x8 reps each leg	2 meters
10	2	3x6 reps each leg	3 meters
11	2	3x6 reps each leg	3 meters
12	2	3x6 reps each leg	3 meters

Lying Hamstring Curl with Dumbbells

The lying hamstring curl with a dumbbell is a lower-body isolation exercise designed to increase the muscular capacity of the hamstrings muscle group (Snarr & Esco, 2014).

To perform this exercise, the athletes were divided into pairs and one participant lay prone on ground with knees together and flexed at 90 degrees, the feet remaining dorsi flexed. The upper body was stabilized and no movement. The dumbbell is then picked up and secured between the dorsi flexed feet by the partner, with the handle positioned vertically between the toes and heels, allowing for controlled lower-body movement during the exercise. Then, knee flexion and extension at the full range of motion from initial position to the buttocks were performed with both legs.

Figure 3. Position of lying hamstring curl with dumbbells

Table 4. Training protocol of prone hamstring curl with dumbbells

Weeks	Session Per Week	Sets and Repetitions	Elastic Band Distance
1	1	2x 12 reps	2 kg dumbbells
2	1	2 x 12 reps	2 kg dumbbells
3	2	3 x 12 reps	2 kg dumbbells
4	2	3 x 10 reps	4 kg dumbbells
5	2	3 x 10 reps	4 kg dumbbells
6	2	3 x 10 reps	4 kg dumbbells
7	2	3 x 8 reps	6 kg dumbbells
8	2	3 x 8 reps	6 kg dumbbells
9	2	3 x 8 reps	6 kg dumbbells
10	2	3 x 4-6 reps	8 kg dumbbells
11	2	3 x 4-6 reps	8 kg dumbbells
12	2	3 x 4-6 reps	8 kg dumbbells

Statistical Analysis Techniques

To analyze the data, descriptive statistics including mean and standard deviation were used to summarize the data of explosive power and heart rate recovery for both the experimental and control groups. Additionally, to assess between-group differences, an independent samples t-Test was applied to compare the explosive power of the experimental and control groups before and after the training intervention. To evaluate the within-group differences, a paired samples t-Test was employed to examine changes in explosive power and heart rate recovery from pre-test to post-training intervention in the experimental group. These statistical approaches provided a comprehensive analysis of both within-group and between-group variations. Statistical packages for social sciences (V-26) were utilized to analyze the data. The level of significance was set at $p < 0.05$.

3. Results

Demographic information such as age and playing experience were recorded before the start of the training program. Fast bowlers who did not meet the inclusion criteria were excluded from the study. The analysis of demographic data was presented using a clear and understandable structure.

Table 5. Mean and standard deviation of age level

Variables	Experimental Group (n-12) (M±SD)	Control Group (n-12) (M±SD)
Age	19.33±2.87	19.66±3.02
Playing Experience	4.83±1.90	4.75±2.01

The age level of experimental and control group are shown in Table 5. The total sample size was 24 fast bowlers with experimental group (n=12) and control group (n=12). The mean age of experimental group was 19.33 (years) with a standard deviation of 2.87. Similarly, mean age of control group was 19.66 years with a standard deviation 3.02. Both group minimum and maximum age was 16 and 25 years respectively.

Playing experience of experimental group and control group are displayed in Table 5. Mean playing experience of EG was 4.83 years with standard deviation 1.90. Similarly, control group mean playing experience was 4.75 years with standard deviation 2.01. Moreover, minimum and maximum playing experience ranging 2 to 9 years in both groups.

Results of between Groups

Independent samples t-test compared the mean of two different groups. In present study, between groups independent t-test was used to compare the mean of experimental group (EG) and control group (CG) before and after the intervention. The test was applied on two research objectives such as difference in explosive power between the experimental group and the control group before the implementation of intervention and difference in explosive power between the experimental group and the control group after the implementation of intervention.

Table 6. Results of 30 m sprint performance of EG and CG before intervention

Variable	Group	N	Mean	Std. Deviation
30 m	Experimental Group	12	4.63	.226
	Control Group	12	4.67	.125

The mean time of experimental group and control group before the intervention are shown in Table 6. The mean time of experimental group was (M=4.63 seconds, and Std. =.226). Similarly, control group mean time and standard deviation was 4.67 seconds and .125 respectively.

