EFFECT OF PLYOMETRIC TRAINING TO IMPROVE LOWER EXTREMITY STRENGTH AND VERTICAL JUMP PERFORMANCE IN YOUNG AMATEUR MALE FOOTBALL PLAYERS (16 TO 20 YEARS) – QUASI-EXPERIMENTAL STUDY

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ABSTRACT:

Background: Plyometric training is an effective training method and widely recognized for improving neuromuscular performance, particularly lower extremities strength and vertical jump height required in football. However, evidence on its effectiveness among young amateur football players remains limited.

Objective: This study aimed to evaluate the effect of a four-week plyometric training program on lower extremity strength and vertical jump performance in young amateur male football players aged 16–20 years.

Methods: A pre–post quasi-experimental design was conducted on 25 amateur male football players aged 16 to 20 years with minimum of two years of training experience in football game. Participants underwent a four-week structured plyometric training protocol, consisting 12 supervised plyometric sessions performed three times per week, incorporating progressive jump based plyometric exercises. Lower extremity strength was assessed using the One Repetition Maximum (1RM) Squat Test, and vertical jump performance was measured using the Sargent Vertical Jump Test. Statistical analysis was performed using paired t-tests with a significance level of $p < 0.05$.

Results: Significant improvements were observed following the intervention in both outcome measures. Mean absolute 1RM increased from 47.72 ± 6.86 kg to 54.64 ± 7.27 kg ($p < 0.001$), while relative strength improved from 0.75 ± 0.06 to 0.86 ± 0.08 ($p < 0.001$). Vertical jump height increased from 37.20 ± 3.25 cm to 41.52 ± 3.89 cm ($p < 0.001$). These findings confirm that short-term plyometric training effectively enhances lower-limb strength and explosive power.

Conclusion: The study concludes that the structured four-week plyometric training program produces significant improvement in lower extremity strength and vertical jump performance among young amateur football players. The improvements are attributed to neuromuscular adaptations and enhanced stretch-shortening cycle efficiency. Plyometric training can therefore be considered an effective, time-efficient method for improving football performance in young amateur athletes.

Keywords: Plyometric training, quasi-experimental study, amateur football players, lower-extremity strength, 1 RM Squat test, vertical jump, Sargent Vertical Jump, football performance, neuromuscular adaptation, stretch-shortening cycle.

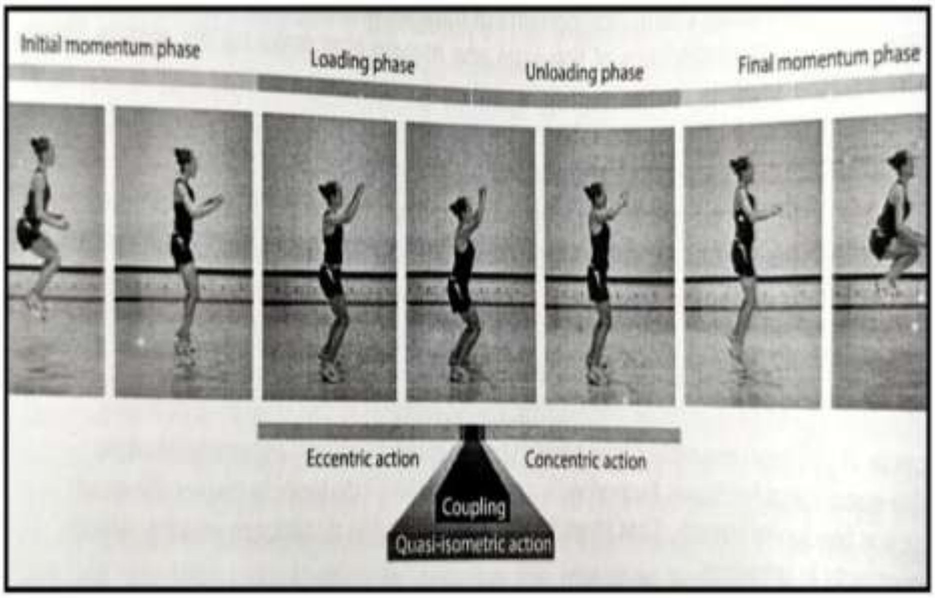
INTRODUCTION

Plyometric exercise is popular form of training used to improve athletic performance.[1] It was initially known as "Stretch Shortening Cycle" or "Jump Training" described by Russian national jump coach. Mr. Yuri Verkhoshansky.[1] The term "Plyometrics" was coined by former athlete and American track and field coach, Mr. Fred Wilt.[1] It is derived from the Greek word "Pliometric".[1] "Plio/Plythine" meaning more/increase and "Metric" meaning measurement, thus meaning "to increase the measurement.[1] By definition, Plyometric exercise is high velocity training characterized by rapid eccentric contraction during which muscle is elongated, immediately followed by rapid reversal of movement with concentric contraction of same muscle.[4] It usually involves exercise that uses Stretch Shortening Cycle in which lengthening movement is quickly followed by shortening movement.[3] This process of muscle lengthening followed by rapid shortening during the Stretch-Shortening cycle is integral to Plyometric exercise.[1]

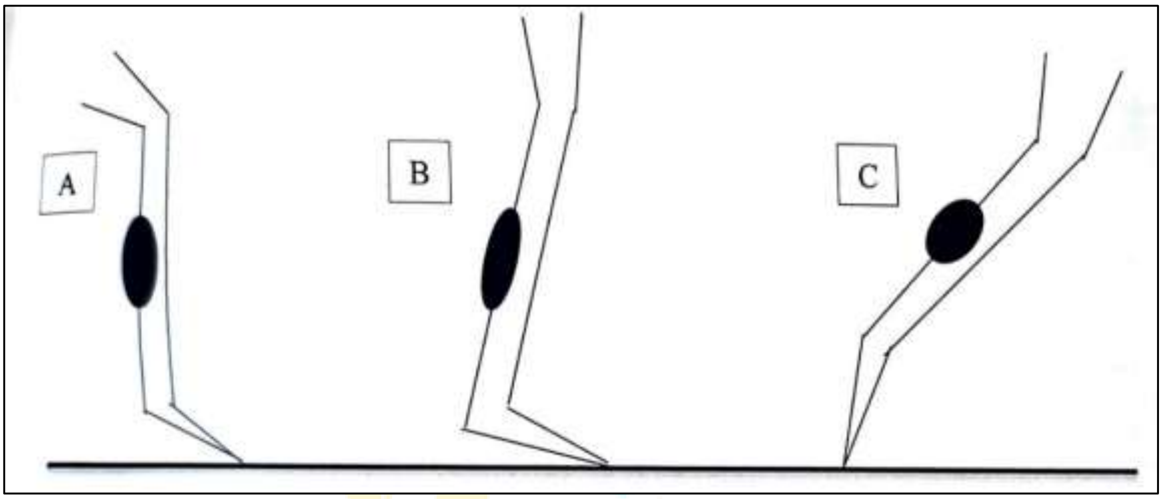
• Stretch Shortening Cycle –

Stretch-Shortening cycle consists of three phases –

a) Loading Phase (Eccentric Phase) – Pre-stretch of the agonist muscle.[1] Elastic energy is stored.[1] Muscle spindles are stimulated. [1]
b) Coupling Phase (Amortization Phase) – Time between the end of pre-stretch and the start of concentric muscle action.[1] Pause between Phase 1 and 3.[1] Phase lasts for 15 milliseconds if last too long stored energy is lost. [1]
c) Unloading Phase (Concentric Phase) – Shortening of muscle fibers.[1] Stored elastic energy is released. [1]



The synergy of the muscles as they transition through each of these muscle actions (eccentric, isometric, concentric) is ultimately what determines the benefits gained from the stretch-shortening cycle.[1] The athlete's timing and execution of the transition through this isometric coupling phase will strongly affect whether the athlete achieves increased power in the plyometric movement.[1] To gain benefits from the stretch-shortening cycle, the athlete must be able to generate appropriate force and properly time the coupling phase with the concentric muscle action. [1]



Phases of stretch shortening cycle – Phase (A) eccentric contraction refers to pre- activation of agonist muscle, where elastic energy is stored in the series elastic components.[21] Phase (B) indicates to amortization, where muscle spindles are stimulated and type 1a afferent nerve synapse with alpha motor neuron transmit a signal to agonist muscle group.[21] Lastly, phase (C) concentric contraction points to shortening of agonist muscle fibers, where elastic energy is released from the series elastic component and alpha motor neurons stimulate the agonist muscle group, which correspond to Plyometric training" [21]

Eccentric Action –

The muscle lengthens in response to an increased load being placed on it produced by gravity and the individual's body weight as he makes contact with the ground.[1] If the eccentric action immediately precedes a concentric action, the muscles will stop acting as shock absorbers and will perform as if they were springs.[1] The muscles are made up of muscle fibres, tendons, and the respective fascial tissues.[1] All of these tissues contribute to the spring properties of the muscle-tendon system that stores and recovers elastic energy during running and jumping.[1] Eccentric muscle actions are particularly useful in a training program for strength development.[1] Athletes who experience recurring hamstring or adductor strains have been shown to have an eccentric strength deficit as great as twice a normal limb.[1] Training isolated muscle actions during dynamic tasks is difficult because isolating specific muscle actions can be a challenge.[1] However, certain techniques can be used to focus on a particular muscular action at a joint.[1] These types of exercises are often used in combination with technical instruction to help athletes improve their overall technical performance of plyometric exercise.[1]

Isometric Action –

Muscle fibrils do move slightly during a static hold, the coupling phase is a point at which little or no observable joint movement occurs thus it is more of a quasi-isometric muscle action.[1] In running or jumping, the coupling phase is the point at which the body "stops" for a very brief period.[1] The one thing we know about good athletes in general is that they don't spend a long time on the ground when running or jumping.[1] These relatively brief ground contact times are directly related to the amortization phase of the athlete's movements.[1] Another way of thinking about the amortization phase is to relate it to its more traditional definition regarding a loan, the shorter the amortization phase (duration of time over which the loan is repaid), the more the borrower likes the loan.[1] Similarly, the shorter the time that athletes spend on the ground, the more effective and faster they will be.[1] The ability to rapidly switch from an eccentric action to a concentric contracting phase is the hallmark of good athletes. [1]

Concentric Action –

Now observers see how high or far the athlete jumps, how fast she turns the legs over (stride frequency), how much ground she covers (stride length), or how far she throws the ball.[1] Though these actions are often impressive, keep in mind that all that beautiful flowing motion is the result of the athlete firmly investing in the body's ability to absorb kinetic energy via muscle-lengthening actions under heavy loads.[1] Think of the eccentric and isometric phases as an investment in the bank of physical performance, and think of the concentric action as the return on that investment.[1] Concentric-focused training should be progressed to link with the other muscle actions so that the athlete learns to capitalize on the payoff portion of plyometric training.[1] However, the use of appropriate plyometric exercises that minimize the loading and coupling phases will allow the athlete to focus on the concentric portions of the movement.[1]

