Lower Limb Plyometric Workouts: Effects on Explosive Strength, Balance, and Landing Strategies in Artistic Gymnastics

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Abstract:

This research aims to identify the effects of lower limb plyometric workouts on explosive strength, balance, and landing strategies on the floor exercise apparatus in artistic gymnastics. The researcher employed the experimental method with pre- and post-measurements of a single group, as this approach best suited the nature of the study. The researcher intentionally selected 10 junior artistic gymnasts as the main sample from those under 13 years old at Tala'ea El-Geish Club, registered with the Egyptian Gymnastics Federation during the 2024/2025 training season. In addition, 10 gymnasts were randomly chosen as an exploratory sample, representing the original community outside the main group, to determine the appropriate plyometric workouts related to the landing performance, and to standardize the training load for these workouts. The most important results were as follows: The improvement percentages in the physical variables ranged from 24.7% to 41.3%, with the highest gain observed in explosive strength at 41.3%. For the technical variables, improvement percentages ranged from 25.7% to 37.2%, with the most significant improvement seen in the (2nd Landing), reaching 37.2%. Additionally, the improvement in the technical routine under study reached 25.7%. The researcher recommends implementing plyometric workouts to improve physical variables, as well as landing strategies in artistic gymnastics.

Keywords: plyometric workouts, explosive strength, balance, landing strategies, artistic gymnastics.

Introduction and Research Problem:

Artistic gymnastics is a demanding sport that requires exceptional strength, balance, and motor control. Gymnasts must combine motor control, balance, and strength to perform elite routines, which demand precise postures and smooth movements on apparatus. In fact, developmental models highlight that before specializing, young athletes should first master basic movement skills and overall physical literacy (Ng et al., 2025). Gymnastics training can improve strength, balance, agility, and coordination, enhancing neuromuscular control. However, young gymnasts often develop side-to-side asymmetries—such as dominant leg flexibility and strength differences—due to repeatedly performing specific skills (Kafrawi et al., 2025).

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The landing strategy relies heavily on leg stiffness, which is primarily influenced by the segmental configuration at touch-down and neuromuscular activation. Regarding the neuromuscular component, stiffness regulation is achieved through the activation of agonist and antagonist muscles before ground contact (pre-activation), as well as during the braking phase (stretch reflex and voluntary response). Pre-activation plays a key role in the landing strategy, with the central nervous system controlling both its timing and amplitude. The magnitude and timing of anticipatory muscle activation before touch-down are affected by various factors, such as the subject's age, the specific muscle involved, the landing surface, and the individual's motor learning experience. Drop height is a debated factor that might influence preactivation, although most studies agree that preactivation increases as drop height increases (Christoforidou et al., 2017).

Landings in gymnastics are often performed with errors, ranging from minimal to significant, which can lead to injury. Common landing errors include inter-limb asymmetries, insufficient element height, inadequate hip flexion, and poor muscle pre-activation prior to ground contact. While improvements in physical conditioning and motor control are generally linked to better landing outcomes, the effectiveness of specific training methods may vary based on the gymnast's age and skill level. Further research is needed to determine which types of preparation are most effective for different groups (Silva et al., 2025).

Explosive strength is required early for gymnasts to learn the new target skills. As a result, there is a need to develop general strength capacity in gymnasts across their training career. and at all performance levels, as well as to produce more in-depth research on strength to assist the future development of gymnastics (Leite et al., 2023). Applying supplementary programs with plyometric, strength, and proprioceptive exercises is a valid way to increase gymnasts' jumping performance, even at young ages. The development of running and changing direction skills and Countermovement Jump (CMJ) performance can, in turn, improve gymnastics skills, increasing flight time. This improvement can also have positive implications for the athlete's long-term development (Korpová et al., 2025).

Lower limb muscular strength is an important performance parameter in gymnastics. The effects of training on muscular strength and jumping ability are pronounced. Adaptations to strength training are more variable, showing an initial spurt during the ages of 10–15 years, which is followed by a second period of rapid improvement during puberty and beyond. A more complex fitness component associated with muscular power, sprinting, balance, and motor coordination is the change of direction (COD) speed. Drills, including plyometric training, and COD, may be used as training tools, from a very young age, to develop general athleticism as well as physical qualities, such as muscular strength (Bogdanis et al., 2019).

In gymnastics skills, isometric force plays a critical role in the pre-activation of the muscle before a contraction of the stretch-shortening cycle (SSC). Isometric strength exercises, such as those used in core stability (CS) exercises, are innovative and highly effective in increasing muscle mass, toning, and developing strength levels to improve fitness and athletic performance. The spine provides essential stability to the body, support for body weight, and, most importantly, cushioning for jumps. In addition, the acceleration or deceleration of body segments in athletic performance depends upon the stability and strength of the core muscles that regulate the upper and lower extremities (Cabrejas et al., 2023).

Jumping is essential for gymnastics routines since this sport demands explosive strength. Gymnasts from various disciplines use these skills for particular purposes. Artistic gymnasts consider the jump one of the three main body elements, alongside balances and rotations. The jump height must be sufficient to display the shape of the jump, execute technical elements correctly, and avoid heavy landings. In Gymnastics, athletes perform balance and dynamic elements. To execute dynamic exercises effectively, ensuring the flight phase reaches the required amplitude, according to the official code of points (Leite et al., 2023).

Plyometric training (PT) improves athletes' explosive strength and jumping ability. PT is intended to enhance muscle force and power production through the SSC of the muscle unit to maximize power production. The SSC is characterized by a rapid transition between the initial eccentric "stretch" and subsequent concentric "recoil". Typically, PT involves exercises such as vertical jumps and box jumps that demand slower SSC or, on the other hand, bounding, repeated hurdle hops, and drop jumps, which call for a faster SSC. However, previous studies have suggested that PT effectively improves physical abilities, such as adult rhythmic gymnasts' explosive strength of the lower limbs, and authors found an improvement in jump performance and evaluated RG leap ability after a month of training combining Pilates and water resistance plyometrics (Cabrejas et al., 2023).

