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The Impact of Eight Weeks of Aquatic Plyometric Training on the Explosive and Agility Capabilities of Swimmers

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ABSTRACT

The objective of this study is to examine the impact of eight weeks of aquatic plyometric training on the explosive and agility abilities of swimmers. The following keywords were used: The objective of this study was to ascertain the impact of aquatic plyometric training (APT) on explosive power and agility. A training program incorporating APT was implemented on a sample of 20 swimmers. The findings revealed that utilizing APT at a depth up to the pelvis for 8 weeks and 3 times a week led to statistically significant differences and improvements in explosive power and agility. The effect size values for the two variables were 0.97 and 0.97, respectively. The researcher recommended the use of APT as a viable alternative to plyometric exercises on hard ground for enhancing explosive power and agility, while also reducing the risk of muscle and tendon injuries.

Keywords: aquatic plyometric training, explosive power, agility.

INTRODUCTION

Soccer is one of the most popular and widespread games in the world and is ranked first in terms of its popular base. It has also received ample attention and studies to improve it for the better, which is due to several factors, the most important of which is the large number of its practitioners and its lack of need for special requirements and equipment for its performance [1]. Plyometric exercises are widely used methods for developing muscular strength. They are designed to enhance muscle contraction strength through various jumping forms and contractions, such as iso-kinetic contractions, which improve dynamic strength through movement, concentric, and eccentric contractions, as well as iso-metric contractions [1]. Muscle elasticity plays a crucial role in plyometric exercises, alongside sensory receptors responsible for pre-tensioning muscles and transitioning from lengthening to shortening contractions to produce powerful movements in the shortest possible time [2, 3].

Plyometric exercises, particularly those of high intensity, increase and enhance muscle tension, leading to higher recruitment levels of motor units (both neural and muscular) during muscle work. This increased resistance due to gravity results in greater muscle strength [4, 5].

Aquatic Plyometric Training (APT) is a popular and effective physical training method. It simulates body movements in water using water resistance, providing a joint and tendon-friendly alternative ideal for individuals with injuries or those looking to reduce physical strain. This has garnered interest from trainers and researchers alike for its benefits, particularly for swimmers. Studies have highlighted the importance of APT for swimmers, showing improvements in muscular strength, flexibility, agility, and overall skill performance [6]. Additionally, Hubret, M., et al. [7] found that APT is as effective as traditional land-based plyometric exercises in developing explosive leg power and improving vertical jump distance. Swimming relies heavily on the techniques used for movement in water, involving repetitive, powerful, and rapid movements in synchronization between the upper and lower limbs to overcome drag forces and propel the body forward [8]. Technical efficiency in entering and exiting the water is vital, with smooth execution minimizing resistance and muscle strength in the lower limbs ensuring quick and effective muscle fiber recruitment for movement [9]. The start speed of a swimmer, crucial for competitive performance, depends on the muscular and explosive strength of the lower body. Proper body positioning, including lifting the head and shoulders back, facilitates smoother water entry and control. The importance of synchronized arm and leg strokes, relying on body coordination, cannot be understated [5].

Muscular strength and agility are paramount for swimmers, particularly in starting movements, where high contraction speed helps overcome resistance [10]. Strength training improves competitive performance by enhancing energy production, increasing ATP and creatine phosphate reserves, and delaying lactic acid accumulation, all critical for short-distance swimming [5].

Studies have demonstrated a strong relationship between lower limb strength and flight distance before water entry, with plyometric exercises significantly enhancing lower body strength and start technique [11]. These exercises can account for up to 25% of the result in sprint swimming events, highlighting their importance in improving explosive leg power [5].