Football, is one of the world's most popular form of sport, being played in every nation without exception. [2] Football has prominent position as most universally acclaimed sports worldwide.[8] It is played on grass field by two opposing teams each of 11 players.[8] Primary objective is to score goal by placing ball into opponents net while simultaneously defending one's own goal against opponents offensive maneuvers.[8] Vertical jump is one of the most explosive physical movement in sports.[5] Success in many sports depends heavily upon muscular strength and ability to jump.[5] Considering the intensive nature of football, delivering high level performance throughout 90 min match can only be achieved through well prepared training program that addresses the athletes physical and physiological needs.[6] Football involved explosive movements, maximal and high intensity muscle motions (sprinting, jumping, kicking, passing, tackling, pacing, change in direction, and diving) during 90 min match.[7] During a football match, amateur players can achieve a length of between 9.5 and 12.4 km.[7] The intricacy of football skills including shooting, dribbling, heading, necessities the execution of complex natural human movements.[8] In modern football, high physiological and physical demands are essential for optimal performance across all age groups without exception adults, youth and juniors.[24] These requirements are influenced by various factors, including player position, skill level, playing style, and the tactical strategies employed by the team.[24] During competitions, players must exert force in a rapid coordinated manner during the braking (eccentric), amortization (isometric), and propulsive (concentric) phases of movement while maintaining posture and position.[28] Furthermore, the game is characterized by frequent positional effort (i.e., picking, rebounding), where lower limb strength facilitates players in contesting to obtain a stable position on the court.[28]

Capacity to perform quick and powerful movements in football is one of the most important abilities to acquire to improve performance, where the leg muscle power in general and vertical jump performance in particular, are considered as critical elements for successful athletic performance.[2] One of training methods that include these actions and that is used for power (Vertical Jump) development is Plyometric exercises.[2] Plyometric Training of lower extremities can be used in almost all sports.[4] Whenever we talk about jumping or sprinting ability training, we associate it with plyometric training.[4] Some studies have shown that the epiphyseal plates of prepubertal adolescents have not yet closed, so high intensity lower extremity training such as deep jumping is inappropriate.[4] Some studies have found that children as early as 7-8 years age can progressively perform plyometric training and continue training into adolescence and adulthood.[4] In number of sports, the higher the athlete jumps, the greater the possibilities to excel in that discipline.[5] Plyometric exercises typically involve explosive movements that require sudden stops, starts, and change in direction.[6]

Muscular Strength can be defined as “the ability to exert a force on an external object or resistance.”[17] Higher level of muscular strength may result in better performance in a range of sport-specific tasks and decrease the risk of injuries in athletes.[17] Functional strength is prioritized during the off-season, followed by maximizing during the early pre-season, muscular power and endurance during the late pre-season, and maintenance throughout the regular season.[16] Maximal strength depends on factors such as intra- (motor unit recruitment and firing rate) and inter- (agonist-antagonist coordination) muscular coordination as well as muscle cross-sectional area.[17] The improvement in neural and morphological factors related to maximal strength allows athletes to have greater potential for power development and sports- related skills.[17] There are different approaches that researchers and practitioners recommend in order to improve these specific neuromuscular abilities.[21] However, strength training and plyometric training are most familiar strategies for improving the sport performance.[21]

NEED OF THE STUDY

Nowadays, awareness regarding the importance of Plyometric training program is well established among elite athletes, however, such awareness and implementation are often limited among young amateur football players. Young amateur football players are at a developmental stage where improving physical capabilities can lay the foundation for future performance. As they aim to progress to higher levels of competition, there is a need for structured training interventions that enhance strength and athletic ability. Plyometric training might offer a means for footballer's success. Researching the effects of plyometric training on this population can guide coaches and trainers in designing age-appropriate, effective training programs that enhance strength and performance. While there is ample research on plyometric training in professional and athletes, studies focusing on young amateur football players are limited. This group, often in the early stages of athletic development, may respond differently to training interventions compared to professional athletes. Along with this, implementing such training can reduce the likelihood of injuries, in younger players who may have inadequate strength and conditioning thereby improving player longevity and performance. This study will contribute to the growing body of knowledge in sports science, particularly in the context of amateur sports. This study will also play important role in improving awareness of proper movement

RESEARCH METHODOLOGY

- Study Design – Pre-test-post-test Quasi-Experimental study
- Study Duration - 4 weeks
- Study Setting - Training ground of Sports Academy, Gymnasium
- Sample Population – Amateur Football Players
- Sample size – 25 (Cohen's dz formula)
- Sampling Method – Purposive Sampling
- Age - Aged between 16 to 20 years old
- Gender - Male
- Performance Level of Sample - Subjects in this group were young amateur football players who had at least two years of football experience but had not undergone any specialized plyometric training.

MATERIALS

- Consent forms
- Data collection sheet
- Yielding surface like training ground, Gym floor
- Wall side area
- Measuring Tape
- Vertical jump measuring sticks or chalk
- Stopwatch
- Cones (20-61cm)
- Hurdles
- Barbell and Squat rack
- Rubber mat
- First Aid
- Comfortable shoes for shock absorption

OUTCOME MEASURES

Assessment of Lower Extremities Strength –

1 RM Squat Test -

- Purpose - One Repetition Maximum Squat Test is used to measure the maximum amount of weight an individual can lift for one complete repetition of a squat. It is a standard outcome measure for assessing lower limb strength. The 1RM test allows for assessing strength in multi-joint exercises.
- Procedure -
- Preparation -

Equipment - Various free weights, Barbell, Squat rack

Warm-Up - 5-10 min of light intensity repetitions. It involved three sets of half squats with progressive loads (40-70-85% of predicted 1 RM) with decreasing number of repetitions (10-6-3).

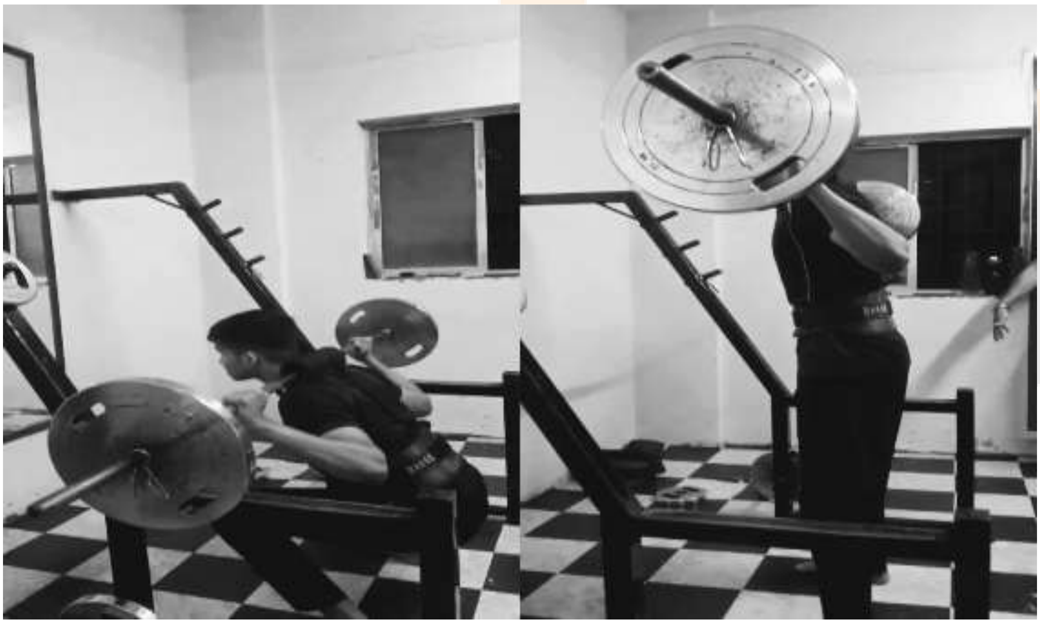
Equipment Setup - Adjust the squat rack height so that the barbell is at chest level when the participant approaches it. Load the barbell with an appropriate starting weight i.e., 50-70% of perceived capacity.

Starting position - The participant stands under the bar, with feet shoulder-width apart. Knees should be in line with the toes. In the upright position they set the barbell on their shoulders and firmly grasped with both hands. Ensure the head and neck are in a neutral position with eyes facing forward (avoid rounding of the spine).

- Execution -

    a) The participant then squats to 90° of knee flexion and returns to upright position with the legs fully extended.
    b) After each successful 1RM attempt the athletes were given 4 min of rest and weight was increased by 2.5-5 kg as long as the athletes felt like they could increase the weight.
    c) If the athletes failed an attempt, they were given instructions to try the same weight again. If they succeed, they would increase, the total weight by 2.5 kg.
    d) During the attempts athletes were to get verbal feedback from their physical coaches about technique and execution until a final 1RM was achieved.
    e) Athletes were given 3 attempts to make a successful 1 RM lift. Whichever weight was successful was used in the analysis for relative and absolute strength.

    - Rest Interval - A rest interval of 3 min was provided between the attempts. On average, 1 RM was achieved within 4-6 attempts.
    - Measurement - Absolute 1 RM is calculated by maximum weight lifted for one repetition. Relative 1 RM is calculated by absolute 1 RM divided by body weight.
      i.e., Relative 1RM = Maximum lift (kg) / Athletes bodyweight (kg)
    - Scoring - The maximum weight lifted is recorded.



Assessment of Vertical Jump Height –

Sargent Vertical Jump Test -

- Purpose - It is standard test used to measure vertical jump height.
- Procedure -

- Preparation -

Equipment - A metric tape, chalk for wall marking, rubber mat to soften landing area.

Warm-Up - The participant should perform a light warm-up consisting of stretching or low-intensity exercises such as jogging to prepare the muscles for the explosive effort.

Starting Position - Player stands with dominant side next to a wall, feet flat on the ground, body upright, and arms fully extended overhead.

Reach Height -The player's standing reach height is measured by marking wall with chalk at the highest point reached while standing flat-foot.

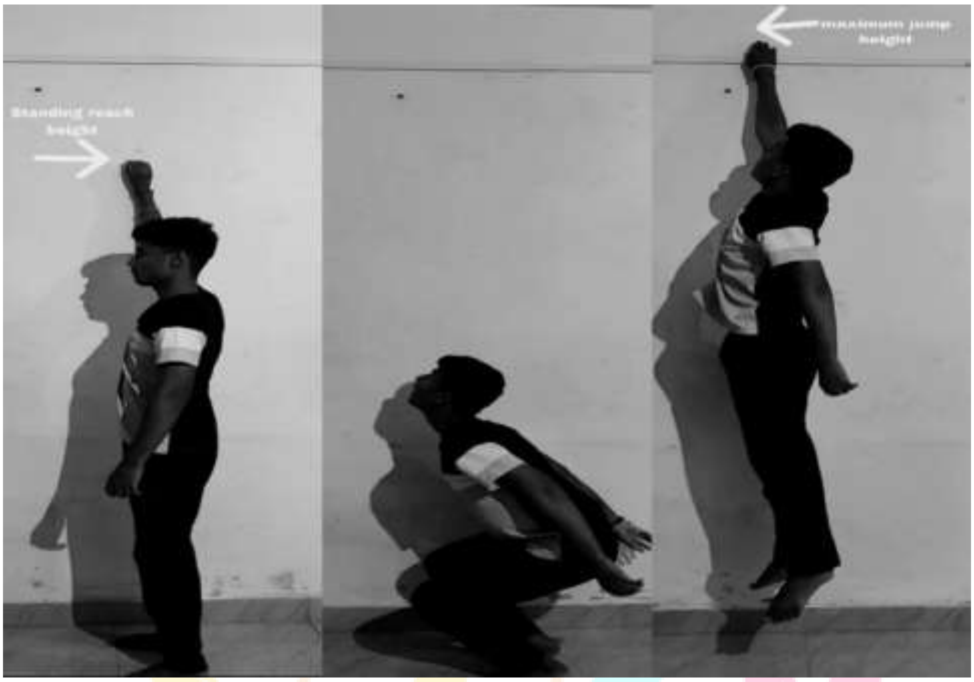
- Execution -

a) Starts in a standing position with their arms at their sides.
b) Bend knees 90° and hips slightly to generate force and perform quick downward movement (countermovement) before explosively jumping upward as high as possible. The measurement of jump is flawed if the athlete is permitted to take one or more steps before jumping, as the athlete will convert some of the energy developed in the steps taken into the force of propulsion that generates upward lift.
c) The goal is to touch or the highest point possible using the hands or using chalk. Measure with tape the maximum jump height.
d) The best of three attempts is typically recorded.

