RESEARCH PAPER

"Effect of Plyometric Training on Selected Pulmonary Function of Football Players"

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The purpose of this study was to investigate the effect of plyometric training on selected pulmonary functions of football players. Thirty male football players aged 16–18 years were selected from Poloi Football Club, Imphal East District, Manipur, India. All participants were actively competing at the state level. The subjects were randomly divided into two equal groups: an experimental group (n = 15) and a control group (n = 15). The selected pulmonary function variables included VO_2 max, maximal voluntary ventilation, and O_2 saturation. VO_2 max was measured using the Cooper 12-minute run test, maximal voluntary ventilation was assessed using a digital spirometer, and O_2 saturation was measured using a pulse oximeter. The experimental group underwent a six-week plyometric training program conducted six days per week, with each session lasting 60 minutes, while the control group did not participate in any special training program. The collected data were analyzed using descriptive statistics and analysis of covariance (ANCOVA). The level of significance was set at 0.05. The findings indicated a notable enhancement in pulmonary functions in the experimental group compared with the control group. The implementation of the plyometric training program proved effective in improving VO_2 max, maximal voluntary ventilation, and O_2 saturation among the football players. The study concluded that a six-week plyometric training program significantly enhanced the pulmonary functions of football players, particularly VO_2 max, maximal voluntary ventilation, and O_2 saturation. Further research is recommended to examine the long-term effects, optimal duration, and underlying mechanisms of plyometric training to gain a deeper understanding of its effectiveness and applications in sports conditioning.

Keywords: Plyometric training; Football players; VO_2 max; Maximal voluntary ventilation; Oxygen saturation; Pulmonary function

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Introduction

Plyometric training, a high-intensity form of exercise that focuses on explosive movements, is integral to improving power, speed, and agility in sports, particularly football (Turner et al., 2015). In football, where explosive power, rapid directional changes, and sprinting are essential, plyometric training is highly beneficial for developing these attributes (Impellizzeri et al., 2008). Plyometric training consists of exercises involving rapid and repetitive muscle stretching and contraction and has become increasingly popular for its effectiveness in sports conditioning. These exercises utilize an eccentric–concentric muscle action sequence to enhance explosive performance (Singh, L. Santosh et al., 2024).

Football is the world's most popular team sport. Modern football is fast-paced by nature, making it enjoyable for both spectators and players. Nowadays, with the increasing demand for high sports performance, the concept of soccer has evolved. Contemporary football emphasizes skill development, tactical awareness, and the development of essential motor components and physiological parameters that are closely associated with and contribute to overall performance. In addition to technical and physiological development, sports scientists are also focusing on enhancing the intellectual abilities of football players. The literature indicates that endurance, speed, agility, maximal leg strength, upper-body strength, leg power, muscular endurance, flexibility, coordination, and reaction time are important prerequisites for efficient football performance (Singh, L. Santosh et al., 2018; Singh, L. Santosh et al., 2024).

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Plyometric exercises have been shown to improve football players' aerobic capacity (VO_2 max), maximal voluntary ventilation (MVV), and oxygen saturation, all of which are critical for maintaining performance intensity throughout a match (Ramirez-Campillo et al., 2014). Furthermore, research suggests that well-structured plyometric programs can significantly enhance specific performance metrics such as vertical jump height, sprint acceleration, and agility, which are directly applicable to match situations (Slimani et al., 2016; Reza et al., 2024). Optimizing plyometric training parameters, including frequency, intensity, and volume, is essential to maximize benefits while minimizing the risk of injury.

In football, aerobic capacity and efficient respiratory function are crucial for sustaining high-intensity performance throughout a match. VO_2 max, O_2 saturation, and MVV are key physiological markers used to assess these aspects of a player's fitness. VO_2 max, which represents the maximum volume of oxygen an athlete can utilize during intense exercise, is widely regarded as a critical indicator of endurance capacity. Higher VO_2 max levels enable players to sustain repeated sprints, recover more quickly, and maintain performance intensity throughout both halves of a match (Stølen et al., 2005; Mola et al., 2025). O_2 saturation, which measures the percentage of hemoglobin binding sites occupied by oxygen, is essential for ensuring adequate oxygen delivery to muscles during intense exercise (Tucker et al., 2009). Higher O_2 saturation supports efficient energy production and reduces fatigue, allowing football players to perform at peak levels for longer durations. The main purpose of the present study was to investigate the effect of plyometric training on selected pulmonary functions of football players.