Through the researcher's work in the field of gymnastics, and continuous communication with the technical staff of Tala'ea El-Geish Club, Through the evaluations of the players' results in the republic championship, and through the technical analysis of the performance in competitive situations, the researcher noticed a deficiency in the level of technical performance of some landing strategies under study, The researcher also noticed the recurrence of technical errors by players when performing the landing strategies after skills under study. The research problem appeared when the researcher noticed a varying defect in the player's inability to maintain stability when landing on the mat, negatively affecting the player's total score. The deductions for formal errors in performance range between (0.1 - 0.3 - 0.5) degrees, depending on the type of error. The deduction may reach (1 full degree) if the player loses his balance and falls while performing the landing stage of the skills.

The researcher assumes that this problem is due to the player's inability to maintain balance when landing on the mat, the gymnasts' inability to reduce collisions with the mat while landing after performing the skills, in this case, the researcher assumes that the player needs to develop his explosive strength of the lower limb muscles using the plyometric workouts, the explosive strength acts as a reaction to resist the force resulting from the collision with the mat.

Gymnasts use this technique to perform jump difficulty elements, followed by a soft and safe landing. take advantage of the impulse to jump, incorporating somersaults and twists, and finishing with a safe landing. Accordingly, most gymnastics skills begin with a powerful takeoff, then a flight to perform the main stage, and finally a landing. jumping performance differs between the start and finish of the skill. We must focus on the relationship between the jump height achieved and the gymnasts' ability to equalize the force resulting from the rebound from the mat, while landing after performing the skills.

Through the researcher’s follow-up to the tremendous development in training methods, to develop explosive strength for lower limb muscles, the researcher believes that using a plyometric workout, which is directly linked to the technical performance of the landing phases under study, the researcher assumes that by increasing explosive power, the player will be more stable in the landing strategies under study, because his lower limb muscles will better resist the force resulting from the collision with the mat.

By reviewing the studies on artistic gymnastics, the researcher noted a scarcity of training programs using plyometric workouts, especially landing skills under study. This requires conducting an experimental study to develop explosive strength, balance, and technical performance of landing strategies under study.

Therefore, the researcher designed and standardized a set of plyometric workouts to identify their effect on developing explosive strength, balance, and the technical performance of landing strategies under study.

Research Aims:

- Developing explosive strength and balance for junior gymnasts, under study.
- Developing the landing strategies in artistic gymnastics under study.

Research Hypotheses:

- There are statistically significant differences between pre- and post-measurements of the experimental group in explosive strength and balance under study in favor of the post-measurement.
- There are statistically significant differences between pre- and post-measurements of the experimental

group in the landing strategies in artistic gymnastics under study in favor of the post-measurement.

Research Terms:

- Plyometric training (PT) is a commonly employed method to enhance explosive strength, sprinting, and the ability to change directions (Zhang et al., 2025a). It is also widely used to enhance lower limb strength and explosive power (Nath et al., 2025).

Methods

Research Methodology:

* The researcher used the experimental method, using the experimental design of one group and making two measurements (pre-post).

* Spatial Domain: Gymnastics hall - Talaie El-Geish club - Cairo - Egypt.

* Time Domain: The exploratory study was conducted from Wednesday, Jan 1, 2025, to Wednesday, Jan 8, 2025, and the pre-measurement was conducted on Friday, Jan 10, 2025. The basic study was conducted from Sunday, Jan 12, 2024, until Thursday, April 3, 2025, and the post-measurement was conducted on Saturday, April 5, 2025.

* Research Sample: The researcher intentionally selected 10 junior artistic gymnasts as the main sample from those under 1٣ years old at Tala'ea El-Geish Club, registered with the Egyptian Gymnastics Federation during the 2024/2025 training season. In addition, 10 gymnasts were randomly chosen as an exploratory sample, representing the original community outside the main group, to determine the appropriate plyometric workouts related to the landing performance, and to standardize the training load for these workouts.

The researcher calculated the equivalence of the distribution of the research sample individuals in growth rates (age - height - weight - training age), as well as the equivalence of the distribution of individuals in the physical variables under study, and also the landing performance in artistic gymnastics for junior artistic gymnasts under 13 years old. This is statistically evident from Tables Nos. (1), (2), and (3).

Statistical description of the sample

Table (1)
Statistical description of growth rate variables (Height - Weight - Age - Training Age) (n=10)

		Statistical data Variables	Measuring unit	Mean	Standard deviation	Median	Coefficient of torsion
Growth rates	1	Tall	Cm	145.8	1.475	146	-0.406
	2	Weight	Kg	41.61	1.065	41.9	-0.816
	3	Age	Year	12.48	0.282	12.45	0.319
	4	Training age	Year	8.34	0.222	8.35	-0.135

Table (1) shows that the torsion coefficient values for each growth rate variable studied ranged from (-0.816 to 0.319). These values were within the range of (±3), indicating that the growth rates of the individuals in the sample were moderated before the experiment.

Table (2)
Statistical description of physical variables (n = 10)

Physical Variables	Test	Measuring unit	Mean	Standard deviation	Median	Coefficient of torsion
Explosive Strength	Sargent test	cm	38.1	1.663	38.5	-0.721
	Long jump	cm	137.7	1.888	137.5	0.3177
Dynamic Balance	Press Balance	degree	7.57	0.637	7.9	-1.552
	Bass test	degree	77.33	2.44	75.75	1.942
Static Balance	Stork Stand	s	16.86	1.692	16.55	0.549

Table (2) shows that the torsion coefficient values for each of the physical variables under study ranged from (-1.552 to 1.942). These values were within the limit of (±3), indicating moderation of the physical variable values for the sample individuals before the experiment.

Table (3)
Statistical description of technical variables (n = 10)

Technical Variables		Measuring unit	Mean	standard deviation	Median	Coefficient of torsion
1st Landing	Landing after a forward somersault straight	degree	1.71	0.428	1.65	0.420
2nd Landing	Landing after a forward somersault tucked	degree	1.91	0.296	1.85	0.607
3rd Landing	Landing after a back somersault straight	degree	1.51	0.486	1.25	1.603
4th Landing	Landing after a back somersault tucked	degree	1.67	0.442	1.5	1.153
Technical Routine		degree	11.68	0.722	11.6	0.332

Table (3) shows that the coefficient of torsion values for each of the technical variables under study ranged between (0.420 and 1.603). These values were limited between (±3), which indicates the moderation of the values for the technical variables of the sample individuals under study before the experiment.