- Measurement - The jump height is calculated by subtracting the standing reach height from the maximum jump height (i.e., the highest point reached during the jump). Difference between standing reach height and peak height achieved on jumping.
- Rest Intervals - Players should take adequate rest (30sec-1min) between each jump attempt to ensure maximal effort.
- Scoring - The vertical jump height is expressed in centimeters or inches.
- Rating of Vertical jump -

Normative Data for Athlete Males and Female –

	MALE		FEMALE	
Rating	(inches)	(cm)	(inches)	(cm)
Excellent	> 28	> 70	> 24	> 60
Very Good	24 – 28	61 – 70	20 - 24	51 – 60
Above Average	20 – 24	51 – 60	16 – 20	41 – 50
Average	16 – 20	41 – 50	12 – 16	31 – 40
Below Average	12 – 16	31 – 40	8 – 12	21 – 30
Poor	8 – 12	21 – 30	4 – 8	11 – 20
Very Poor	< 8	< 21	< 4	< 11



- **Reliability and Validity –**

Adequate research and studies supported that Sargent jump test can really be considered as one of the most reliable tests in measuring Vertical jump height. It is valid and reproducible instrument for measuring the explosive strength. [5] The ICC for this this test has been observed to be 0.99. [13]

The 1RM test has good-to-excellent test-retest reliability. [18] The 1 RM has shown moderate to strong level of reliability with ICC 0.64-0.99. [17]

PROCEDURE

- **CONSENT –**

Throughout the study, ethical considerations were strictly observed. Study began with the presentation of synopsis to an ethical committee and clearance was obtained. Informed consents were obtained from all participants, ensuring the voluntary participation and understanding of study's purpose and procedures. Parents or Guardians were informed about the research protocol and importance of participating in the study.

- **ASSESSMENT –**

Prior to test protocol, participants underwent a familiarization session to ensure no issues during testing.[6] Baseline assessment was done one week prior to training protocol. Pre-test assessment was done on 1st week. Post-test in 4th week after finishing plyometric training.

a) Lower limb Strength - 1 RM Squat test
b) Vertical Jump performance - Sargent Vertical jump test

- **TRAINING PROTOCOL –**

Subjects underwent 4 weeks of Plyometric Jump Training focusing on lower limb strength and vertical jump. Plyometric Training sessions took about 35 – 40 min. Recovery time between each session was around 48 hrs. There were 12 sessions in total.

Breathing - Hold your breath on exertion i.e., hardest part of exercise and exhale on return/completion of exercise which is important for explosiveness.

Warm Up – Start with regular 10-15 min warm up. You can use FIFA 11+ style warm-up program.[13] E.g., exercise like jogging, dynamic stretching, running, skipping, plank, lunges, side shuffling, etc. perform as a set of 10 repetition.

Cool Down - End with 10-15 min cool down. E.g., exercise like jogging, static stretching, walking, etc.

• PLYOMETRIC TRAINING PROGRAM -

VARIABLES	WEEK 1	WEEK 2	WEEK 3	WEEK 4
Exercises	Squat Jump, Tuck Jump, Lunge Jump, Standing Jump and Reach, Hurdle Jump, Side to Side Hops	Squat Jump, Tuck Jump, Lunge Jump, Standing Jump and Reach, Hurdle Jump, Side to Side Hops	Squat Jump, Tuck Jump, Lunge Jump, Standing Jump and Reach, Hurdle Jump, Side to Side Hops	Squat Jump, Tuck Jump, Lunge Jump, Standing Jump and Reach, Hurdle Jump, Side to Side Hops
Repetition	10 – 12	10 – 15	10 - 15	15 - 20
Set	1 – 2	1 – 2	2 - 3	3
Rest Interval	2 – 3 min	1 – 2 min	1 – 2 min	30 sec – 1 min
Progression	Not allowed until adequate competency acquired	Gradual increase in complexity	Moderate increase with participants feedback	High intensity progression allowed with careful monitoring
Intensity	Low	Moderate	Moderate	High
Volume	60 – 100 foot contacts	100 - 150 Foot contacts	150 – 200 Foot contacts	200 - 250 Foot contacts
Frequency	3 sessions on Monday, Wednesday, Friday	3 sessions on Monday, Wednesday, Friday	3 sessions on Monday, Wednesday, Friday	3 sessions on Monday, Wednesday, Friday

Squat Jump –

- Starting Position - Stand with feet shoulder-width apart, lower into a squat position by bending your knees and pushing your hips back.

- Jumping Action –
  Explode Upward - Push through your feet and jump as high as you can while swinging your arms up for momentum.
  Land Softly - Land gently with knees bent, returning to squat position to absorb the impact.
- Repetition - Perform continuous jumps, focusing on height and form.

Tuck Jump -

- Starting Position: Stand with feet shoulder-width apart and knees slightly bent.
- Jumping Action –
  Jump Up - Explode vertically, pushing through your legs and swinging your arms upward for momentum.
  Knees to Chest: At the peak of the jump, tuck your knees towards your chest, aiming to bring them as high as possible.
  Land Softly: Land softly with knees slightly bent to absorb the impact and prepare for the next jump.
- Repetition: Perform continuous jumps, focusing on height and form.

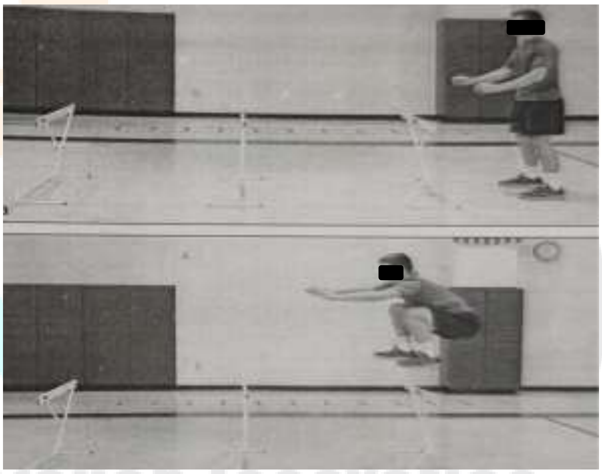
Side To Side Hops –

- Starting Position - Stand with feet hip-width apart, knees slightly bent, and hands in front for balance.
- Jumping Action –
  Push-off - Bend your knees, then push off one foot to jump (laterally (sideways) to the opposite side.
  Land - Land softly on the other foot with knees slightly bent, absorbing the impact. Repeat - Immediately push off from the landing foot and jump back to the other side.

- Repetition: Continue jumping side-to-side in a smooth, rhythmic motion, focusing on maintaining balance and control.


Hurdle Jumps -

- Setup - Place hurdles at a distance that challenges athlete but allows for proper execution and height of the hurdles should be appropriate for the athlete’s skill level.
- Starting Position - Stand behind the first hurdle with feet shoulder-width apart & knees slightly bent.
- Jumping Action –
  Preparation - Bend your knees & swing your arms back to generate momentum.
  Take-off - Explode upward, driving your knees towards your chest while swinging your arms forward to propel yourself over the hurdle.
  Clear the Hurdle - Aim to clear the hurdle without touching it and focus on a quick, efficient motion.
  Landing: softly on the balls of your feet, absorbing impact with your legs slightly bent. Maintain balance and prepare for the next jump.
- Repetition - Continue jumping over successive hurdles, focus on maintaining speed, form, proper landing mechanics.

Lunge Jumps -

- Starting Position - Begin in a lunge position with one foot forward and the other foot behind, both knees bent at about 90°.
- Jumping Action –
  Explode Upward: Jump straight up, switching legs mid-air.
  Switch Legs: Land softly with the opposite leg forward in a lunge position.
- Repetition: Continue jumping and alternating legs, focusing on balance and control.

Standing Jump and Reach –

- Starting Position - Stand with feet shoulder-width apart, arms at your sides, and knees slightly bent.
- Jumping Action –

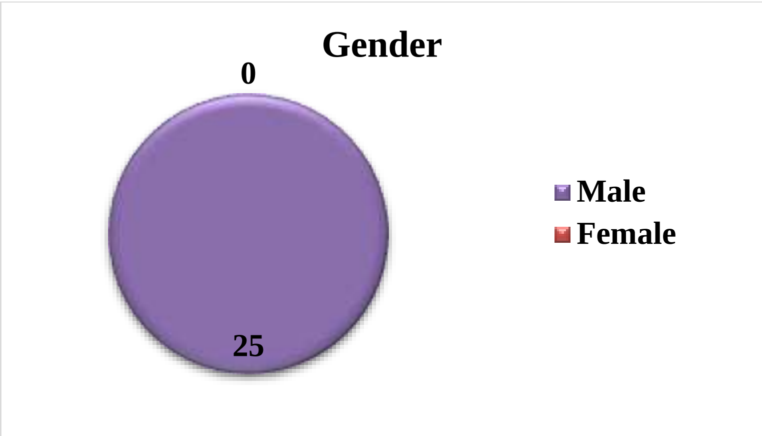
  Squat and Explode - Bend your knees slightly, then jump as high as you can, extending your arms overhead for maximum height reaching for target.
  Land Softly - Land with knees slightly bent to absorb the impact.

DATA ANALYSIS AND INTERPRETATION

- Statistical analysis was performed after entering the collected data into Microsoft. The statistical analysis of data was done using IBM SPSS version 26 software. Microsoft excel was used for preparing tables and graphs.
- Participant characteristics such as gender, age, height, weight, BMI, Years of experience were summarized using descriptive statistics, including mean, standard deviation (SD), range, minimum and maximum values.
- The normality of data distribution was analysed by using Shapiro-wilk test.
- Both pre-post data for absolute and relative strength as well as vertical jump performance, followed a normal distribution ($p>0.005$).
- As data were normally distributed, parametric tests were used for pre-post comparisons.
- Paired sample t-tests were used to analyse the difference between pre-post training scores for 1RM Squat test (Absolute and Relative) and Sargent Vertical Jump performance
- All data were presented as mean ± standard deviation (SD) and p value < 0.05 was considered statistically significant.
- Graphs and tables were derived from the statistical analysis to facilitate easy interpretation of results and visual comparison of pre-post-test performance.

TABLE NO. 1 – Gender

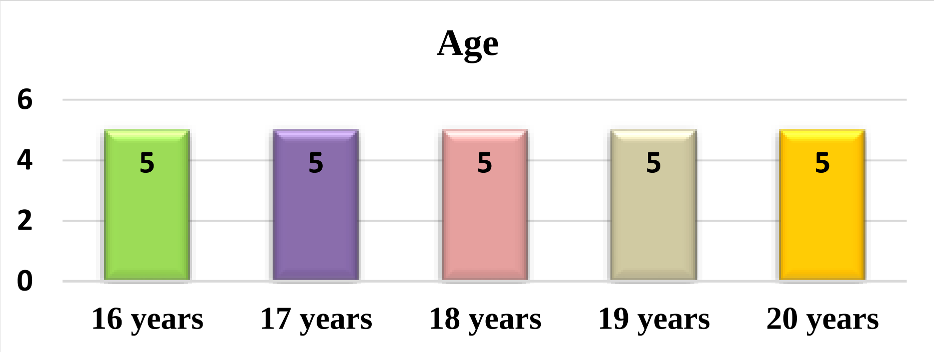
Gender	Count	Percentage
Male	25	100%
Female	0	0%
Total	25	100%



Interpretation - The participant demographics confirm a strictly homogeneous sample in terms of gender, consisting exclusively of 25 male players, which aligns perfectly with the predefined inclusion criteria. This 100% male composition effectively controls for gender as a potential confounding variable, ensuring that the study's outcomes are specifically attributable to the effects of plyometric training on young males. Consequently, the findings will be directly relevant to the stated aim but will not be generalizable to female football players. This focused approach strengthens the internal validity of the study for its target population.