Materials and Methods

Selection of subjects

For the purpose of the present study, thirty male football players were randomly selected from Poloi Soccer School, Imphal East, Manipur (India) who participated in the state level competitions. The aged of the subjects ranged between 16 to 18 years.

Selection of the Test

The study employed Cooper's 12-minute run/walk test to evaluate VO2 max, while Maximal Voluntary Ventilation by using digital spirometer. Additionally, O_2 saturation was assessed by using pulse oximeter. These specific tests were selected as they provide accurate measures of the pulmonary functions under investigation in this study.

Criterion Measures

The testing protocol for evaluating VO2 max, Maximal Voluntary Ventilation, aerobic capacity, and O_2 saturation adheres to specific criteria. The assessment involves the utilization of Cooper's 12-minute run/walk test to gauge VO2 max, with results measured in minutes. Maximal Voluntary Ventilation was determined through the digital spirometer and recorded in litters per minute (L/min). O_2 saturation by using a pulse oximeter and recorded as a percentage (%). Adherence to these criteria is crucial to maintain precision in measurements and to ensure the reliability of the obtained results.

Design of the Study

The primary aim of this study was to examine the impact of a plyometric training program on selected pulmonary functions of football players. The research involved two equal groups of participants, randomly assigned for the investigation: an experimental group comprising 15 players and a control group consisting of 15 players. Prior to the implementation of the plyometric training program, baseline measurements were taken for the selected parameters in both groups. The selected pulmonary functions are VO2 max was assessed using Cooper's 12-minute run/walk test, while Maximal Voluntary Ventilation was assessed using digital spirometer and O_2 saturation was measured utilizing the pulse oximeter, respectively. The plyometric training program spanned six weeks, with five training sessions per week, each lasting for 60 minutes. The experimental group adhered to the prescribed plyometric training regimen, while the control group continued with their regular match practice. The intervention period encompassed the timeframe from from 4th March to 27th April 2024.

Training Program

Training was carried out for the study's goal, and then a six-week plyometric training programmed. This training regimen adhered to Thompson et al. (2013)'s prescribed allotment for exercise. Five times a week, the programmed comprised 60 minutes of exercise, consisting of a 10-minute warm-up, a 40-minute main activity, and a 10-minute warm-down. Five times a week for six weeks, the workout was done. By increasing the size and quantity of exercise motions, we have developed a programmed that remains within the bounds of the peak performance exercise intensity that was previously established (Singh, 2018). Furthermore, we prioritized safety over accuracy when rehearsing each man oeuvre, therefore we proposed slightly altering the movement in portions that were challenging to execute. The specifics of the weekly training schedule for the plyometric training programmed are outlined in Tables 1 and 2.

Table 1: Weekly Plyometric Training Program

Sl. No	Particulars	Duration
1.	Number of weeks	6 weeks
2.	Number of sessions per week	60 minutes
3.	Duration of each training	45 minutes

4.	Rest interval between repetition	3 minutes
5.	Rest interval between exercise	1 minute
6.	Warm up and cooling down	15 minutes

Table 2: Specific Plyometric Training Program

Weeks	Components of Plyometric Training	Repetition	Set	Intensity
1 -2 Weeks	Squat jump & Tuck jump	2	2	40% to 50%
	Power skipping			
	Alternate leg bounding			
	Vertical depth jump: starting from the top of a box, jump down			
	Broad jump: Straddle jump, single and double leg hops up to 20 meters			
3 -4 Weeks	Squat jump & Tuck jump	3	2	50% to 60%
	Power skipping			
	Alternate leg bounding			
	Vertical depth jump: starting from the top of a box, jump down			
	Broad jump: Straddle jump, single and double leg hops up to 20 meters			
5 -6 Weeks	Squat jump & Tuck jump	4	2	60% to70%
	Power skipping			
	Alternate leg bounding			
	Vertical depth jump: starting from the top of a box, jump down			
	Broad jump: Straddle jump, single and double leg hops up to 20 meters			

N.B.: - Low Intensity: 40% to 50%, Moderate intensity: 50% to 60% and High intensity: 60% to 70

Statistical Analysis
The data collected was entered into an Excel spreadsheet, and we used IBM SPSS software (version 22.0; SPSS Inc., Chicago, IL, USA) to conduct statistical analyses. The statistical distribution of pre and post-test scores was assessed using descriptive statistics, and group differences were investigated through the application of an analysis of covariance test (ANCOVA). The significance threshold for statistical analyses was set at 0.05.