Table 7. Results of 30 m sprint performance before intervention for EG and CG

Variable	Mean Difference	F	Sig.	T	Df	Sig (2-tailed)
30 m	-0.333	2.70	.114	-.446	22	.660
	-0.333			-.446	17.22	.661

The mean time difference of experimental group and control group 30m sprint are shown in the Table 7. The t value -.466 showed the slight difference between the two groups and experimental group have lower mean time. However, p value is greater than 0.05 which indicate that the difference between the groups is not statistically significant, meaning there is no statistical difference between the groups before the intervention.

Table 8. Results of 30 m sprint performance of EG and CG after intervention

Variable	Group	N	Mean	Std. Deviation
30 m	Experimental Group	12	4.45	.217
	Control Group	12	4.67	.124

30m mean time of control and experimental group after the intervention are shown in Table 8. Experimental group performed better in post-test with mean time 4.45 seconds and standard deviation .217, whereas control group mean time was 4.67 seconds and standard deviation .124. It is indicated that plyometric and hamstring curl exercises are beneficial to enhance the 30m sprint speed.

Table 9. Results of 30 m sprint performance after intervention for EG and CG

Variable	Mean Difference	F	Sig.	T	Df	Sig (2-tailed)
30 m	-0.217	2.38	.137	-3.004	22	.007
	-0.217			-3.004	17.22	.008

Mean time difference of control and experimental groups 30m sprint performance after the intervention is shown in Table 9 after the intervention. The results are statistically significant because p value is less than 0.05. The experimental group showed improvement in 30m sprint time after the intervention, which indicated both training program are useful to enhance 30m sprint speed of fast bowlers.

Table 10. Results of 50 m sprint performance of EG and CG before intervention

Variable	Group	N	Mean	Std. Deviation
50 m	Experimental Group	12	6.94	.250
	Control Group	12	6.99	.236

The summary of 50m mean time of experimental and control group is presented in Table 10. EG mean time before the intervention was 6.94 seconds and standard deviation .250. Similarly, CG mean times were 6.99 seconds and standard deviation .236 in pre-test.

Table 11. Results of 50 m sprint performance before intervention for EG and CG

Variable	Mean Difference	F	Sig.	T	Df	Sig (2-tailed)
50 m	-0.508	.106	.747	-.512	22	.614
	-0.508			-.512	21.929	.614

50m sprint times of the experimental and control group before the intervention through independent t-test is compared in Table 11. The assumption of equal variance met (since p > 0.05) due to the F = 0.106 and p = 0.747. There is no statistical difference between two groups t (22) = -0.512, p = 0.614. At baseline, both groups performed similarly in 50m sprint time.

Table 12. Results of 50 m sprint performance of EG and CG after intervention

Variable	Group	N	Mean	Std. Deviation
50 m	Experimental Group	12	6.66	.239
	Control Group	12	6.99	.233

The results displayed of both groups of 50m sprint time after the intervention in Table 12. Experimental group mean time and standard deviation was (M=6.6 6 seconds and Std. = .239). Moreover, control group mean time of 50m sprint was 6.99 seconds and standard deviation .233. The results indicated that experimental group performed better after the intervention.

Table 13. Results of 50 m sprint performance after intervention for EG and CG

Variable	Mean Difference	F	Sig.	T	Df	Sig (2-tailed)
50 m	-0.326	.030	.864	-3.38	22	.003
	-0.326			-3.38	21.98	.003

Independent samples t-Test outcomes of the control and experimental group after the intervention is summarized in Table 13. The variance between the groups is equal (F = 0.030, p = 0.864). There is statistical difference between the groups after the intervention t (22) = -3.388, p = 0.003. The experimental group performed better after the intervention. The results indicated that plyometric and hamstring curl exercises are useful to enhance the 50m sprint speed.

Table 14. Results of broad jump performance of EG and CG before intervention

Variable	Group	N	Mean	Std. Deviation
Broad Jump	Experimental Group	12	7.6483	.62001
	Control Group	12	7.6350	.27744

Broad jump distance before the intervention of both groups is explained in Table 14. The distance of experimental group was 7.64 feet with the standard deviation 0.62. Similarly control group broad jump mean distance was 7.6 3 feet and standard deviation .277.