TABLE NO. 2 – Age

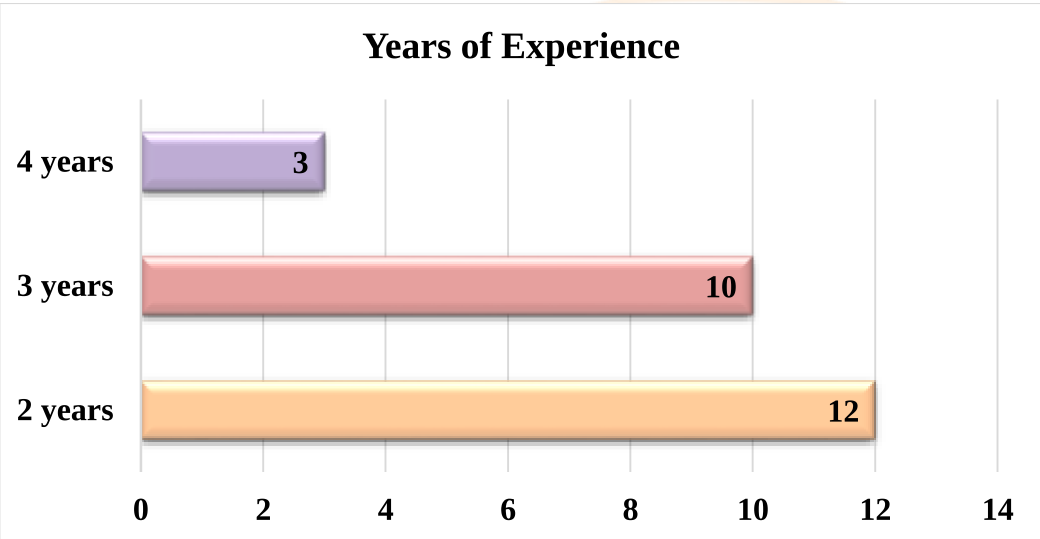
Age	Count	Percentage
16 years	5	20%
17 years	5	20%
18 years	5	20%
19 years	5	20%
20 years	5	20%
Total	25	100%



Interpretation - The age distribution table reveals a perfectly uniform sample, with an equal number of participants (5 each, 20%) across each year from 16 to 20. This ideal stratification ensures that the study's findings are not skewed toward the physical maturation of a single age group, providing a balanced view of the training effects across the entire late-adolescent to young-adult spectrum. Such a distribution strengthens the internal validity of the results for the specified 16–20 years of age range. However, the perfectly even split may suggest a deliberate sampling strategy to achieve this balance rather than a natural reflection of the academy's population.

TABLE NO. 3 - Years of Experience

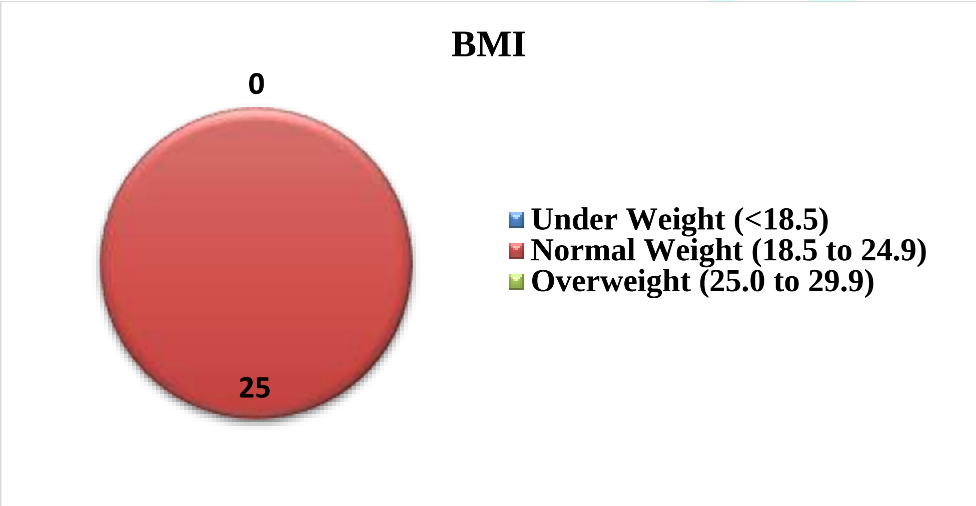
Years of Experience	Count	Percentage
2 years	12	48%
3 years	10	40%
4 years	3	12%
Total	25	100%



Interpretation - The data on years of football experience shows that the vast majority of participants (88%) have either 2 or 3 years of training background, which solidly meets the study's inclusion criterion of a minimum 2-year background. This indicates a sample comprised largely of developing athletes with a foundational, but not extensive level of experience. The presence of a smaller group with 4 years of experience adds a slight range, suggesting the sample captures players at different stages within the amateur spectrum. This distribution is appropriate for investigating a training intervention aimed at players who are still building their athletic fundamentals.

TABLE NO. 4 -BMI

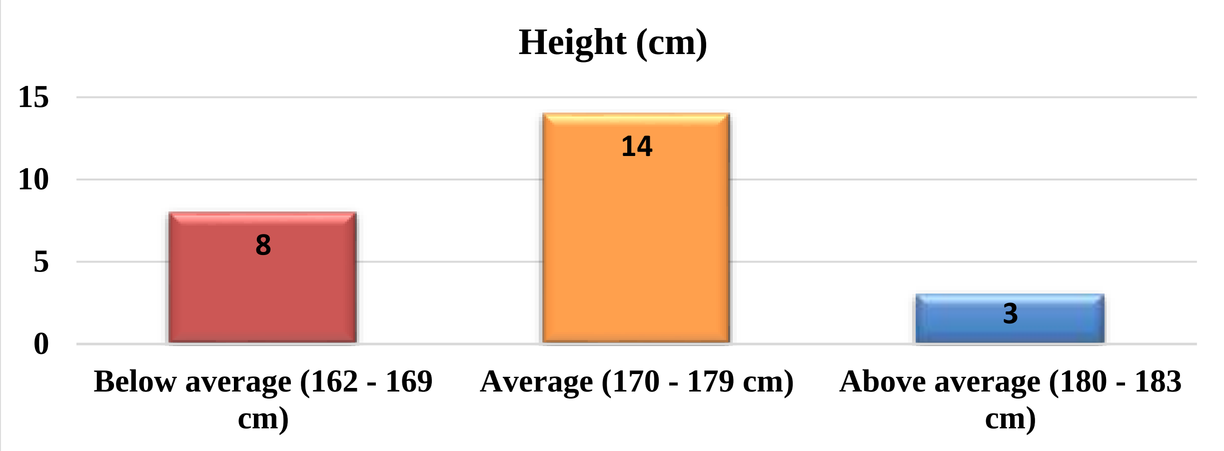
BMI	Count	Percentage
Under Weight (<18.5)	0	0%
Normal Weight (18.5 to 24.9)	25	100%
Overweight (25.0 to 29.9)	0	0%
Total	25	100%



Interpretation - The BMI data indicates a highly homogeneous sample, with 100% of participants falling within the Normal Weight category. This effectively eliminates body composition as a significant confounding variable, ensuring that differences in strength and jump performance are more likely a result of the plyometric intervention rather than variations in weight status. This uniformity strengthens the study's internal validity by creating a controlled baseline for physical characteristics. However, it may also limit the generalizability of the findings, as the results will be most applicable to populations with a similar, normal BMI profile.

TABLE NO. 5 - Average Height

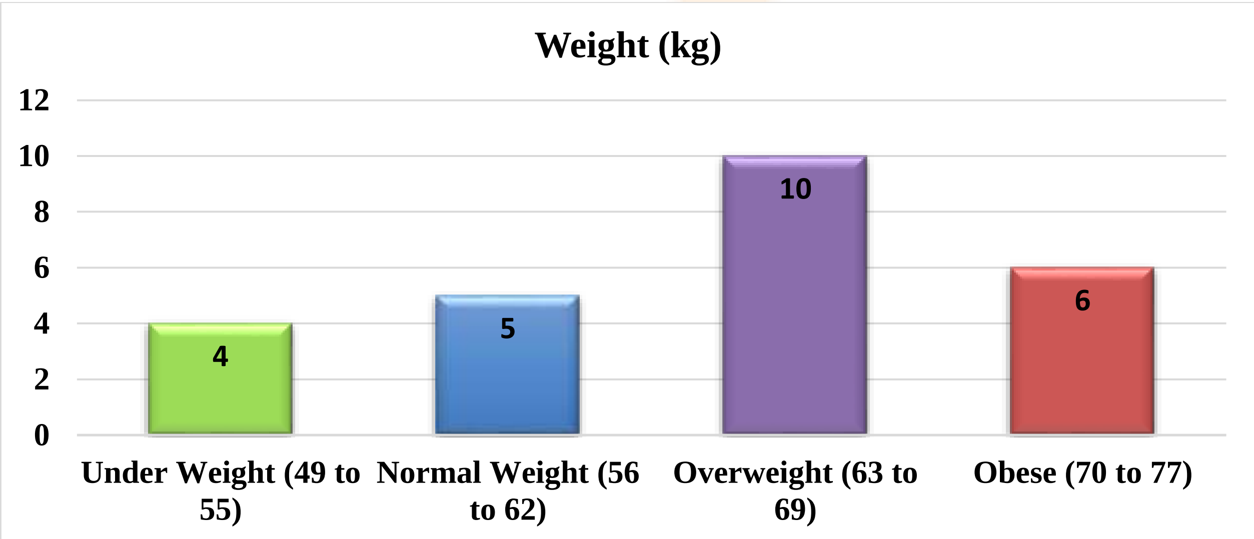
Height (cm)	Count	Percentage
Below Average (162 - 169 cm)	8	32%
Average (170 - 179 cm)	14	56%
Above Average (180 - 183 cm)	3	12%
Total	25	100%



Interpretation - The data reveals that the majority of individuals, precisely 56%, fall within the Average height range of 170-179 cm, indicating this is the most common stature in the group. A significant portion (32%) is categorized as Below average, while above average individuals are the least represented at only 12%. This distribution suggests a sample that is predominantly of average height, with a smaller but notable presence of shorter individuals and a very limited representation of taller ones.