Results

Table 3: Pre and Post Means Score of VO2 max performance Experimental and Control Groups

Variables	Test	Mean	N	Std. Deviation	Std. Error Mean	t	df	Sig
VO2 max	Experimental pre-test	24.80	15	2.704	.698	-5.134	14	.000
	Experimental post-test	27.07	15	1.870	.483			
	Control pre-test	24.33	15	2.769	.715	1.964	14	0.070
	Control post-test	23.73	15	2.939	.759			

Table 3 reveals that the pre and post means score of VO2 Max performance for Experimental and control Groups. The experimental group exhibited a significant increase in VO2 max following the plyometric training program. The pre-test mean for VO2 max was 24.80 (SD = 2.704), while the post-test mean increased to 27.07 (SD = 1.870). The paired t-test result (-5.134) with 14 degrees of freedom (df) and a p-value of .000 indicates that this improvement is statistically significant. The control group showed no significant change in VO2 max. The pre-test mean was 24.33 (SD = 2.769), and

the post-test mean slightly decreased to 23.73 (SD = 2.939). The paired t-test result (1.964) with 14 (df) and a p-value of .070 suggests that the change was not statistically significant.
The pre-test and post-test mean values of experimental and control groups on VO2 max was presented in Figure-1.

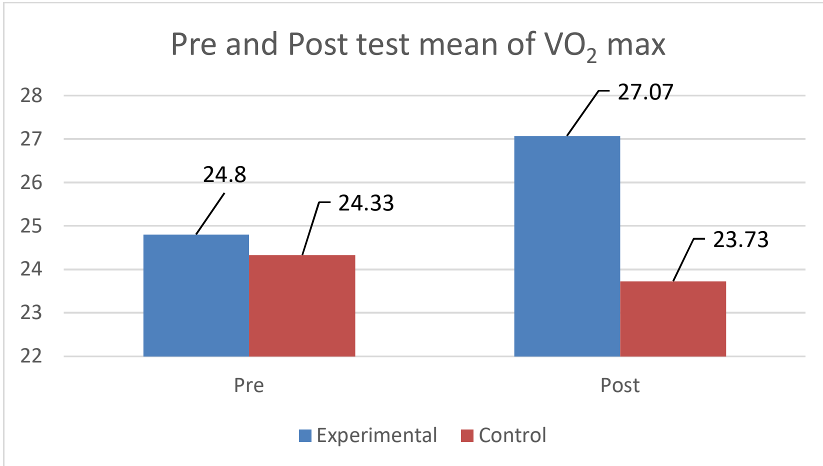

Fig 1: Means values of experimental and control group on VO2 max

Table 4: Pre and Post Means Score of Maximal Voluntary Ventilation performance for Experimental and Control Group

Variables	Test	Mean	N	Std. Deviation	Std. Error Mean	t	df	Sig
Maximal Voluntary Ventilation	Experimental pre-test	168.72	15	26.362	6.807	-3.477	14	.004
	Experimental post-test	175.46	15	29.716	7.673			
	Control pre-test	169.16	15	25.365	6.549	.415	14	.685
	Control post-test	168.87	15	25.097	6.480			

Table 4 reveals that the pre and post means score of Maximal Voluntary Ventilation performance for the experimental and control groups. The experimental group showed a significant increase in maximal voluntary ventilation (MVV). The pre-test mean was 168.72 (SD = 26.362), while the post-test mean increased to 175.46 (SD = 29.716). The t-test result (-3.477) with 14 (df) and a p-value of .004 indicates that this increase is statistically significant. The control group did not show significant changes in MVV, with a pre-test mean of 169.16 (SD = 25.365) and a post-test mean of 168.87 (SD = 25.097). The paired t-test result (.415) with 14 (df) and a p-value of .685 indicates no statistically significant change.
The pre-test and post-test mean values of experimental and control group on Maximal Voluntary Ventilation was presented in Figure-2.