Problem Statement

Recently, aquatic plyometric training has become a popular alternative to land-based training due to water buoyancy reducing joint stress, commonly observed with dry-land plyometrics. These exercises result in lower muscle damage indicators and effectively improve physical capabilities [12, 13] noted that muscle soreness from aquatic plyometrics is less than that from land-based exercises, proving beneficial for athletes' physical performance. Aquatic plyometric training has been integrated into training programs for sports like basketball, volleyball, and soccer to enhance physical capabilities [7]. Studies have utilized APT at knee, waist, and chest levels, addressing various physical, skill, physiological, and health variables. They are also used in rehabilitation programs for sports injuries and diseases, demonstrating reduced ground reaction forces and effective improvements in leg strength, running speed, and vertical jump power [14, 15]. This study aims to answer the primary question: What is the effect of aquatic plyometric exercises at the waist level on explosive leg strength and agility in swimmers?

Research Questions

The study seeks to answer the following questions:

1. What is the effect of aquatic plyometric exercises at the waist level on the curve of explosive leg strength changes in swimmers?
2. What is the effect of aquatic plyometric exercises at the waist level on the curve of agility changes in swimmers?

Hypotheses

The study aims to test the following hypotheses:

1. There is a statistically significant effect at the alpha level ($\alpha \leq 0.05$) of aquatic plyometric exercises at the waist level on the curve of explosive leg strength changes in swimmers.
2. There is a statistically significant effect at the alpha level ($\alpha \leq 0.05$) of aquatic plyometric exercises at the waist level on the curve of agility changes in swimmers.

Objectives

The study aims to determine the effect of aquatic plyometric exercises at the waist level on explosive strength and agility in swimmers. The specific objectives include:

- Identifying the statistically significant effect at the alpha level ($\alpha \leq 0.05$) of aquatic plyometric exercises at the waist level on the curve of explosive leg strength changes in swimmers.
- Identifying the statistically significant effect at the alpha level ($\alpha \leq 0.05$) of aquatic plyometric exercises at the waist level on the curve of agility changes in swimmers.

This study provides valuable insights for coaches and experts in swimming regarding aquatic plyometric exercises. It highlights the types of APT used to improve physical abilities in swimmers and guides coaches in incorporating these exercises into their training programs to enhance swimmers' physical and skill performance while reducing the risk associated with land-based plyometrics.

STUDY METHODOLOGY

The researcher employed an experimental method using a single experimental group with repeated measurements. This experimental method was chosen for its suitability to the study's nature and objectives and to verify the hypotheses by following a systematic scientific approach.

Study Population

The study population comprised 26 male swimmers from the An-Najah National University team, officially registered in the national team lists for the academic year 2022-2023.

Study Sample

The study sample consisted of 20 swimmers from the An-Najah National University swimming team. All tests were applied to them, along with the training program.

Sample Selection Method

The sample was intentionally selected, excluding 6 swimmers who were part of the preliminary study. After conducting the pilot study, the final sample consisted of 20 swimmers. To ensure homogeneity in age, mass, weight, and height data among all sample members, the Shapiro-Wilk test was conducted. Table 1 presents the mean, standard deviation, Z-value, and its significance level.

Table 1: Mean, Standard Deviation, Z-value, and Significance Level for Shapiro-Wilk Test for Normality of Mass, Age, and Height Data of the Sample Members (n=20).

Variable	Mean	Standard Deviation	Z-value	α
Age (year)	20.3	1.97	0.944	0.59
Mass (kg)	78.37	2.13	0.96	0.196
Height (cm)	181.6	3.28	0.962	0.217

Table 1 shows the mean, standard deviation, and Z-value for the age, mass, and height data of the study sample members. The mean age was 20.3 ± 1.97 years, the mean mass was 78.37 ± 2.13 kg, and the mean height was 181.60 ± 3.28 cm. The Z-values ranged from 0.944 to 0.962, indicating no statistical significance, thus demonstrating the normality of these variables and the homogeneity of the study sample members.