TABLE NO. 6 - Average Weight

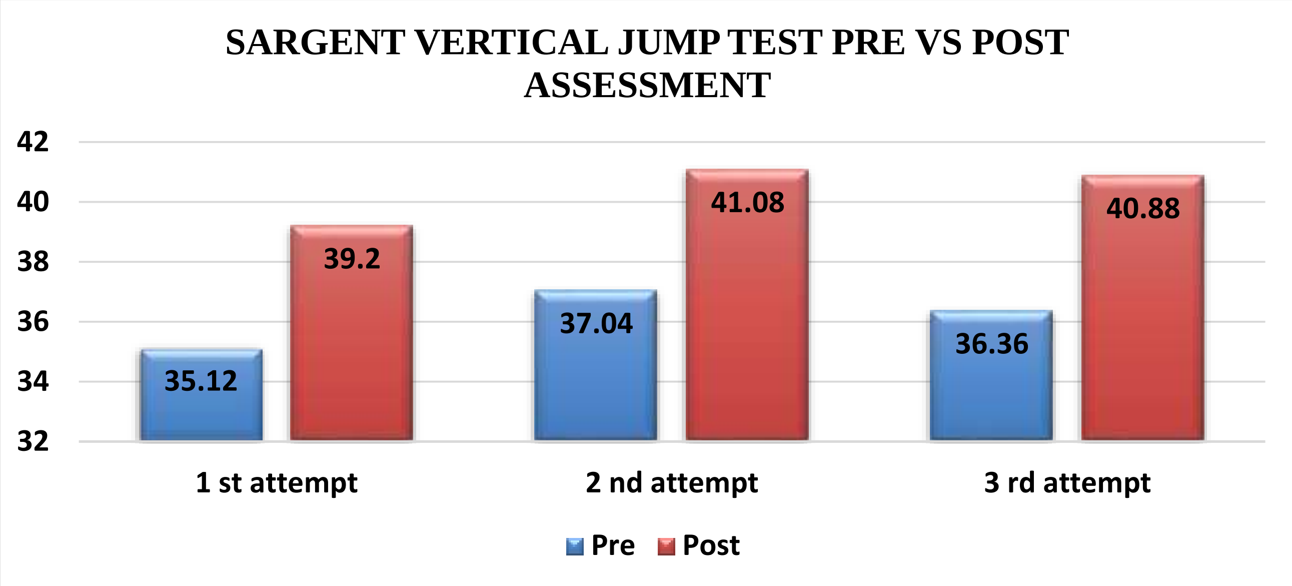
Average Weight as per BMI	Count	Percentage
Under Weight (49 to 55kg)	4	16%
Normal Weight (56 to 62kg)	5	20%
Overweight (63 to 69kg)	10	40%
Obese (70 to 77kg)	6	24%
Total	25	100%



Interpretation - The data confirms that the average weight of the participant group, all of whom are in the Normal Weight BMI category, is 63.56 kg. When combined with the previously noted average height of 172.12 cm, it provides a complete anthropometric profile, confirming that the sample is physically homogeneous. This specific average weight is a crucial baseline metric for interpreting the results of the strength (1RM Squat) and power (Vertical Jump) tests, as performance in these is often relative to an athlete's body weight. The consistency in weight, like height, strengthens the study's internal validity by controlling for these physical variables.

TABLE NO. 7 - SARGENT VERTICAL JUMP TEST PRE VS POST

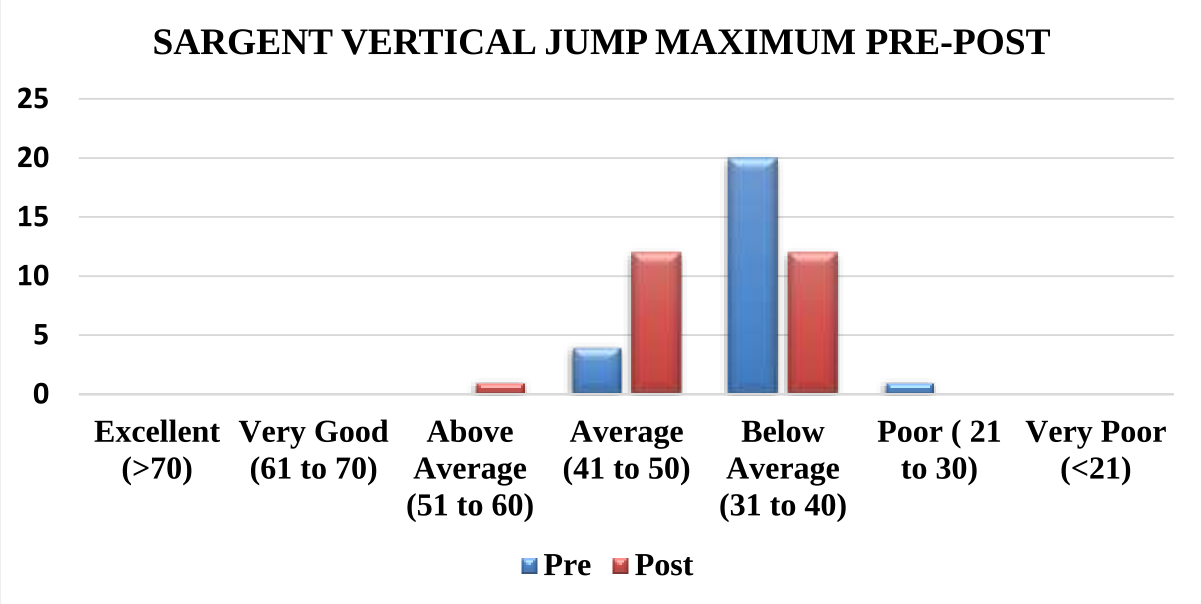
SARGENT VERTICAL JUMP TEST	1st attempt	2nd attempt	3rd attempt
Pre Assessment	35.12	37.04	36.36
Post Assessment	39.2	41.08	40.88



Interpretation - The results from the Sargent Vertical Jump Test indicate a positive effect of the plyometric training on vertical jump performance. In all three attempts, the post-assessment scores show a consistent and notable increase of approximately 4 centimetres compared to the pre-assessment scores. The highest values were recorded on the second attempt in both pre- and post-tests, suggesting a potential learning or potentiation effect. This clear improvement across all trials confirms that the training intervention successfully met its objective of enhancing explosive lower body power, as measured by vertical jump height.

TABLE NO. 8 - DESCRIPTIVE STATISTICS OF SARGENT VERTICAL JUMP PRE VS POST

Rating	Pre	Post
Excellent (>70)	0	0
Very Good (61 to 70)	0	0
Above Average (51 to 60)	0	1
Average (41 to 50)	4	12
Below Average (31 to 40)	20	12
Poor (21 to 30)	1	0
Very Poor (<21)	0	0
Total	25	25



Interpretation - The descriptive statistics reveal a significant positive shift in the Vertical jump height profile of the participants following the plyometric training. Post-intervention, 12 players now rate as Average compared to only 4 beforehand, and one player has even progressed to the Above Average category, a rating no one achieved in the pre-test. Crucially, the number of players in the Below Average category decreased substantially from 20 to 12. This collective upward shift across the ratings clearly demonstrates that the 4-week training program was effective in enhancing the overall Vertical jump performance of the group.

TABLE NO.9 - SARGENT VERTICAL JUMP TEST PRE- JUMP MAXIMUM DESCRIPTIVE STATISTICS

SARGENT VERTICAL JUMP TEST PRE-JUMP MAXIMUM DESCRIPTIVE STATISTICS											
	N	Range	Min	Max	Mean	Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
PRE JUMP MAX	25	14.00	30.00	44.00	37.2000	3.24037	10.500	0.021	0.464	0.139	0.902

Interpretation - The pre-intervention vertical jump data shows a mean maximum jump height of 37.20 cm among the participants, with scores ranging from 30.00 cm to 44.00 cm. The relatively small standard deviation of 3.24 cm indicates that the group was fairly homogeneous in their baseline vertical jump performance, with most players clustering around the average. The near-zero values for both skewness (0.021) and kurtosis (0.139) confirm that the data follows a normal distribution, which is ideal for subsequent statistical comparisons. This establishes a consistent and reliable baseline for measuring the effects of the plyometric training intervention on explosive power.

SARGENT VERTICAL JUMP TEST POST JUMP MAXIMUM DESCRIPTIVE STATISTICS											
	N	Range	Min	Max	Mean	Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
POST JUMP MAX	25	16.00	35.00	51.00	41.5200	3.89572	15.177	0.749	0.464	0.272	0.902

TABLE NO. 10 - SARGENT VERTICAL JUMP TEST POST JUMP MAXIMUM DESCRIPTIVE STATISTICS

Interpretation - The post-intervention data reveals a substantial improvement in vertical jump performance, with the mean maximum jump height increasing by 4.32 cm to 41.52 cm. Notably, both the minimum and maximum scores improved (from 30 cm to 35 cm and from 44 cm to 51 cm, respectively), indicating that all participants benefited from the training. The increase in standard deviation and range suggests a wider dispersion of performance post-training, meaning that while all players improved, some made greater gains than others. The positive skewness (0.749) in the post-test data indicates that the distribution is now skewed toward the higher end, with a cluster of participants achieving particularly strong results.

TABLE NO.11 – PRE VS POST SARGENT JUMP MAXIMUM TEST OF NORMALITY

PRE VS POST SARGENT JUMP MAXIMUM TEST OF NORMALITY			
	Shapiro-Wilk		
	Statistic	df	Sig.
PRE-JUMP MAXIMUM	0.982	25	0.917
POST-JUMP MAXIMUM	0.954	25	0.315

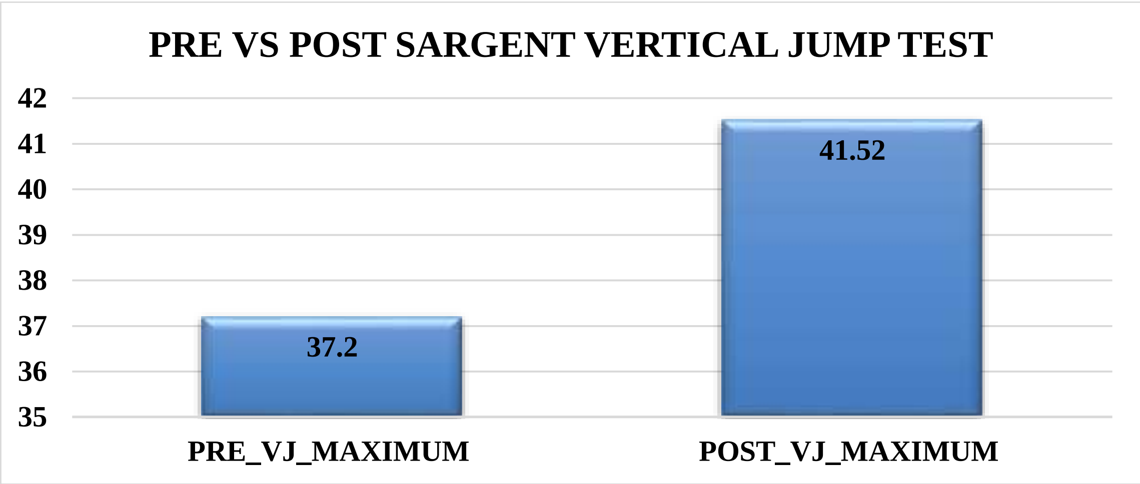
Interpretation - The Test of Normality confirms that both the pre-training and post-training vertical jump data are normally distributed. This is strongly supported by the Shapiro-Wilk test results, which show non-significant p-values of 0.917 (pre) and 0.315 (post), both well above the 0.05 threshold. This validation of normality for the vertical jump data is methodologically crucial, as it justifies the use of parametric statistical tests for comparing the pre-post intervention differences, thereby ensuring the statistical validity of any conclusions drawn about the training's effect on jump performance.