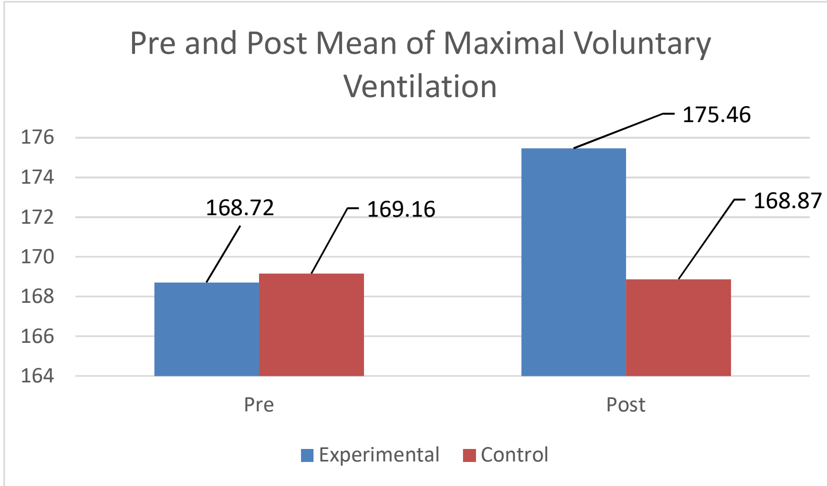

Fig 2: Means values of experimental and control group on Maximal Voluntary Ventilation

Table 5: Pre and Post Means Score of O2 Saturation Performance for Experimental and Control Groups

Variables	Test	Mean	N	Std. Deviation	Std. Error Mean	t	df	Sig
O2 Saturation	Experimental pre-test	94.33	15	3.735	.964	-2.578	14	.022
	Experimental post-test	96.13	15	2.503	.646			
	Control pre-test	94.20	15	3.321	.857	-1.000	14	.334
	Control post-test	94.33	15	3.395	.877			

Table 5 reveals that the pre and post means score of O2 saturation performance for the experimental and control groups. The experimental group also demonstrated a significant improvement in oxygen saturation. The pre-test mean was 94.33 (SD = 3.735), which increased to 96.13 (SD = 2.503) in the post-test. The paired t-test result (-2.578) with 14 (df) and a p-value of .022 indicates a statistically significant improvement. For the control group, the pre-test mean for oxygen saturation was 94.20 (SD = 3.321), and the post-test mean slightly increased to 94.33 (SD = 3.395). The paired t-test result (-1.000) with 14 (df) and a p-value of .334 shows that this change was not statistically significant.

The pre-test and post-test mean values of experimental and control group on O_2 saturation was presented in Figure-3.

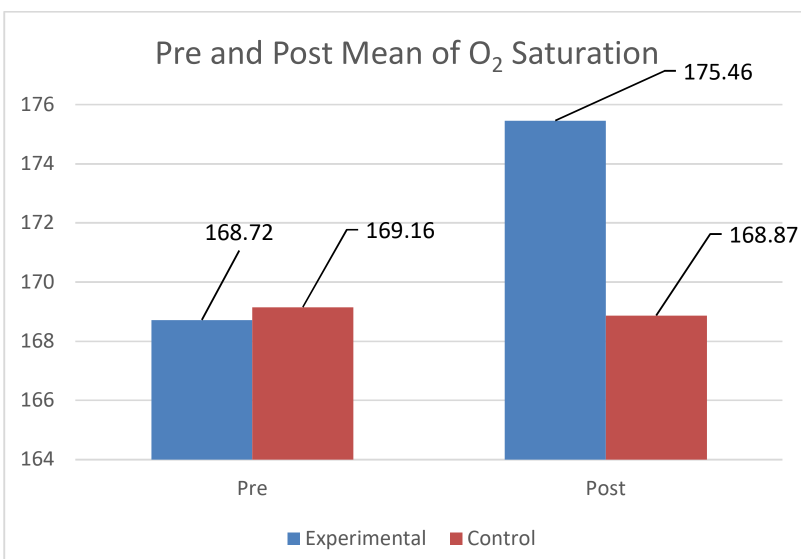

Fig 3: Means values of experimental and control group on O2 Saturation

Table 6: Computation of Analysis of Covariance (ANCOVA) on VO2 max

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	On served Power
Corrected Model	181.989a	2	90.994	81.055	.000	.857	162.109	1.000
Pre_VO2 max	125.956	1	125.956	112.197	.000	.806	112.197	1.000
Group	41.861	1	41.861	37.288	.000	.580	37.288	1.000
Error	30.311	27	1.123					
Total	20027.000	30						

Table 6 reveal that the F value for the group effect is 37.288 with a significant level of $p = .000$. This indicates a statistically significant difference between the experimental and control groups in VO2 max performance in football players.

Table 7: Computation of Analysis of Covariance (ANCOVA) on Maximal Voluntary Ventilation

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	On served Power
Corrected Model	21085.616a	2	10542.808	301.901	.000	.957	603.801	1.000
Pre MVV	21085.616a	2	10542.808	301.901	.000	.957	603.801	1.000
Group	556.084	1	556.084	15.924	.000	.371	15.924	.970
Error	942.879	27	34.921					
Total	919310.391	30						

Table 7 reveals that the F-value for the group effect is 15.924 with a significance level of $p = .000$. This indicates a statistically significant difference between the experimental and control groups in Maximal Voluntary Ventilation performance among football players.