Means of collecting data:

The researcher used the following means:

- Means of collecting data related to anthropometric measurements:

The scientific references, research, and previous studies in gymnastics training and some other sports identified the means and data collection tools appropriate to the study's nature. The researcher has used the following tests, measures, and devices:

- A stadiometer device to measure the body height to the nearest 1cm.
- The medical scale device to measure the player's weight up to the nearest 1kg.

- Means of collecting data related to physical variables under study:

Physical variables tests under study attachment (5) (Allawi & Radwan, 2017).

- Sargent test (to measure the explosive strength of leg muscles) in the vertical direction.
- Long jump from stability test (to measure the explosive strength of leg muscles) in the horizontal direction.
- Modified Bass Test (to measure dynamic balance).
- Press Balance test standing on the arms with force (to measure dynamic balance).
- Stork Stand (Static Balance test). (Hassanein, 2015).

- Means of collecting data related to the technical variables under study:

The technical variables under study were recorded using a "video camera." The videos were shown to four arbitrators accredited by the Egyptian Gymnastics Federation (EGF) to assess the landing performance under study. Each arbitrator assigns a score that reflects the skill level of the technical variables for each player in the sample. The highest and lowest scores are discarded, and the player's final score is the average of the two middle scores.

Subjective evaluation is a type of assessment that does not depend on standards, norms, or criteria but rather on the experiences of the evaluators (arbitrators). Subjective evaluation is used in many sports activities, especially gymnastics in all its branches, diving, and water ballet, where unified international legal conditions are established and agreed upon among the arbitrators to achieve the highest possible degree of objectivity in evaluation (Khalil, 2020) & (Hassanein, 2015).

Table (4)
Technical routine on the floor exercise apparatus (stage 13 years)

	Technical Skills	difficulty
1	Running in 2-3 steps, a one-legged forward handspring, followed immediately by a forward handspring, followed immediately by a piked or forward somersault stretched. The ability of motor connection	0.1 0.2 0.3 0.2
2	A forward tucked somersault Immediately followed by a forward somersault tucked. The ability of motor connection	0.2 0.2 0.2
3	Passing a handstand and landing in a piked roll, powering up from a foot stand to a handstand and holding for 2 seconds (press balance piked), changing direction 180 degrees (double change), landing backwards (back roll), passing a handstand and changing direction 360 degrees (full twist), landing on the feet and changing direction. The ability of motor connection	0.2 0.2 0.1
4	Lie face down and then perform 2 flenks or 2 Thomas	0.2
5	V-support Hold 2 seconds. If the gymnast performs a V-support or mana followed by a force rise (Press Balance) or a piked Forward Roll, the gymnast receives 0.3 benefits.	0.2
6	Run 2-3 steps to perform a (roundoff), followed by a backflip (back dive), then take off to perform a back somersault stretched. (If the gymnast performs a back somersault tucked, he receives only half the difficulty). The ability of motor connection	0.1 0.3 0.2
7	Changing direction from a standing start, pushing off with the feet to perform a round-off, followed by two back dives, followed by a back somersault tucked. The ability of motor connection	0.2 = 0.1/for each back dive 0.2 – 0.2
	D.Score	3.5

)FIG, 2025(&)EGF, 2025(

Selecting the assistants:

The Exploratory Study:

The exploratory study was conducted in the period from Wednesday, Jan 1, 2025 to Wednesday, Jan 8, 2025, on a sample of (10) artistic gymnasts, randomly selected from junior gymnasts under 13 years-old, who are registered with the Egyptian Gymnastics Federation in the 2024/2025 training season, in Tala'ea El-Geish club, representative of the original community and outside the main research sample, the pre-measurement was conducted on Friday, Jan 10, 2025.

This exploratory study focused on:

- Ensuring the safety of the proposed plyometric workouts.
- Training assistants to take measurements and perform tests according to specified conditions.
- Selecting and testing plyometric workouts to assess their compatibility

with the technical variables under study.
- Adjusting training load variables for the plyometric workouts under study.
- Conducting scientific validation of the tests used (validity and reliability) and confirming their suitability for the research sample.
- Identifying the optimal camera angle to evaluate the skill performance of the technical variables under study.

The Exploratory Study resulted in ensuring that all objectives were met and that the proposed plyometric workouts were appropriate for the sample's age. The members of the exploratory sample completed the exercises without any difficulties, which enabled the researcher to implement these exercises with the main research sample.

• Scientific Transactions:

Validity coefficient:

The researcher calculated the validity coefficient using the validity differentiation method between two groups: one with five distinguished and the other with five less distinguished, both from the same research community and outside the basic research sample. This was done to determine the validity coefficient of the physical and technical tests under study, as shown in Table No. (5).

Table (5)

Differentiation validity of physical and technical tests under study (n1=n2=5)

Variables		Test	Measure unit	distinguished group		less distinguished group		Subtract averages	(T) value	(Z) value
				Mean	St.D.	Mean	St.D.			
Explosive Strength	1	Sargent test	cm	39.40	0.547	36.80	1.303	2.6	3.833*	2.660*
	2	Long jump	cm	139.20	1.30	136.20	0.836	3.00	3.586*	2.635*
Dynamic Balance	3	Press Balance	degree	8.04	0.194	7.10	0.570	0.94	4.451*	2.371*
	4	Bass test	degree	79.26	1.99	75.38	0.277	3.88	3.953*	2.627*
Static Balance	5	Stork Stand	s	18.14	1.262	15.58	0.870	2.56	2.707*	2.611*
1st Landing	6	arbitrators	degree	2.06	0.251	1.36	0.207	0.70	3.545*	2.619*
2nd Landing	7	arbitrators	degree	2.16	0.167	1.66	0.114	0.50	5.967*	2.627*
3rd Landing	8	arbitrators	degree	2.00	0.316	1.18	0.083	0.82	6.833*	2.305*
4th Landing	9	arbitrators	degree	2.02	0.327	1.32	0.164	٠.70	8.367*	2.530*
Technical Routine	10	arbitrators	degree	12.26	0.403	11.10	0.412	1.16	5.493*	2.619*