Table 15. Results of broad jump performance before intervention for EG and CG

Variable	Mean Difference	F	Sig.	T	Df	Sig (2-tailed)
Broad Jump	.0133	2.226	.150	.068	22	.946
	.0133			.068	15.23	.947

Independent sample t-test result before the intervention of experimental and control group is presented in Table 15. The p-value is greater than 0.05 which indicated that there is no statistical difference between the groups before the intervention (df =22 and p= .946). The Levene's Test for Equality of Variances showed an F-value of 2.226 with a p-value of 0.150, indicating that the assumption of equal variances is valid.

Table 4.16: Results of broad jump performance of EG and CG after intervention

Variable	Group	N	Mean	Std. Deviation
Broad Jump	Experimental Group	12	8.1092	.65711
	Control Group	12	7.6375	.27746

Experimental and control group mean difference of broad jump distance are shown in Table 16. It is indicated that experimental group performed better after the intervention (M= 8.10 and Std. =.657). Whereas, control group mean distance was 7.63 and standard deviation .277 after the training program.

Table 4.17: Results of broad jump performance after intervention for EG and CG

Variable	Mean Difference	F	Sig.	T	Df	Sig (2-tailed)
Broad Jump	.471	2.605	.121	2.291	22	.032
	.471			2.291	14.802	.037

Independent samples t-test after the intervention of control and experimental group is discussed in Table 17. Between the groups performance of broad jump showed significant difference which confirmed with F-value 2.605 and significant 0.121. There is statistical difference between the groups after the intervention (df=22 and p= 0.032). It is indicated that intervention had positive impact on the enhancement of broad jump performance.

Paired sample t-test compares the mean difference of same group measures at two different times. The present study used the paired samples t-test to compare the mean difference of explosive power and heart rate recovery before and after the intervention. The test was applied on two objectives such as difference in explosive power during pre and post intervention of experimental group and difference in heart rate recovery between pre and post intervention of experimental group.

Results of Within Group

Table 18. Results of broad jump performance of experimental group

Variable	N	Mean	Std. Deviation
Pre-Broad Jump	12	7.64	.620
Post-Broad Jump	12	8.10	.657

Mean and standard deviation of pre-test (Mean= 7.64 feet and Std. = .620) and post-test (Mean= 8.10 feet and Std. = .657) of experimental group is presented in Table 18. The distance of broad jump was increased in post-test which indicated that fast bowlers improved lower body strength after the 12 weeks plyometric and hamstring curl training.

Table 19. Results of broad jump performance of experimental group

Variable	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the difference		t	Df	Sig. (2-tailed)
				Lower	Upper			
Broad Jump	.460	.037	.010	-.484	-.437	42.81	11	.000

Broad jump paired sample t-test results of experimental group are explained in Table 19. The mean difference was .460 feet from pre to post and p value is less than 0.05. It indicted that there is statistical difference of broad jump in EG group after the intervention which confirmed the plyometric and hamstring curl training had positive impact to enhance lower body explosive strength.

Table 20. Results of 30 m sprint performance of experimental group

Variable	N	Mean	Std. Deviation
Pre-30 m	12	4.63	.226
Post-30 m	12	4.45	.217

30m pre and post-test mean and standard deviation of experimental group are explained in Table 20. Mean 30m sprint time in pre-test was 4.63 seconds and standard deviation .226, whereas, post-test mean and standard was found 4.45 seconds and .217 respectively. It is indicated that plyometric and hamstring curl training had positive impact to enhance 30m sprint time.

Table 21. Results of 30 m sprint performance of experimental group

Variable	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the difference		T	Df	Sig. (2-tailed)
				Lower	Upper			
30 m	.184	.009	.002	.178	.189	70.85	11	.000

The paired sample t-test confirmed a mean difference and standard deviation for the 30 m sprint time (Mean = 0.184, SD = 0.009), indicated that the experimental group showed improvement. However, this improvement in sprint time was relatively small and might vary if the test distance were increased to 100 m or 200 m. The p-value was less than 0.05 indicating a statistically significant effect of the intervention. Plyometric and hamstring curl exercises contributed to the improvement in 30 m sprint performance.