Table 8: Computation of Analysis of Covariance (ANCOVA) on O2 Saturation

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	On served Power
Corrected Model	197.804 a	2	98.902	35.340	.000	.724	70.679	1.000
Pre O2 S	173.504	1	173.504	61.996	.000	.697	61.996	1.000
Group	21.822	1	21.822	7.797	.009	.224	7.797	.768
Error	75.563	27	2.799					
Total	272355.000	30						

Table 8 reveals that the F-value for the group effect is 7.797 with a significance level of $p = .009$. This indicates a statistically significant difference between the experimental and control groups in O2 saturation among football players.

Discussion

The plyometric training program in the present study lasted six weeks, with training sessions conducted five days per week (Monday to Friday), each lasting 60 minutes. The findings revealed that plyometric training had a significant impact on VO_2 max, maximal voluntary ventilation, and O_2 saturation. In contrast, the control group, which did not follow any specific training regimen, showed no improvement in these parameters. These results were supported by statistical analyses, including descriptive statistics and ANCOVA.

Based on the results presented in Tables 3, 4, and 5, it is evident that VO_2 max, maximal voluntary ventilation, and O_2 saturation improved significantly in the experimental group. On the other hand, no significant improvements were observed in the control group, as they did not undergo the plyometric training intervention. The plyometric training program provided to the experimental group resulted in significant improvements in these parameters among football players. Hence, the findings demonstrated that plyometric training was significantly more effective than regular training in enhancing VO_2 max, maximal voluntary ventilation, and O_2 saturation levels.

Supporting the present findings, Singh et al. (2024) investigated the effects of a six-week plyometric training program on physiological variables in 30 male national-level football players aged 18–24 years. The results showed significant improvements in aerobic capacity, blood pressure, and pulse rate in the experimental group, suggesting that plyometric training is an effective method for improving physiological performance in football players. Similarly, Muhammad et al. (2020) reported that recreational football players exhibited significant improvements in speed and agility following a six-week plyometric training program, with the intervention group outperforming the control group. Another study by Singh, L. Santosh et al. (2021) & Mola and Bayisa, (2020) also found that a four-week plyometric training program significantly improved muscular endurance in football players compared to those who continued regular football training, concluding that plyometric training effectively enhances muscular endurance.

Further evidence from related studies supports the role of plyometric training and aerobic assessment methods. Karampreet Kour Buttar et al. (2020) reported significant differences between direct and indirect methods of measuring VO_2 max in an Indian population, with indirect methods yielding higher VO_2 max values and males showing significantly higher values than females. Orkun Pelvan et al. (2024) observed that different exercise protocols resulted in comparable reductions in intramuscular oxygen saturation, although the Bruce protocol produced higher peak VO_2 values, indicating a strong interaction between physiological and biomechanical factors during maximal exercise (Oljirra et al., 2026). Benoit Wallaert (2011) reported reduced VO_2 peak in sarcoidosis patients, which was strongly correlated with pulmonary function measures, emphasizing the importance of cardiopulmonary exercise testing in assessing exercise intolerance.

Additional studies further corroborate the present findings. Maulidi Abdillah et al. (2016) reported that the 3200-meter run test produced higher predicted VO_2 max values than the 12-minute run test among Indonesian Army personnel, although both tests were useful for evaluating aerobic fitness. Nurper Ozbar (2015) found that a 10-week plyometric training program significantly improved explosive strength, speed, and kicking speed in female soccer players compared to a control group. Nicholas A. Jamnick et al. (2016) reported that the Mankato Submaximal Exercise Test provided more accurate VO_2 max estimates than the YMCA submaximal test. Consistent findings were also reported by Singh, L. Santosh et al. (2022, 2024), who demonstrated that six-week plyometric and interval training programs significantly improved speed, explosive power, cardiorespiratory endurance, and muscular endurance in football players, concluding that such training methods are effective strategies for enhancing endurance- and performance-related physiological parameters.

Conclusion

It was concluded that a six-week plyometric training program significantly enhanced the pulmonary functions of football players, particularly VO2 max, maximal voluntary ventilation, and O_2 saturation. Further research should be conducted to examine the long-term effects and optimal duration of plyometric training, as well as the underlying pulmonary functions mechanisms, in order to gain a deeper understanding of its effectiveness and applications in sports conditioning.

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Conflicts of interest

The authors declare no conflicts of interest.

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