TABLE NO. 12 - PAIRED TEST WITHIN PRE AND POST JUMP MAXIMUM

PAIRED TEST WITHIN PRE AND POST JUMP MAXIMUM									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	PRE-JUMP MAXIMUM POST-JUMP MAXIMUM	-4.32000	1.24900	0.24980	-4.83556	-3.80444	-17.294	24	<0.001

Interpretation - The results demonstrate a statistically significant improvement in vertical jump performance following the plyometric training program. The analysis shows a mean increase of 4.32 cm in maximum jump height from pre-test to post-test ($t(24) = -17.294$, $p < .001$). This highly significant result ($p < 0.001$) provides strong evidence to reject the null hypothesis. Therefore, we conclude that the 4-week plyometric training program led to a substantial and significant enhancement in vertical jump performance for the young amateur male football players.

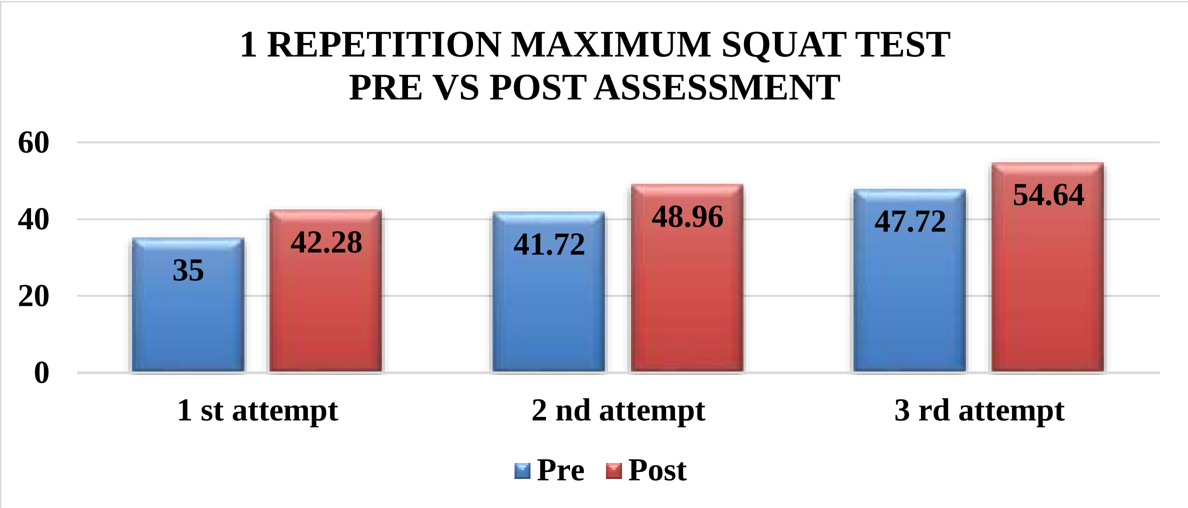
PRE VS POST SARGENT VERTICAL JUMP TEST	
PRE VERTICAL MAXIMUM	37.2
POST VERTICAL JUMP MAXIMUM	41.52



Interpretation - The post-training vertical jump height increased substantially from 37.2 cm to 41.52 cm, reflecting a mean improvement of 4.32 cm. This significant gain demonstrates a clear enhancement in lower-body explosive power and plyometric efficiency among the young amateur football players. The results confirm that the 4-week plyometric training program was highly effective in translating strength gains into improved functional athletic performance.

TABLE NO. 13 - 1 REPETITION MAXIMUM SQUAT TEST PRE VS POST

1 RM SQUAT TEST	1st attempt	2nd attempt	3rd attempt
Pre Assessment	35	41.72	47.72
Post Assessment	42.28	48.96	54.64



Interpretation - The data demonstrates a clear and consistent improvement in lower extremity strength following the 4-week plyometric training program. Across all three attempts, the post-assessment scores are substantially higher than the pre-assessment scores, showing an average increase of over 7 kg per attempt. This progressive increase from the first to the third attempt in both pre- and post-tests also suggests an effective warm-up and performance strategy within the testing protocol itself. The results strongly indicate that the plyometric training was effective in achieving the primary objective of enhancing maximal strength in the study's participants.

TABLE NO. 14 - DISCRIPTIVE STATISTICS OF 1 RM SQUAT TEST PRE

1 REPETITION MAXIMUM SQUAT TEST PRE ASSESSMENT DESCRIPTIVES											
	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
PRE_1ST_ ATTEMPT	25	17.00	28.00	45.00	35.0000	5.32291	28.333	0.550	0.464	-0.557	0.902
PRE_2ND_ ATTEMPT	25	17.00	33.00	50.00	41.7200	5.60892	31.460	-0.299	0.464	-1.031	0.902
PRE_3RD_ ATTEMPT	25	25.00	35.00	60.00	47.7200	6.85881	47.043	-0.184	0.464	-0.776	0.902

Interpretation - The pre-assessment descriptive statistics show a consistent and expected increase in the mean scores from the first (35.00 kg) to the third (47.72 kg) attempt, indicating a learning or potentiation effect where participants improved their performance within the testing session itself. The data displays a moderate spread around the mean, as shown by the standard deviations, suggesting some natural variation in strength levels among the participants at the study's outset. The skewness and kurtosis values are all within an acceptable range, indicating that the data for all three pre-assessment attempts is approximately normally distributed, which is a positive characteristic for applying parametric statistical tests later.

TABLE NO. 15 - DESCRIPTIVE STATISTICS 1 RM SQUAT TEST POST

1 REPETITION MAXIMUM SQUAT TEST POST ASSESSMENT DESCRIPTIVES											
	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
POST_1ST_ ATTEMPT	25	17.00	33.00	50.00	42.2800	4.83494	23.377	-0.237	0.464	-0.687	0.902
POST_2ND_ ATTEMPT	25	22.00	38.00	60.00	48.9600	6.53503	42.707	-0.097	0.464	-1.363	0.902
POST_3RD_ ATTEMPT	25	25.00	43.00	68.00	54.6400	7.27370	52.907	0.071	0.464	-1.239	0.902

Interpretation - The post-assessment data demonstrates a clear improvement over the pre-test results, with the mean scores for all three attempts showing a substantial increase. Notably, the maximum values achieved rose significantly, reaching 68 kg in the final attempt compared to 60 kg pre-training, indicating enhanced peak strength in the group. The standard deviations remain moderate but have increased slightly in the later attempts, suggesting that while all participants improved, there was a wider dispersion in performance levels post-intervention. The skewness and kurtosis values continue to fall within an acceptable range, indicating that the post-intervention data also maintains a relatively normal distribution suitable for further statistical analysis.

TABLE NO.16 - DESCRIPTIVE STATISTICS ABSOLUTE 1 RM SQUAT TEST

1RM ABSOLUTE PRE VS POST DISCRIPTIVES				
			Statistic	Std. Error
PRE_1RM_ABSOLUTE	Mean		47.7200	1.37176
	95% Confidence Interval for Mean	Lower Bound	44.8888	
		Upper Bound	50.5512	
	5% Trimmed Mean		47.7333	
	Median		48.0000	
	Variance		47.043	
	Std. Deviation		6.85881	
	Minimum		35.00	
	Maximum		60.00	
	Range		25.00	
	Interquartile Range		11.00	
	Skewness		-0.184	0.464
	Kurtosis		-0.776	0.902
POST_1RM_ABSOLUTE	Mean		54.6400	1.45474
	95% Confidence Interval for Mean	Lower Bound	51.6376	
		Upper Bound	57.6424	
	5% Trimmed Mean		54.5556	
	Median		53.0000	
	Variance		52.907	
	Std. Deviation		7.27370	
	Minimum		43.00	
	Maximum		68.00	
	Range		25.00	
	Interquartile Range		12.00	
	Skewness		0.071	0.464
	Kurtosis		-1.239	0.902

Interpretation - The comparison between the pre and post 1RM absolute values reveals a significant strength improvement, with the mean increasing from 47.72 kg to 54.64 kg, a gain of nearly 7 kg. The 95% confidence intervals for the pre and post means do not overlap, providing strong statistical evidence that the observed improvement is a real effect and not due to random chance. The distribution of scores became slightly more variable post-training, as indicated by the increased standard deviation and range, suggesting that while all participants benefited, the degree of improvement varied across the group. The near-zero skewness values for both pre and post data indicate that the distributions are fairly symmetrical around the mean.

TABLE NO.17 - TEST OF NORMALITY 1RM ABSOLUTE PRE VS POST

TEST OF NORMALITY PRE VS POST 1RM ABSOLUTE			
	Shapiro-Wilk		
	Statistic	df	Sig.
PRE_1RM_ABSOLUTE	0.956	25	0.333
POST_1RM_ABSOLUTE	0.941	25	0.158

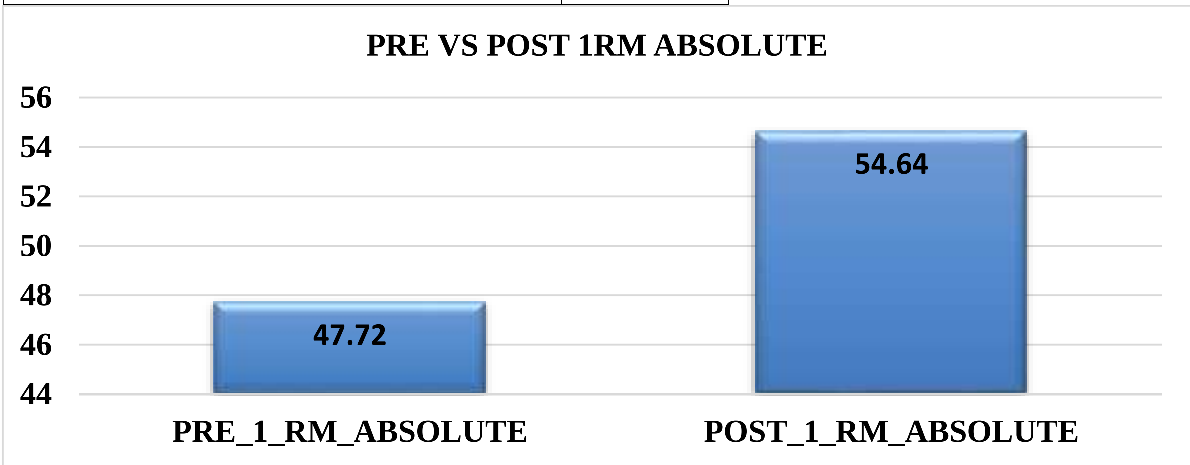
Interpretation - The Test of Normality results confirm that the data for both the pre and post 1RM absolute scores are normally distributed. This is evidenced by the Shapiro-Wilk test, where the significance values (p = 0.333 for pre and p = 0.158 for post) are well above the common alpha level of 0.05. This is a crucial finding as it validates the use of parametric statistical tests, such as a paired-sample t-test, for comparing the pre and post intervention results, thereby strengthening the reliability of the subsequent inferential analysis.

TABLE NO. 18 - TEST OF NORMALITY 1RM ABSOLUTE PRE VS POST

PAIRED SAMPLE TEST 1RM ABSOLUTE PRE VS POST									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Dev	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	PRE AND POST 1RM ABSOLUTE	-6.92000	2.62869	0.52574	-8.00507	-5.83493	-13.162	24	<0.001

Interpretation - The results of the paired samples t-test lead to a clear rejection of the null hypothesis. The data reveals a statistically significant increase in lower extremity strength, with the post-training values being an average of 6.92 kg greater than the pre-training values ($t(24) = -13.162$, $p < .001$). Since the p-value is less than .001 and the 95% confidence interval does not include zero, we can conclude that the 4-week plyometric training program led to a significant improvement in lower extremity strength, as measured by the RM Absolute test, in young amateur male football players.