Table 22. Results of 50 m sprint performance of experimental group

Variable	N	Mean	Std. Deviation
Pre-50 m	12	6.94	.250
Post-50 m	12	6.66	.239

50m sprint descriptive of experimental group is shown in Table 22. The mean and standard deviation in pre-test was (Mean= 6.94 seconds and Std. = .250). Moreover, post-test mean and standard deviation of 50m sprint was (Mean= 6.66 seconds and Std. = .239). Experimental group improved the 50m sprint time after the intervention which indicated that both training program are useful to enhance 50m sprint time.

Table 23. Results of 50 m sprint performance of experimental group

Variable	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the difference		t	Df	Sig. (2-tailed)
				Lower	Upper			
50 m	.276	.011	.003	.269	.284	83.00	11	.000

Mean difference of 50m sprint was .276 seconds and standard deviation .011 which confirmed by paired sample t-est. P-value was less than 0.05 which shown that there is statistical difference of within the group after the intervention. Plyometric and hamstring curl exercises improved the 50m sprint time after the 12 weeks training.

Table 24. Heart rate responses of 1st over in pre-test

Variable	N	Mean Heart Rate (bpm)	Std. Deviation
Heart Rate (Before Bowling)	12	99.50	4.18
Heart Rate after 1st Over	12	149.3	5.61
Heart Rate Recovery after One Minute	12	130	8.33

The heart rate of fast bowlers in pre-test of 1st over is shown in Table 24. Mean heart rate before start of the bowling was 99.50 bpm and standard deviation 24. The maximum mean heart rate at 70-80% effort after the 1st over was 149.3 and standard deviation 5.61. Mean heart rate recovery after 1-minute was 130 bpm, with a standard deviation of 8.33.

Table 25. Heart rate responses of 2nd over in pre-test

Variable	N	Mean Heart Rate (bpm)	Std. Deviation
Heart Rate (Before Bowling)	12	101.5	3.89
Heart Rate after 1st Over	12	149.2	7.19
Heart Rate Recovery after One Minute	12	130.3	6.89

The heart rate responses of 2nd over in pre-test are shown in Table 25. Before start of the bowling mean heart rate was 101.5 bpm and standard deviation 3.39. The mean heart before bowling was higher in 2nd over as compare to 1st over. The mean after heart at 70-80% effort was 149.2 bpm with standard deviation 7.19. The heart rate recovery after 1-minute was 130.3 bpm with standard deviation 6.89.

Table 26. Results of paired sample t-test of 1st over

HR Type	Pre-Test Mean±SD	Post-Test Mean±SD	MD±SD	t	Df	Sig.
Heart Rate Before Bowling	99.50±4.18	97.42±4.14	2.08±.99	7.24	11	.000
Heart Rate after Bowling 1st Over	149.3±5.61	147.9±5.66	1.41±.66	7.34	11	.000
Heart Rate Recovery after One Minute	130±8.33	128±8.66	1.66±.77	7.41	11	.000

1st over results of paired samples t-test is showed significant improvement in participants heart rate responses after the intervention which indicate improvement in cardiovascular performance. Before the start of the bowling mean heart rate was 99.50 bpm with standard deviation 4.18 and it decreased in post-test 97.42 ± 4.14. The mean difference was 2.08 ± 0.99 ($t = 7.24$, $p = .000$), showing statistically significant improvement. Similarly, after the over heart rate decreased from pre-test (149.3 ± 5.61) to post-test (147.9 ± 5.66), and the mean difference was 1.41 ± 1.66 ($t = 7.34$, $p = .000$), which showed statistically significant improvement in heart rate after the over Furthermore, heart rate recovery after 1-minute was improved from pre-test mean (130 ± 8.33) to post-test mean (128 ± 8.66), with a mean difference of 1.66 ± 0.77 ($t = 7.41$, $p = .000$). It was showed statistically significant improvement in heart rate recovery after 1-minute. Overall, results showed 12 weeks plyometric and hamstring curl exercises improved the heart rate responses of fast bowlers.

Table 27. Heart rate responses of 1st over in post-test

Variable	N	Mean Heart Rate (bpm)	Std. Deviation
Heart Rate (Before Bowling)	12	97.4	4.14
Heart Rate after 1st Over	12	147.9	5.66
Heart Rate Recovery after One Minute	12	128.3	8.67

The heart rate responses observed during the 2nd over are shown in Table 27. The mean heart rate before the start of the bowling was 97.4 bpm and standard deviation 4.14. Fast bowlers was improved the pre heart rate in pos-test. The mean heart rate indicated at 70-80% effort of maximum heart rate 147.9 bpm with standard deviation 5.66. Fast bowlers was improved the maximum heart rate in post-test. Similarly, mean heart rate recovery after 1-minute was 128.3 bpm with standard deviation 8.67.