Tabular T value at a significant level of 0.05 = 1.860 on one side * = significant
* Tabular value (Z) at the level of 0.05 = ± 1.96

Table (5) shows that by applying the "T" test to calculate the significance of differences between two independent groups, one distinguished and the other less distinguished, the calculated "T" values, which ranged between (2.707 and 8.367), are greater than the tabular "T" value at a significant level. (0.05), which amounted to (1.860). Also the calculated values of (Z) for the variables under study have ranged between (-2.305 and -2.660) and these values are not limited to (± 1.96), which indicates that there are statistically significant differences between the two groups in favor of the distinguished group, which confirms the validity of the tests under study in what they were designed to measure, and that they can differentiate between the distinguished and less - distinguished players of the same age group.

Reliability Coefficient:

The reliability coefficient was determined by applying and reapplying the test (Test—Retest) for the physical and technical tests under study. The first application of the tests was conducted on Wednesday, Jan 1, 2025, on a sample of (10) players, while the second application took place on Wednesday, Jan 8, 2025, with an interval of (6) days between the two applications. Moreover, the correlation coefficient between them is calculated, as shown in Table No. (6).

Table (6)

Reliability coefficient of physical and technical tests under study (n=10)

Variables		Test	Measure unit	TEST		RE-TEST		Correlation Coefficient(r)
				Mean	St.D.	Mean	St.D.	
Explosive Strength	1	Sargent test	cm	38.1	1.663	39.00	1.632	0.969*
	2	Long jump	cm	137.70	1.888	139.70	1.828	0.646*
Dynamic Balance	3	Press Balance	degree	7.570	0.637	7.860	0.585	0.956*
	4	Bass test	degree	77.33	2.44	81.79	1.944	0.756*
Static Balance	5	Stork Stand	s	16.86	1.692	19.13	0.871	0.758*
1st Landing	6	arbitrators	degree	1.71	0.428	2.06	0.397	0.836*
2nd Landing	7	arbitrators	degree	1.91	0.296	2.17	0.362	0.795*
3rd Landing	8	arbitrators	degree	1.51	0.486	1.95	0.450	0.650*
4th Landing	9	arbitrators	degree	1.67	0.442	2.03	0.326	0.769*
Technical Routine	10	arbitrators	degree	11.68	0.722	12.22	0.545	0.782*

Tabular value "r" at the level of significance 0.05 = 0.564 on one side * = significant

Table (6) shows that the “r” values for the physical, functional, and technical tests ranged from (0.646 to 0.969), which are higher than the tabular “r” value of (0.564) at the (0.05) significance level. This indicates a statistically significant correlation between the test and retest, confirming the reliability of the tests under study.

Basics of designing the program

* Identify the primary muscles involved based on the landing performance in artistic gymnastics: The muscles responsible for about 90% of landing are located in the lower body. include the glutes, quads, hamstrings, and calves. Muscle activity occurs in three stages: hip, knee, and ankle (FIG, 2025).

Suggested lower limb plyometric workouts:

* The researcher applied a group of lower limb plyometric workouts attachments (6) corresponding to the motor pathway of landing performance under study to develop the mentioned working muscles.

* The researcher also considered, when designing these plyometric workouts, the following:

- Paying attention to the anatomical position of the body during exercises.
- Including the technical stages of the skill or some of its parts.
- Simulating the actual performance of landing skills in terms of force exerted.
- Analyzing plyometric workouts to determine the training load variables for each exercise.
- Using gradual, varied exercises, progressing from easy to difficult and simple to complex.

• Training load variables for the proposed plyometric workouts:

The researcher has codified the training load variables for the proposed plyometric by reviewing previous and related studies, specialized references, sports training science sources, and the international information network. Attachment (7)

• Intensity: The researcher relied on calculating pulse rates to determine the training load's intensity using the Carvonein equation to find the Target Pulse Rate (TPR): TPR = resting pulse rate + target load intensity × (heart rate reserve).

Table (7)
Intensity Percentage

load levels	Percentage	Pulse Rate
Medium	50 to 74 %	130 to 150 p/m
high	75 to 84 %	150 to 170 p/m
Maximum	85 to 100 %	170 to 200 p/m

The researcher observed the gradual increase in intensity by carefully adjusting the variables. The training loads were planned and scheduled throughout the training weeks, with appropriate load levels applied during the training period.

• Volume, (Repetitions – Sets):

The main part of the training session was plyometric workouts. Each exercise lasted 20-30 seconds at high intensity, followed by 10-15 seconds of active rest. The exercises were repeated for 3-5 sets. Performing four sets of each exercise took about 2 minutes. Rest periods were taken after each exercise, with a 1-minute break in between, resulting in a total session duration of 20-40 minutes.

Rest Periods: Set the proper rest time between exercises based on plyometric workouts, which involve 20–30 high-intensity seconds of exercise followed by 10–15 seconds of active rest.

Plyometric workout duration:

• The plyometric workouts lasted 12 weeks, with 3 sessions per week.

• The researcher set the duration for each weekly session, averaging between 90 and 120 minutes, to account for fluctuations in load between sessions.

• Each plyometric training lasted between 20 and 40 minutes per session. The load intensity varied from medium to high and maximum.