1 RM ABSOLUTE PRE VS POST	
PRE 1RM ABSOLUTE	47.72
POST 1RM ABSOLUTE	54.64



Interpretation - The post-training 1RM absolute strength demonstrated a substantial increase of 6.92 kg, rising from 47.72 kg to 54.64 kg. This marked improvement indicates a significant enhancement in the lower extremity maximal strength of the young amateur male football players following the 4-week plyometric training program. The results provide clear evidence that the training stimulus was effective in eliciting positive neuromuscular adaptations.

TABLE NO. 19 - 1RM RELATIVE PRE VS POST DESCRIPTIVES

PRE VS POST 1RM RELATIVE DESCRIPTIVES				
			Statistic	Std. Error
PRE_1RM_RELATIVE	Mean		0.7504	0.01235
	95% Confidence Interval for Mean	Lower Bound	0.7249	
		Upper Bound	0.7759	
	5% Trimmed Mean		0.7468	
	Median		0.7500	
	Variance		0.004	
	Std. Deviation		0.06174	
	Minimum		0.66	
	Maximum		0.92	
	Range		0.26	
	Interquartile Range		0.09	
	Skewness		0.781	0.464
	Kurtosis		0.708	0.902
POST_1RM_RELATIVE	Mean		0.8620	0.01513
	95% Confidence Interval for Mean	Lower Bound	0.8308	
		Upper Bound	0.8932	
	5% Trimmed Mean		0.8611	
	Median		0.8600	

	Variance	0.006	
	Std. Deviation	0.07566	
	Minimum	0.74	
	Maximum	1.00	
	Range	0.26	
	Interquartile Range	0.14	
	Skewness	0.027	0.464
	Kurtosis	-0.980	0.902

Interpretation - The analysis of relative strength (1RM relative to body weight) shows a substantial improvement following the plyometric training, with the mean increasing from 0.75 to 0.86. This indicates that the athletes are now able to lift a significantly greater proportion of their own body weight. The 95% confidence intervals for the pre and post means do not overlap, providing strong evidence that this improvement is statistically significant. The distribution of relative strength scores became more symmetrical after training (skewness changed from 0.781 to 0.027), suggesting more consistent performance gains across the entire sample. The increase in both maximum value (reaching 1.00) and interquartile range indicates that some participants made particularly strong gains in relative strength.

TABLE NO. 20 - PRE VS POST 1RM RELATIVE DESCRIPTIVES

TEST OF NORMALITY 1RM RELATIVE PRE VS POST			
	Shapiro-Wilk		
	Statistic	df	Sig.
PRE 1RM RELATIVE	0.941	25	0.153
POST 1RM RELATIVE	0.958	25	0.373

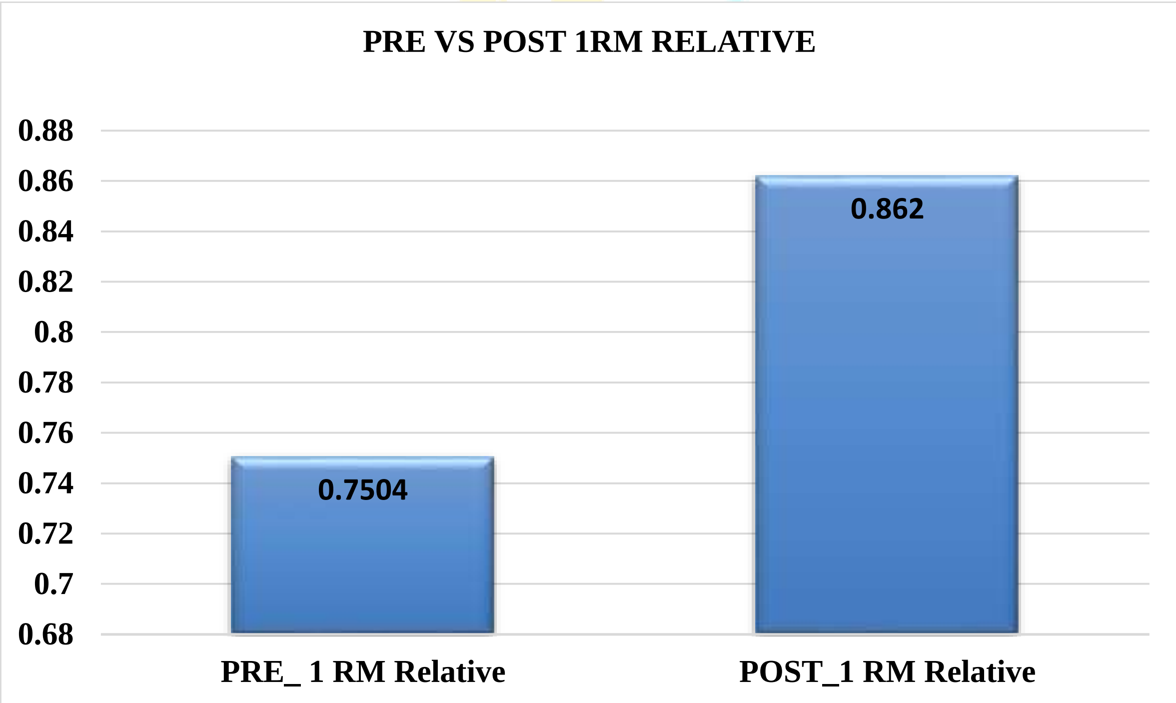
Interpretation - The Test of Normality results confirm that both the pre-training and post-training relative 1RM data are normally distributed. This is confirmed by the Shapiro-Wilk test, where the significance values (p = 0.153 for pre and p = 0.373 for post) are well above the standard alpha level of 0.05. This validation of normality for the relative strength data is crucial as it justifies the use of parametric statistical tests for analysing these variables, ensuring that any subsequent comparisons of pre-post differences in relative strength are statistically valid and reliable.

TABLE NO. 21 - PAIRED SAMPLE TEST PRE VS POST 1RM RELATIVE

PAIRED SAMPLE TEST PRE VS POST 1RM RELATIVE									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Dev	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	PRE AND POST 1 RM RELATIVE	-0.11160	0.04732	0.00946	-0.13113	-0.09207	-11.793	24	<0.001

Interpretation - The paired samples t-test indicates a statistically significant improvement in relative lower extremity strength following the training intervention. The post-test values showed a mean increase of 0.11 kg per unit of body mass ($t(24) = -11.793$, $p < .001$). With the p-value being far less than 0.05 and the confidence interval excluding zero, we reject the null hypothesis. This confirms that the 4-week plyometric training program resulted in a significant enhancement of strength relative to body weight in the participants.

PRE VS POST 1 RM RELATIVE	
PRE 1 RM RELATIVE	0.7504
POST 1 RM RELATIVE	0.862



Interpretation - The post-training 1RM relative strength showed a clear improvement, increasing from 0.7504 to 0.862. This gain of 0.1116 units indicates that the athletes were able to lift significantly more weight relative to their body mass after the 4-week plyometric training program. This demonstrates that the training effectively enhanced not just raw strength, but functional strength efficiency, a critical factor for athletic performance.

RESULT

The present study was conducted on 25 male football players aged 16–20 years, all within the normal BMI range with a mean height of 172.12 cm and mean weight of 63.56 kg. After the 4-week plyometric training program, a significant improvement was observed in both lower-body strength and vertical jump performance. The sample was thus homogenous in term of anthropometric characteristics, ensuring uniformity in baseline physical profiles.

- **1 Repetition Maximum (1RM) Squat Test -**

The mean absolute 1RM increased from 47.72 ± 6.86 kg (pre) to 54.64 ± 7.27 kg (post). The paired t-test indicated a significant improvement in lower extremity strength,
$t(24) = -13.162$, $p < 0.001$.
Similarly, relative strength (1RM/body weight) improved from 0.75 ± 0.06 to 0.86 ± 0.08,

t (24) = -11.793, p < 0.001.

A significant improvement was observed in lower extremities strength after 4 weeks of plyometric training.

- **Sargent Vertical Jump Test -**

The mean vertical jump height increased from 37.20 ± 3.249 cm (pre) to 41.52 ± 3.89 cm (post).
The paired t-test indicated a statistically significant improvement in vertical jump height of
t (24) = -17.294, p < 0.001
A significant improvement was observed in vertical jump height following the 4-weeks of plyometric training.

The Shapiro-Wilk tests confirmed normal distribution (p > 0.05)
The paired t-test confirmed that all variables increased significantly (p < 0.001)
Both lower extremities strength and vertical jump performance data met assumptions of normality, homogeneity, and reliability.

DISCUSSION

The present study aimed to determine the effect of a four-week plyometric training program on lower extremity strength and vertical jump performance among young amateur male football players aged 16 to 20 years. The study employed a pre–post quasi-experimental design, with assessments conducted using the 1 Repetition Maximum (1RM) Squat Test for lower limb strength and the Sargent Vertical Jump Test for vertical jump height. The analysis revealed a statistically significant improvement (p < 0.001) in both strength and vertical jump performance following the intervention, thereby supporting the alternative hypothesis that there will be significantly greater improvement in lower extremities strength and vertical jump performance from the baseline measure following 4 weeks of Plyometric Training program in young amateur male football players. These findings confirm the effectiveness of short-term plyometric training in enhancing neuromuscular performance parameters critical to football.

The study demonstrated a notable increase in absolute 1RM squat performance, with a mean gain of 6.92 kg, representing a statistically significant enhancement (p < 0.001). This improvement indicates that the four-week plyometric program successfully activated and strengthened the muscles of the lower limb, particularly the quadriceps, hamstrings, gluteal, and calf musculature. A football player needs a good amount of strength, especially in the lower limb which are the basic axis of efficacy in the game. It is one of the differentiating factors in achieving a high level in football. The strength gains can be attributed to the repeated Stretch-Shortening Cycle (SSC) actions involved in plyometric exercises, which promote both neural and muscular adaptations. Neural adaptations may include enhanced motor unit recruitment, improved synchronization of agonist and antagonist muscle groups, and elevated firing frequency of motor neurons, allowing for more efficient muscle activation. Although morphological changes may be limited within four weeks, early signs of increased cross-sectional muscle area and improved muscle-tendon unit elasticity could occur. These findings are aligned with Roy and Debnath (2023), who found that strength and plyometric training improved lower-limb strength parameters in football players, and Wee et al. (2023), who reported that short-term plyometric programs improved maximal leg strength and endurance in collegiate soccer players.
The mean vertical jump height improved by 4.32 cm, indicating a significant enhancement in the explosive power of the lower limbs (p < 0.001). Plyometric training enhances the muscle's ability to generate force quickly, thereby improving jump height. This improvement can be attributed to the training-induced optimization of the Stretch-Shortening Cycle (SSC), which enhances the efficiency of elastic energy storage and utilization during rapid eccentric-concentric muscle actions. This is achieved by improving the efficiency of the amortization phase of the SSC i.e., the brief transition between eccentric and concentric muscle actions. Efficient utilization of elastic energy and potentiation of the stretch reflex contribute to higher jump performance. These results are consistent with Idriss et al. (2022), who reported a significant increase in jump height among adolescent footballers after 10 weeks of plyometric training, and Turkarslan and Deliceoglu (2024), who found improvements in vertical jump and sprint performance after six weeks of training.