Table 28: Heart rate responses of 2nd over in post-test

Variable	N	Mean Heart Rate (bpm)	Std. Deviation
Heart Rate (Before Bowling)	12	99.5	4.08
Heart Rate after 2nd Over	12	147.6	7.33
Heart Rate Recovery after One Minute	12	127.9	7.19

The heart rate responses of 2nd over were shown in table 28. The mean pre heart rate was 99.5 bpm with standard deviation 4.08, whereas, the mean heart rate after the 2nd over was found 147.6 bpm with standard deviation 7.33. Moreover, mean heart rate recovery was 127.9 with standard deviation 7.19.

Table 29: Results of paired sample t-test of 2nd over

HR Type	Pre Test Mean±SD	Post Test Mean±SD	MD±SD	T	df	Sig.
Heart Rate Before Bowling	101.5±3.89	98.4±4.07	3.1±.95	5.34	11	.000
Heart Rate after Bowling 2nd Over	149.1±7.19	147.5±7.32	1.58±.79	6.91	11	.000
Heart Rate Recovery after One Minute	130.3±6.89	127.9±7.19	2.14±.79	10.55	11	.000

The results of paired sample t-test heart rate responses of 2nd over are shown in Table 29. Firstly, heart rate before the start of the over was improved from pre-test mean (101.5±3.89) to post-test mean (98.4±4.07) with the mean difference (3.1±.95). The improvement in heart rate was statistically significant ($t = 5.34$, $p = .000$) which suggested participant improved the cardiovascular fitness before bowling. Secondly, the post 2nd over heart rate was also significantly reduced, although by a small margin, 149.1 bpm to 147.5 bpm (MD = 1.58 bpm, $t = 6.91$, $p = .000$), which indicated statistically significant improvement in heart rate in post-test. Lastly, heart rate recovery after 1-minute was improved (130.3±6.89) to (127.9±7.19) with mean difference (2.14±.79). The improvement in heart rate recovery was statistically significant ($t = 10.50$, $p = .000$). Overall, results indicated that the training intervention had positive effects on heart rate recovery and improved the cardiovascular fitness of fast bowlers.

4. Discussion

The findings of present study demonstrate that a 12-week intervention combining plyometric and hamstring curl exercises led to significant improvements in 30m sprint in the experimental group after the intervention, while no such enhancements were observed in the control group. These results are consistent with previous research (Ashraf et al. (2023), which also reported significant improvements in 30m sprint performance of cricketers with plyometric exercises. Furthermore, Adıguzel et al. (2024) reported that 8 weeks Nordic hamstring exercises significantly enhanced the 30m linear sprint speed. Similarly, Gulu and Dogan, (2021) found 6 weeks nordic hamstring exercises is significantly improved 30- meter sprint speed. NHE improved the strength of hamstring which supported to increase the 30m sprint speed.

Furthermore, Janusevicius et al. (2017) demonstrated the 5 weeks low load high velocity elastic band training significantly enhanced the stationary 30m and flying 30m. This study suggested that high velocity with low load movement closely related neuromuscular demand of actual sprint. The improvement in sprint performance is due to increased knee flexor and extensor torque at high speeds and reduced muscle co activation, which enhance the muscles contraction during sprinting.

However, the present study proved that combination of plyometric and hamstring curl exercises significantly improved the 30m sprint of fast bowlers. PT improved the explosive power and hamstring exercises improved the hamstring strength which supports in enhancement of short sprint speed.

The results of present study demonstrated that experimental group improved the 50m sprint performance and control group had no gain in performance after 12 weeks plyometric and hamstring curl exercises.