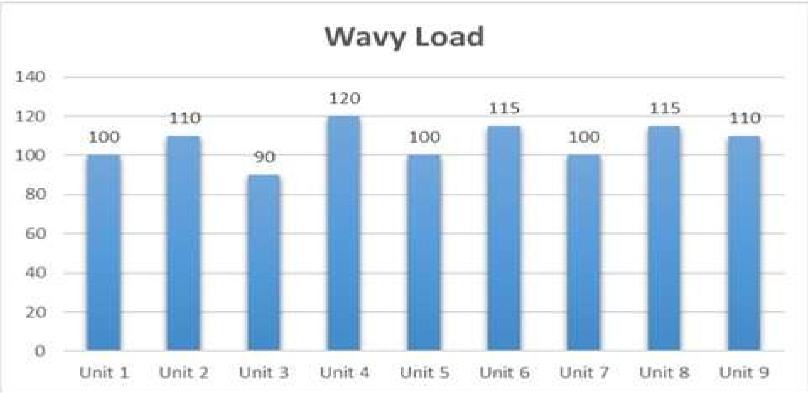

Figure 1. Wavy Load of Training Sessions

The distribution of training load levels over the training weeks during the stages of the training program is moderate load between 50% and 74%, high load between 75% and 84%, and maximum load between 85% and 100%.

• Stages of applying plyometric workouts:

Table (8)
Stages of applying plyometric workouts

Stages	Weeks	Units/ week	session time	Load Cycle
1st stage	3	3	90 to 120 minutes	1 to 2
2nd stage	4			
3rd stage	5			

Training methods: The researcher employed High-Intensity Interval Training. Training Load Cycle: The training load cycle per session was selected using the training load (1 to 2) method, meaning a medium load for one session, followed by a high load in the subsequent two sessions.

Basic study: The study was conducted from Sunday, Jan 12, 2024, to Thursday, April 3, 2025. The post-measurement took place on Saturday, April 5, 2025, and the pre- and post-technical performance was recorded in the gymnastics hall of Talaie El-Geish club, as shown in the time distribution table of the research application, attachment (10).

The main research sample performed plyometric workouts during the physical preparation phase of the training program. Exercise durations ranged from 80 to 160 minutes per week over 12 weeks, with 3 weekly training sessions.

Table (9)

Axes of the plyometric workouts

	Axes	**Content**	
1	program duration	12 weeks	
2	Number of training units in the program	36 training sessions	
3	Number of training sessions per week	3 training sessions	
4	training session time	(90 - 120) minutes	average 105 minutes
5	plyometric workouts time by session	(20 - 40) minutes	average 30 minutes
6	Total program time	3,780 minutes	100%
7	General physical preparation time	1,814.4 minutes	48% of the total time
8	Private physical preparation time	2,419.2 minutes	64% of physical preparation
9	Plyometric workouts time in the program	1,137.02 minutes	47% of private preparation
10	Technical preparation time in the program	1965.6 minutes	52% of the total time
11	Training load degrees used	Medium - High - Max	
12	Training load weekly cycle	(1 - 2)	
13	Number of plyometric workouts	(86) exercises	

Statistical Treatments: The researcher used the program (Statistical Package for Social Sciences) (SPSS v25), applying the following statistical parameters: Mean, Standard Deviation, Correlation Coefficient, T-test, Wilcoxon test, and Improvement Percentage.

RESULTS:

Presenting results of the first hypothesis:

Table (10)

Significance of differences between pre- and post-measurements for the experimental group in the physical variables under study (n = 10)

Physical Variables	Test		Measure unit	Pre mean	Post mean	Positive ranks		Negative ranks		(Z) Value
						Mean rank	Sum of ranks	Mean rank	Sum of ranks	
Explosive Strength	1	Sargent test	cm	38.10	53.82	5.5	55	0.00	0.00	- 2.803 *
	2	Long jump	cm	137.70	186.30	5.5	55	0.00	0.00	- 2.812 *
Dynamic Balance	3	Press Balance	degree	7.57	9.44	5.5	55	0.00	0.00	- 2.818 *
	4	Bass test	degree	77.33	99.82	5.5	55	0.00	0.00	- 2.805 *
Static Balance	5	Stork Stand	s	16.86	22.30	5.5	55	0.00	0.00	- 2.807 *

* Tabular value (Z) at the level of 0.05 = ± 1.96

Table (10) shows that the calculated (Z) value for each physical variable under study ranged from (-2.818 to -2.803). These values are outside the range of (± 1.96), indicating statistically significant differences. At the (0.05) significance level for the variables studied, there is a significant difference between the pre- and post-measurements of the experimental group in favor of the post-measurement.

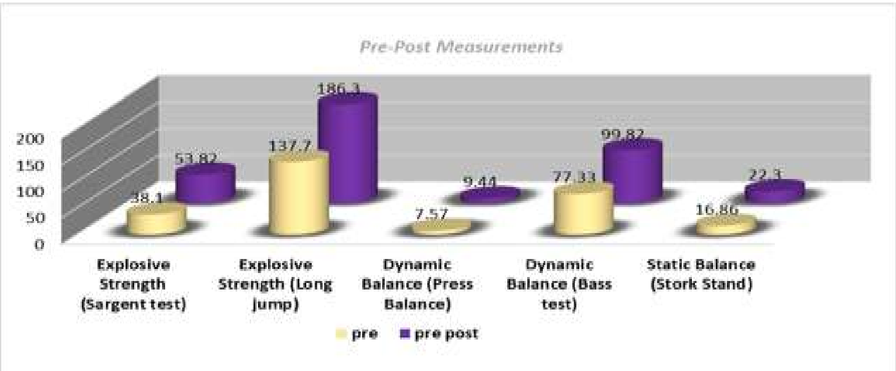

Figure 2. Significance of differences between pre- and post-measurements of the experimental group's physical variables under study.

Table (11)
Improvement percentage of the experimental group in the physical variables under study

Physical Variables		Test	Measure unit	Pre mean	Post mean	Means Difference	Improvement Percentage
Explosive Strength	1	Sargent test	cm	38.10	53.82	15.72	41.3%
	2	Long jump	cm	137.70	186.30	48.60	35.3%
Dynamic Balance	3	Press Balance	degree	7.57	9.44	1.87	24.7%
	4	Bass test	degree	77.33	99.82	22.49	29.1%
Static Balance	5	Stork Stand	s	16.86	22.30	5.44	32.3%

Table (11) shows that the experimental group's improvement percentages in the physical variables studied ranged from (24.7% to 41.3%). The highest improvement was explosive strength at (41.3%), while the lowest was dynamic balance at (24.7%). The improvement rates for the other variables fell between these two values.