The current study's shorter intervention still produced meaningful results, suggesting that even brief but intense training cycles can stimulate rapid neuromuscular adaptation, particularly in developing athletes who may have untapped training potential. The observed increase in vertical jump also correlates with improved lower-limb force symmetry and coordination, both crucial in football-specific tasks such as heading, tackling, and rapid direction changes. Enhanced vertical jump ability thus indicates better functional transferability of training gains to on-field performance. Studies such as Eng Hoe Wee et al. (2023) and Firmansyah et al. (2024) reinforced that plyometric training, when integrated with regular football practice, yields improvements not only in jumping ability but also in speed, agility, and kicking power essential performance factors in football. The present research, focusing specifically on strength and vertical jump, provides complementary evidence that supports these multidimensional benefits. Comparative studies by Anversha and Ramalingam (2024) and Loukia et al. (2025) also support these findings, reporting significant gains in jump height and sprint performance following 4–6-week interventions.

Collectively, the present study corroborates existing evidence that short-term, high-quality plyometric programs are sufficient to produce meaningful neuromuscular adaptations, particularly in amateur athletes at a developmental stage.

The performance enhancements observed in this study can be attributed to several interrelated physiological mechanisms. Adaptations occur at both neurological and muscular levels. Repeated exposure to rapid eccentric–concentric transitions during plyometric exercises induces significant neuromuscular adaptations. This includes increased neural drive, improved motor unit synchronization, and reduced inhibitory feedback from Golgi tendon organs, all of which enhance the efficiency of force production and coordination of movement. Furthermore, the efficiency of the stretch-shortening cycle (SSC) improves, allowing greater storage and utilization of elastic potential energy within the tendons during dynamic movements. The mechanical behaviour of the SEC is a major contributor in the plyometric action. The SEC acts like a spring, where the energy release will be greater with higher forces. This process minimizes energy loss and increases propulsion efficiency, ultimately contributing to superior performance outcomes. Additionally, plyometric training enhances muscle–tendon unit stiffness, which promotes rapid force transfer and recoil which are the key factors in generating high power outputs during explosive activities such as jumping and sprinting. The training also facilitates selective recruitment and conditioning of Type II (fast-twitch) muscle fibers, leading to improvements in force and velocity capacities essential for explosive actions which translates into enhanced sprinting, tackling, and jumping abilities which are crucial performance elements in football. There are various reasons for the increase in maximum muscle strength due to plyometric training, including changes in muscle structure due to increase in muscle fascicle angle and fascicle length and changes in stiffness of various elastic components. The finding in this study is also supported by the principle of reversibility which states that an athlete can lose the effect if training when they stop and gain the effect when they start again.

Football is characterized by dynamic, high-intensity actions requiring repeated acceleration, deceleration, and rapid directional changes. Lower-limb power directly influences essential performance skills such as jumping for headers, sprinting, shooting, and defensive manoeuvres. The improvements observed in this study in lower extremities strength and vertical jump height indicate that incorporating structured plyometric exercises into football training can substantially enhance these performance parameters. Plyometric drills such as squat jumps, tuck jumps, and hurdle hops simulate the high-velocity, sport-specific actions encountered during gameplay. By strengthening neuromuscular coordination and reactive strength, these exercises can help young amateur football players execute explosive movements more efficiently. The resulting increase in jump height and leg strength may improve heading ability, sprint initiation, and positional stability, offering a competitive advantage on the field. Plyometric training not only enhances performance but also contributes to injury prevention by improving muscular control and dynamic stability during eccentric loading phases. This aligns with findings by Case et al. (2020), who linked higher relative squat strength with reduced lower-limb injury risk in collegiate athletes. Therefore, integrating plyometric exercises into regular football conditioning can simultaneously enhance performance and minimize injury incidence. Plyometric training can be one of the best boosts your body needs for staying in shape. Plyometric exercise responses are affected by several factors during childhood or adolescence, including the subjects age, gender, maturation status, body composition, physical fitness level, experience with plyometric drills, and plyometric training characteristics (intensity, number of foot contacts, frequency, resting time between sets, and recovery duration between training sessions).

Although the present study used a relatively short four-week intervention, the significant outcomes indicate that early-stage adaptation can occur rapidly, predominantly through neural rather than structural when exercises are performed consistently and with progressive overload. Similar short-duration studies (4–6 weeks) by Anversha and Ramalingam (2024) and Loukia et al. (2025) demonstrated meaningful improvements in jump and sprint performance among football and basketball players. However, other authors such as Idriss et al. (2022) and Moran et al. (2024) recommend training durations exceeding six weeks for more stable and long-lasting neuromuscular changes. According to Mokkedes Moulay Idris et al. (2022), extended interventions (≥6 weeks) elicit additional morphological adaptations, including increased muscle cross-sectional area and tendon stiffness. Thus, while this study captured the initial neuromuscular phase of adaptation, longer-term training would likely lead to compounded strength and endurance benefits. The principle of training specificity suggests that adaptations in a given physical capacity will occur if there is a high degree of similarity between an applied training stimulus and the intended outcome of that stimulus. In the case of adolescents, the development of lower limb explosive strength is influenced not only by training interventions but also by various other factors, with maturation being one of the primary determinants. Identical training interventions may yield different effects during different maturation stages in adolescents suggesting that training adaptations may vary across maturation periods. Biological maturation, which is the process of an individual progressing towards maturity, is one of the primary factors influencing these adaptations. This process differs in terms of timing and velocity and the maturation of different bodily systems is also asynchronous. The adolescent stage epitomizes a paramount epoch of intrinsic evolution, underscored by swift transformations and maturation within the body's neurological and physiological system. Specifically, adolescents in the pre-pubertal phase exhibit high neuro-muscular plasticity, while adolescents in mid-puberty experience significant increases in growth hormone and testosterone levels, which promote the development of muscle fibre types and muscle mass. These physiological and neurological developments can significantly impact training outcomes.

However, the level, rate, and timing of biological maturity vary among individuals. Furthermore, the observed variability in post-test outcomes suggests individual differences in adaptability, potentially influenced by baseline strength, muscle fibre composition, and training compliance. Absolute strength is affected by body mass and relative strength is typically greatest in lighter individual. Such differences highlight the importance of individualized load progression and technique supervision in optimizing outcomes and preventing overtraining risk.

Plyometric exercises such as squat jumps, lunge jumps, hurdle jumps, and side-to-side hops, etc are cost-effective, require, minimal equipment, and easily integrated into football training sessions. Plyometric exercises can be implemented within standard warm-up or conditioning sessions without additional infrastructure. Noticeable improvements can occur within four weeks, making plyometrics suitable for pre-season or mid-season conditioning cycles. When executed with proper technique and progressive loading, plyometric training is safe for young amateur football players. Gains translate directly into enhanced sprinting, jumping, and reactive abilities on the field. By adopting structured plyometric regimens, coaches can enhance their athletes' explosive power, agility, and overall match performance while minimizing injury risk.

The findings hold substantial practical relevance for physiotherapists, strength coaches, and sports trainers. The findings can serve as basis for the Physical Education teachers in prescribing appropriate exercises for the improvement of the students vertical jumping ability. It will help students recognize their physical capabilities, needs and limitations in the area of vertical jump, and utilize the prescribed intervention exercise to improve their vertical jumping ability and how this can be applied in their day-to-day activities. It will provide baseline information in the formulation of needs-based development plan of the physical education department. It can help provide research-based data to support the Physical Education Program in implementing appropriate sports programs. The findings would provide basis in creating effective programs and activities to help motivate the athletes and improve their performance. As such, the coaches would be able to come up with appropriate exercise program in enhancing specific skill, also it can help the parents in providing adequate and appropriate support in the area of training and conditioning for their children. The findings may serve as basis for future studies in terms of the intervention exercises using other components of fitness and profiling of fitness level. Due to widespread and growing popularity, many advanced nations have taken serious steps towards the scientific development and nurturing of youth football teams. These youth teams are considered the foundation for growth and prosperity of these popular sports. It has found that successful football players possess a unique talent, in addition to high level of physical fitness and proficient technical skills. Developing 'athleticism' is to maintain health, increase physical fitness ability, reduce injury risk, and enhance the confidence and competence of players for long term progression and development of youth players. The youth of today needs to be instructed on the proper time and method for learning new skills, "TIMING IS EVERYTHING", as said.

CONCLUSION

The results of this study clearly demonstrate the efficacy of a 4-week of plyometric training in significantly improving key athletic performance metrics in young amateur male football players. The analysis provides robust statistical evidence to firmly reject the null hypothesis of no improvement. The results revealed a substantial and statistically significant increase in absolute lower-extremity strength, with a mean gain of 6.92 kg in the absolute 1RM squat test. Furthermore, a critical improvement in relative strength was also observed, indicated by a mean increase of 0.11 kg per unit of body mass, which is essential for sports performance. Most notably, these strength gains translated into a direct and significant enhancement of functional power, evidenced by a mean improvement of 4.32 cm in the Sargent Vertical Jump test. The consistency of these findings is underscored by the exceptionally high statistical significance ($p < 0.001$) for all paired tests. The post-training data also suggested that while all participants benefited, the training elicited varied individual responses, leading to a wider dispersion of performance outcomes. Therefore, the alternative hypothesis is fully supported, confirming that plyometric training significantly improves lower extremities strength and vertical jump performance in young amateur male football players. In summary, this research validates the integration of plyometrics as a highly effective training methodology for the athletic development of young football players aged 16 – 20 yrs. Coaches and trainers should consider integrating plyometric training into their athletic development programs to exploit its benefits fully.

LIMITATIONS OF STUDY

Despite promising results, certain limitations must be acknowledged.

- The sample size (n=25) was relatively small and limited to a specific age group (16–20 years). This restricts the generalizability of the findings to players of different ages, training backgrounds, or competitive levels. Additionally, the gender composition of the sample was not balanced, which may limit the applicability of results across both male and female populations.

- The intervention lasted only four weeks, which may not be sufficient to fully capture the long-term physiological adaptations or retention of strength and power gains. Longer training durations could yield more robust and sustainable results.
- The absence of a control group limits the ability to attribute changes exclusively to plyometric training intervention. General maturation or concurrent football practice might have also influenced the observed changes.
- Environmental factors such as training surface, footwear, weather conditions, and participant motivation might have introduced uncontrolled variability. Minor deviations in exercise execution could also have affected the accuracy of performance data.
- Individual differences in adherence, effort levels, and recovery were not strictly monitored, potentially leading to inconsistencies in training intensity and performance outcomes.
- The study primarily focused on lower-extremity strength and vertical jump height, without examining related performance domains such as agility, endurance, or balance, which could provide a more holistic view of plyometric training benefits.

FUTURE SCOPE

- Future studies incorporating larger sample sizes, control groups, and extended training durations could provide a more comprehensive understanding of the long-term effects of plyometric training.
- Future studies could incorporate parameters such as agility, sprint speed, endurance, balance, and coordination to understand the holistic impact of plyometric training on overall athletic performance.
- Tracking participants over competitive seasons can reveal how plyometric adaptations translate to real-game performance and injury resilience during match play.
- Investigating effects in female players or pre-/post-pubertal athletes could help design age and gender appropriate plyometric protocols for safe and effective training.
- Integrating plyometric exercises with sport-specific football drills (e.g., kicking, dribbling, and change of direction tasks) could enhance functional transfer and real-game application.
- Exploring how plyometric training can be adapted for rehabilitation or injury prevention programs can expand its role beyond performance enhancement.
- Incorporating technology such as wearable sensors, force plates, and mobile applications in future research could allow for real-time feedback, data tracking, and individualized load monitoring.
- Further studies can explore combining plyometric training with strength, balance, or neuromuscular training approaches to optimize overall athletic performance

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