Plyometric exercises used the stretch shortening cycle which enhances the explosive power, several previous studies supported the plyometric exercises effective to improve the sprint performance. Jawalkar et al. (2024) proved there is significant improvement in 50m sprint performance of male cricketers after the intervention. Doina et al. (2021) highlighted that 8 weeks plyometric raining had significant impact on 50m sprint time after the training protocol in experimental. Furthermore, plyometric exercises significantly enhanced the 50m sprint after the intervention (Gokula et al., 2021). The plyometric exercises utilized SSC cycle, SSC cycle improved the efficiency of neuromuscular system which enhance the abilities of muscles to produce force in shortest time which support sprint acceleration and maximal sprint velocity (Hasan et al., 2021).

Veierod (2020) reported that 9 weeks nordic hamstring exercise significantly improved the 40m print performance, particularly between 20-40m. This study explained that high NH peak force supported over longer sprint because hamstring utilized high strength during long sprint and large hamstring activation increased the speed and control ground forces during sprinting. The results of previous studies, in line with the findings of present studies which support the plyometric exercises and hamstring exercises are effective to improve the 50m sprint performance.

In between group analysis of experimental and control group before and after the 12 weeks intervention. Experimental group significantly improved the standing broad jump performance in the post-test. The results of this study in line with previous study of Krishna et al. (2019) which also found plyometric training significantly improved the standing broad jump performance of cricket fast bowler between the experimental and control group. Asadi et al. (2013) highlighted that basketball players significantly enhanced the standing long jump after plyometric training. El-Ashke et al. (2019) proved that plyometric training is more effective to significantly enhance the standing long jump performance in long jumper.

The findings of the present study demonstrate that the 12-week intervention program, combining plyometric and hamstring curl exercises, significantly enhanced the explosive power of fast bowlers, as indicated by improvements in 30m and 50m sprint times and standing broad jump performance. These results are consistent with previous research highlighting the positive impact of plyometric exercises on explosive power and sprint performance.

Plyometric and hamstring curl exercises significantly improved the sprint and jump standing broad jump performance of fast bowlers from pre-test to post-test after 12 weeks training.

Bashir et al. (2018) found that plyometric training significantly improved the sprint speed of cricket players as compare to resistance training. Within group results of sprint performance aligned with findings of Hasan (2023) who found that plyometric training significantly improved the 50m sprint performance. The observed performance is likely due to better utilization of stretch shortening cycle, faster ground contact time, and enhanced neuromuscular ability. Huang et al. (2023) proved that plyometric training significantly enhanced the sprint and explosive strength performance of basketball players. In contrast, Adıgüzel et al. (2024) found slight improvement in sprint performance after nordic hamstring training but changes were not statistical significant. Chandra et al. (2023) found that plyometric exercises significantly improved the standing broad jump and 30m sprint performance.

After the 12 weeks plyometric and hamstring curl exercises participants significantly improved the pre heart rate, heart rate after the overs, and heart rate recovery after 1-minute. This improvement indicated the fast bowlers enhanced cardiovascular efficiency and heart rate recovery during the high intensity bowling deliveries.

Johnstone et al. (2017) found that mean heart rates of 143 ± 14 bpm in one-day cricket match and 137 ± 16 bpm in multi-day match which are slightly consistent with pre intervention heart rate responses after the first over (149.3 ± 5.61 bpm) in present study. The observed higher heart rate was found in present study likely due to 70–80% effort of maximum heart rate. Moreover, reduction in post heart rate after the first over (147.9 ± 5.66 bpm) close to the heart rate observed in one day cricket match. The results suggested that fast bowlers improved the cardiovascular fitness in post-test.

Heart rate after the both overs declines in pre to post-test which indicated the fast bowlers improved the cardiovascular fitness and recovery capacity. The present findings aligned with Vickery et al. (2018) medium fast bowlers produced closely similar results in one day matched. Moreover, author reported that net-based cricket imposed higher cardiovascular stress as compare to centre-wicket training. However, match specific training enhanced the cardiovascular fitness in fast bowlers. In present study, Fast bowlers used 70–80% effort of their maximum heart rate.

Fast bowler in present study sustained stable heart rate responses during 2 overs spells at 70-80 % which indicated moderate cardiovascular stress. Previously, Duffield et al. (2009) found that closely similar heart rate responses at 75–85% during repeated spells of fast bowling, while the constant cardiovascular stress, the performance of fast bowlers did not decline during repeated spells. The heart rate responses observed after the overs align with the findings of Stretch and Lambert (1999) who reported that fast bowlers maintained a consistent heart rate during six-over spells, ranging between 74–79% of their maximum heart rate. In the present study, heart rate responses increased after the second over, which is still consistent with their findings, indicating sustained cardiovascular intensity without fatigue.