Figure 3. Percentage of improvement in the physical variables under study.

Presenting results of the second hypothesis:

Table (12)
Significant differences between pre- and post-measurements of the experimental group in technical variables under study. (n = 10)

Technical Variables		Test	Measure unit	Pre mean	Post mean	Positive ranks: Mean rank	Positive ranks: Sum of ranks	Negative ranks: Mean rank	Negative ranks: Sum of ranks	(Z) Value
1st Landing	1	arbitrators	degree	1.71	2.33	5.5	55	0.00	0.00	- 2.675 *
2nd Landing	2	arbitrators	degree	1.91	2.62	5.5	55	0.00	0.00	- 2.670 *

Follow Table (12)
Significant differences between pre- and post-measurements of the experimental group in technical variables under study. (n = 10)

Technical Variables	Test		Measure unit	Pre mean	Post mean	Positive ranks		Negative ranks		(Z) Value
						Mean rank	Sum of ranks	Mean rank	Sum of ranks	
3rd Landing	3	arbitrators	degree	1.51	1.96	5.5	55	0.00	0.00	-2.199 *
4th Landing	4	arbitrators	degree	1.67	2.20	5.5	55	0.00	0.00	-2.199 *
Technical Routine	5	arbitrators	degree	11.68	14.68	5.5	55	0.00	0.00	-2.818 *

* Tabular value (Z) at the level of 0.05 = ± 1.96

Table (12) shows that the calculated values of (Z) for the technical variables under study ranged between (-2.818 and -2.199). These values are not limited to (± 1.96), indicating statistically significant differences. The means of the experimental group's pre- and post-measurements favor the post-measurement at a significance level of (0.05) for the technical variables under study.

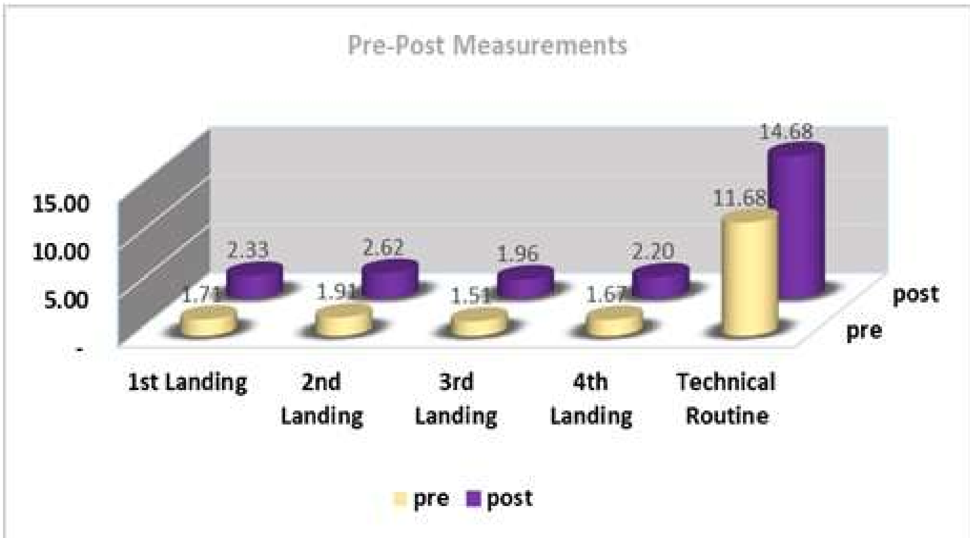

Figure 4. Significant differences between pre- and post-measurements of the experimental group in the technical variables under study.

Table 13
Improvement percentage of the experimental group in the technical variables under study

Technical Variables	Test		Measure unit	Pre mean	Post mean	Means Difference	Improvement Percentage
1st Landing	1	arbitrators	degree	1.71	2.33	0.620	35.3 %
2nd Landing	2	arbitrators	degree	1.91	2.62	0.710	37.2 %
3rd Landing	3	arbitrators	degree	1.51	1.96	0.450	29.8 %
4th Landing	4	arbitrators	degree	1.67	2.20	0.530	31.7 %
Technical Routine	5	arbitrators	degree	11.68	14.68	3.00	25.7 %

Table (13) shows that the improvement percentage of the experimental group in the technical variables under study ranged from (25.7% to 37.2%). The highest improvement was in 2nd Landing at (37.2%), and the lowest was in technical routine at (25.7%).

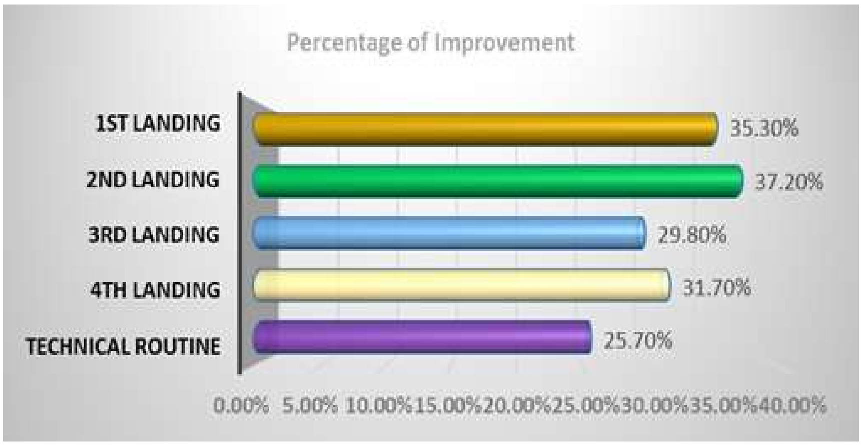

Figure 5. Improvement percentage of the experimental group in the technical variables under study.

Discussion"

Discussion results of the first hypothesis:

Which states, "There are statistically significant differences between pre- & post-measurements of the experimental group in explosive strength and balance under study in favor of the post-measurement."