5. Conclusion

The aim of present study was to find out the contribution of plyometric and hamstring curl exercises in explosive power and heart rate recovery of fast bowlers. The findings indicated that plyometric and hamstring curl exercises played a key role in enhancing explosive power and heart rate recovery responses of fast bowler. Initially, there was insignificant difference found between the control group and the experimental group indicating that both groups had a similar explosive power and heart rate responses. After the application of the training program, the experimental group significantly improved explosive power compared to the control group which supported the significance of the intervention. In the experimental group, there was a significant change in the rate of improvement since explosive power greatly improved between pre- and post-training which confirmed the positive effect of the exercises selected. Besides the muscular gains, the intervention also improved the heart rate recovery which enhanced the cardiovascular efficiency and general fitness. In conclusion, the findings supported that targeted strength and plyometric training played the vital role to accelerate fast bowlers performance.

Implications of the Study

The present research concluded that an organized training program based on plyometric exercises and different hamstring curl exercises is more effective in enhancing explosive power and heart rate recovery among fast bowlers as compared to traditional training. The statistically significant changes in the post-intervention between the experimental and control groups showed that the targeted intervention had a direct effect on the improvement of explosive power. This shows the importance of integrating scientifically-designed, sport-specific conditioning programs instead of relying on the traditional training program.

The significant changes in 30 m, 50 m sprint performance and standing broad jump distance indicated that enhanced lower-limb explosive strength and neuromuscular efficiency. These performance characteristics directly apply to fast bowling where high run-up speed, good force production and efficiency in transfer of momentum are key to the best bowling. According to the findings, the combination of the hamstring-based strength training with the plyometric exercises is effective in improving the fast bowlers' physical abilities of high-intensity, explosive, high-intensity cricket fast bowler.

The heart rate recovery after bowling spells was also significantly improved in the experimental group. The higher rate of recovery of heart rate after the 1st and 2nd overs signifies better cardiovascular efficiency and recovery ability which is essential to maintain performance during repeated high-intensity efforts during match conditions. Better recovery between overs may allow fast bowlers to keep bowling intensity and consistency during longer bowling spells thus improving the performance during the match.

In practical and applied terms, the training intervention that was used in this study utilized accessible and low-cost equipment, including dumbbells and elastic bands, and it is feasible in club and academy-level cricket settings. This increases the ecological validity of the research and justifies the use of integrated plyometric and hamstring strengthening interventions in resource-limited institutions. Such training protocols may be considered by coaches, trainers, and strength and conditioning professionals as an addition to regular training regimes to maximize the performance and recovery outcomes.

Finally, the study contributed to the existing body of cricket-specific sports science literature by providing evidence-based support for integrated training approaches in young fast bowlers aged 16–26 years. The results emphasize the value of systematic and structured conditioning interventions and highlight the role of targeted lower limb in enhancing key performance and physiological recovery indicators in cricket.

Future Recommendations

The current study produced important and useful results; however there are some future recommendations to improve these results. Future research should investigate using a bigger sample size and incorporating individuals from various competitive levels to improve the generalisability of the findings. The inclusion of elite and professional fast bowlers should provide more insight into whether similar adaptations occur at higher performance levels.

The long-term impact of combined plyometric and hamstring curl training during a complete competitive season should also be investigated in future studies. Longitudinal designs would assist in establishing whether the observed improvements are sustained over time and whether such training aids in injury prevention especially hamstring strains that are common among fast bowlers.

Moreover, comparisons between various strength and power training modalities (e.g., plyometrics with hamstring training or Olympic lifting) should be conducted in future research to determine the most effective training models to use in improving explosive power and recovery.

It is further suggested that future studies should incorporate some physiological indicators like lactate clearance, heart rate variability or perceived exertion to give a more holistic view of recovery adaptations. Such measures would strengthen the physiological interpretation of heart rate recovery improvements observed in the present study.

Finally, future investigations should explore gender-specific responses and include female fast bowlers, as well as younger age groups, to support the development of age- and sex-appropriate training guidelines. This would further expand the practical relevance of plyometric and hamstring-focused interventions within cricket conditioning programs.

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