It is clear from Table No. (10) and Figure No. (2) that there are statistically significant differences at the level (0.05) between the pre- and post-measurements of the experimental group in favor of the post-measurement in explosive strength and balance under study. The tabular (Z) value at the 0.05 level was (±1.96). In contrast, the calculated (Z) values for the physical variables ranged between (-2.818, -2.803), and all of these values are less than (-1.96). This means they are not within the range of (± 1.96), indicating the presence of statistically significant differences between the pre- and post-means of the experimental group in favor of the post-measurement at a significance level of (0.05) for the physical variables studied. The researcher attributes these results to the effect of the plyometric workouts and the consistency of weekly training for 12 weeks, at a rate of 3 sessions per week.

It is also evident from Table No. (11) and Figure No. (3) There are statistically significant differences between the pre- and post-measurements of the experimental group in favor of the post-measurements in the physical variables under study. The percentage of improvement ranged from (24.7% to 41.3%), highest improvement was explosive strength at (41.3%), while the lowest was dynamic balance at (24.7%). The improvement percentages of the remaining variables fell within this range.

Variables of explosive strength and balance under study. These workouts featured specific goals and diverse, engaging methods that motivate the gymnasts. The researcher considered the codification of training loads based on the gymnasts' capabilities, considering individual differences and gradual progression during implementation. Rest periods were adjusted to allow the body's systems to adapt, and the principle of specificity in training was applied, considering the nature of muscular activity work

The researcher attributes these statistically significant differences in the studied physical variables to the applied plyometric workouts, which are well designed to achieve the research aims. The training load variables during the plyometric workouts performed in the main part of the training session are shown in Appendix (6). Each exercise lasted 20-30 seconds at high intensity, followed by 10-15 seconds of active rest. The exercises were repeated for 3-5 sets. Performing four sets of each exercise took about 2 minutes. Rest periods were taken after each exercise, with a 1-minute break in between, resulting in a total session duration of 20-40 minutes.

Gymnastics is regarded as one of the most difficult techniques, requiring high levels of strength, balance, flexibility, and grit. Gymnastics is a year-round sport requiring early specialization. Competitive gymnasts train more than 15 h/week, with elite and collegiate levels training 25–40 h/week, leading to hundreds of skills performed each practice. Therefore, there is great importance of muscular strength training (Ng et al., 2025).

plyometric workouts (PW) significantly improve leg explosive strength. These findings underscore the effectiveness of plyometric exercises in stimulating neuromuscular adaptations resulting in increased power production and explosive strength. Encourage greater recruitment of fast-twitch muscle fibers and improve the efficiency of stretch-shortening cycles. Significant improvements in lower limb explosive strength after plyometric workouts that emphasize vertical and lateral jumping movements. In addition, the substantial increase in motor and static balance observed highlights that plyometric training not only improves muscle strength but also balance, endurance, and flexibility, which contribute to overall athletic performance. It also concurred with the findings of the following studies (Luo et al., 2025), (Zheng et al., 2025), (Matuszczyk et al., 2025), (Putera et al., 2025), (Shuai et al., 2025).

The dynamic balance under study shows an improvement percentage ranging from 24.7% to 29.1%. Meanwhile, the static balance improves by 32.3%. The researcher also attributes these statistically significant differences which was due to the positive effect of 12 weeks of plyometric workouts, strengthening the lower limb muscles and increasing the player's ability to react positively to collisions with the mat during landing. It also concurred with the findings of the following studies (Yuan et al., 2025), (Zhang et al., 2025b), (Guo & Xu, 2025), (Yan et al., 2025), (Kons et al., 2023).

Plyometric training could activate the mechanical or proprioception receptors on the foot or tendon ligaments around the ankle joint (Yan et al., 2025). This may explain the improved dynamic balance observed in our study due to enhanced ankle joint reposition sense, suggesting that additional strength training is necessary to achieve the benefits of dynamic balance (Guo & Xu, 2025).

Based on the results above, the first hypothesis has been confirmed: "There are statistically significant differences between pre- and post-measurements of the experimental group in explosive strength and balance under study in favor of the post-measurement."

Discussion results of the second hypothesis:

Which states: “There are statistically significant differences between pre- and post-measurements of the experimental group in the landing strategies in artistic gymnastics under study in favor of the post-measurement.”

It is clear from Table No. (12) and Figure No. (4) that there are statistically significant differences at the 0.05 level between pre- and post-measurements of the experimental group, favoring the post-measurement in the technical variables under study. The tabular (Z) value at the 0.05 significance level was (±1.96). Conversely, the calculated (Z) values for the technical variables under study ranged between (-2.818 and -2.199), all less than (-1.96). This indicates significant differences between the pre- and post-measurement means at the

(0.05) significance level in favor of the post-measurement.

As shown in Table No. (13) and Figure No. (5), there are statistically significant differences at the 0.05 level between pre- and post-measurements of the experimental group, favoring the post-measurement in the studied technical variables. The percentage of improvement ranged from (25.7% to 37.2%). The average 1st Landing in the pre-measurement was (1,71) degrees, while the post-measurement increased to (2.33) degrees, indicating a (35.3%) improvement. Additionally, the average 2nd Landing in the pre-measurement was (1,91) degrees, increasing to (2.62) degrees post-measurement, reflecting a (37.2%) improvement. The average 3rd Landing in the pre-measurement was (1,51) degrees, which increased to (1.96) degrees after the intervention, showing a (29.8%) improvement. The average 4th Landing in the pre-measurement was (1,67) degrees, rising to (2.20) degrees post-measurement, demonstrating a (31.7%) improvement. Finally, the average of the technical routine in the pre-measurement was (11,68) degrees, increasing to (14.68) degrees after the intervention, representing a (25.7%) improvement.

The researcher attributes the positive effects on the technical variables under study to the positive effects of the various plyometric workouts, since the researcher used the same type of muscle work and ensured that the physical preparation engaged the same motor pathways for the technical variables under study. Developing physical qualities through a muscle work method similar to technical performance is considered one of the best training approaches for enhancing skills. (Alhenawy, 2024). The skill level of a gymnast mainly depends on their physical abilities, which help them meet the requirements of performing new skills (Al-Hadi, 2016); (Shehata, 2018).

Jumping ability, an essential part of gymnastics performance, is linked to successful execution and is sometimes seen as an overall indicator of gymnastics proficiency. Therefore, coaches should consider the sport's specificity and individual athletes' adaptations, creating conditions for gymnasts in all disciplines to improve their physical abilities, especially those identified as key performance factors. This reflects the importance of applying plyometric workouts to improve the technical performance in gymnastics (Passacantando et al., 2025); (Leite et al., 2023).

Gymnasts use this technique to perform jump difficulty elements, followed by a soft and safe landing. take advantage of the impulse to jump, incorporating somersaults and twists, and finishing with a safe landing. Accordingly, most gymnastics skills begin with a powerful takeoff, then a flight to perform the main stage, and finally a landing. jumping performance differs between the start and finish of the skill. We must focus on the relationship between the jump height achieved and the gymnasts' ability to reduce collisions with the mat while landing after performing the skills.

That could lead to variations in jumping skills (Leite et al., 2023).

Plyometric workouts could activate the mechanical or proprioception receptors on the foot or tendon ligaments around the ankle joint (Yan et al., 2025). This may explain the improved dynamic balance observed in our study due to enhanced ankle joint reposition sense, suggesting that additional strength training is necessary to achieve the benefits of dynamic balance (Cabrejas et al., 2023). This clearly explains the reasons for improving the landing performance after using plyometric workouts under study.

Landing performance involves using actual gymnastic-specific skills, including saltos, during the completion of drop landing tasks. Drop land assessments have been used to examine impact forces and injury risk in other groups, such as those with ACL injuries. This study will use drop land from a box as an assessment method to recreate the rapid impact forces bilaterally experienced by the lower limbs during landing tasks. The task will be modified to include a mid-air 180-degree rotational turn as the gymnast completes the drop land task, reflecting the airborne rotation around the transverse axis, which is relevant to how a gymnast lands during competition or training (Glynn et al., 2022).

Landings in gymnastics are often performed with errors. Common landing errors include inter-limb asymmetries, insufficient element height, inadequate hip flexion, and poor muscle pre-activation prior to ground contact. While improvements in explosive strength of lower limb muscles using plyometric workouts (PW) are generally linked to better landing outcomes, the explosive strength acts as a reaction to resist the force resulting from the collision with the mat. This helps the gymnast to be more controlled and balanced while landing, which also agrees with the results of the following studies (Silva et al., 2025), (Alhenawy, 2023), (Nitzsche et al., 2022), (Secomb et al., 2017), (Grigore et al., 2016) They recommended conducting more scientific research on plyometric workouts to determine their effectiveness in technical performance on various gymnastic apparatuses.

Therefore, the second hypothesis has been confirmed: “There are statistically significant differences between pre- and post-measurements of the experimental group in the landing strategies in artistic gymnastics under study in favor of the post-measurement.”

Conclusion:

Based on the research results and in light of the research aim and hypotheses, the researcher draws the following conclusions:

- Plyometric workouts positively affect the physical variables under study, as seen in:
  - The percentage of improvement in the physical variables ranged from 24.7% to 41.3%.
  - The average score for explosive strength in the Sargent test was 38.10 cm in the pre-test, improving to 53.82 cm in the post-test, a 41.3% improvement.

- The average score for explosive strength in the standing Long jump test was 137.70 cm in the pre-test, improving to 186.30 cm in the post-test, a 35.3% improvement.
- The average score for dynamic balance in the press balance test was 7.57 degrees in the pre-test, improving to 9.44 degrees in the post-test, a 24.7% improvement.
- The average score for dynamic balance on the modified Bass test was 77.33 degrees in the pre-test, increasing to 99.82 degrees in the post-test, a 29.1% improvement.
- The average score for static balance on the stork stand test was 16.86 seconds in the pre-test, increasing to 22.30 seconds in the post-test, a 32.3% increase.

• Plyometric workouts positively affect the technical variables under study, through:

- The percentage of improvement in the technical variables ranged from 25.7% to 37.2%.
- The average score for the 1st Landing was 1.71 degrees in the pre-test, improving to 2.33 degrees in the post-test, a 35.3% improvement.
- The average score for the 2nd Landing was 1.91 degrees in the pre-test, improving to 2.62 degrees in the post-test, a 37.2% improvement.
- The average score for the 3rd Landing was 1.51 degrees in the pre-test, improving to 1.96 degrees in the post-test, a 29.8% improvement.
- The average score for the 4th Landing was 1.67 degrees in the pre-test, improving to 2.20 degrees in the post-test, a 31.7% improvement.
- The average score for the technical routine was 11.68 degrees in the pre-test, increasing to 14.68 degrees in the post-test, a 25.7% improvement.

Recommendations:

Based on the research findings and conclusions, the researcher recommends the following:

- Combining physical training to match the motor pathways of the technical skills being developed.
- Ensure that training is in accordance with the energy production system prevailing in artistic gymnastics.
- Focus on agility, balance, and coordination training during the plyometric workouts.
- Considering the diversity in the direction of movement, between the vertical and horizontal paths, while using the plyometric workouts to develop explosive strength.
- Increasing the rest period between the workouts due to the increased intensity of the plyometric workouts, where the exercise duration is (20-30) high-intensity seconds, followed by (20-30) seconds of active rest.
- Increasing coaches' awareness of the importance and proper application of plyometric workouts, aligned with the technical skills.
- It is also essential for future coaching strategies to be grounded in a solid theoretical framework. Strength training, physical conditioning, and specific landing technique training must be rigorously integrated into practice.

- Applying plyometric workouts to first-class and national team players to increase their chances of qualifying for international tournaments.
- Applying plyometric workouts to different age groups of artistic gymnastics, as well as other sports, to determine its impact on skill performance.
- More research is required to identify the successful elements of landings that contribute to talent development in gymnastics.
- Conduct future studies, including comparing the effect of plyometric workouts with other skills, and other age stages.
- Collaboration between gymnastics clubs and research laboratories is crucial for promoting regular assessments and safeguarding the well-being of gymnasts.
- Using auxiliary equipment and assistive tools has proven effective in improving gymnasts' technical performance

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