Study Domains

- Spatial Domain: This research was conducted at the College of Physical Education building at An-Najah National University in Palestine. The training program and skill tests were implemented in the college's indoor swimming pool, and all physical tests were conducted in the closed hall of the College of Physical Education at An-Najah National University.
- Temporal Domain: The training program started on Sunday, January 29, 2023, at 12:00 PM and continued for eight weeks, with sessions three times a week. Repeated measurements were taken for all study sample members, with four measurements for all physical and skill variables.

Study Variables

This study included the following variables:

- Independent Variable: The training program using aquatic plyometric exercises (APT).
- Dependent Variables: Explosive leg strength and agility.

Training Program

After reviewing educational literature and scientific studies and research in the field, such as those by various researchers [16-25], a training program using aquatic plyometric exercises was developed as follows:

- Allocating (3) training units per week for (8) weeks.
- Allocating (60) minutes per training unit.
- Allocating (15) minutes for warm-up.
- Allocating (5-7.5) minutes for relaxation.
- Allocating (30-37.5) minutes for the main part of the proposed training program.
- Identifying the physical and skill tests to be used in the study.
- Specifying the targeted physical and skill exercises in the program.
- Subjecting the tools to scientific validation.
- Determining the water depth used in the training program to reach the swimmer's hip level.
- Testing the exercises through the pilot study.
- Subjecting the proposed training program to evaluation by a committee of Ph.D. holders in sports training and swimming. After considering experts' and evaluators' opinions, the final training program was developed as detailed in Table 2.

Table 2: Aquatic Plyometric Training Program (APA).
Week One, Two, and Three
Training Days: Sunday, Tuesday, Thursday

Content	Intensity (%)	Total Work and Rest (min)	Total Rest Between Exercises	Total Exercise Time (s)		Rest Time (s)	Repetitions	Exercise Time (s)	Expected Pulse (beats / min)
Primer part									
Aqua jogging-in		2	60	60		20	3	20	
Aqua jogging-out		2	60	60		20	3	20	
Punching Water		2	60	60		20	3	20	100-120
Squat	50-60	2	60	60		20	3	20	
Jump Higher		2	60	60		20	3	20	
Total		10							
Main part									
Side Jump		2	60	60		20	3	20	
Front Jumping		2	60	60		20	3	20	
Jumping Jacks		2	60	60		20	3	20	
Split Squat		2	60	60		20	3	20	
Knee Tucks		2	60	60		20	3	20	
Aqua Sprint		2	60	60		20	3	20	
One Leg Jump		2	60	60		20	3	20	
One Leg Jump with Knee Tuck	70-75	2	60	60		20	3	20	140-150
Side to Side Double		2	60	60		20	3	20	
Reverse Plank		2	60	60		20	3	20	
Mini Crunches		2	60	60		20	3	20	
Back Ups		2	60	60		20	3	20	
Push Ups		2	60	60		20	3	20	

Arms Down		2	60	60		20	3	20	
Swing Kicks		2	60	60		20	3	20	
Total		30							

Week four, five and six:
Training days Sunday, Tuesday, Thursday

Content	Intensity (%)	Total Work and Rest (min)	Total Rest Between Exercises (s)	Total Exercise Time (s)	Rest Time (s)	Repetitions	Exercise Time (s)	Expected Pulse (beats / min)
Primer part								
Aqua jogging-in	50-60	2	60	60	20	3	20	100-120
Aqua jogging-out		2	60	60	20	3	20	
Punching Water		2	60	60	20	3	20	
Squat		2	60	60	20	3	20	
Jump Higher		2	60	60	20	3	20	
Total		10						
Main part								
Side Jump	80-85	2.15	60	75	20	3	25	160-170
Front Jumping		2.15	60	75	20	3	25	
Jumping Jacks		2.15	60	75	20	3	25	
Split Squat		2.15	60	75	20	3	25	
Knee Tucks		2.15	60	75	20	3	25	
Aqua Sprint		2.15	60	75	20	3	25	
One Leg Jump		2.15	60	75	20	3	25	
One Leg Jump with Knee Tuck		2.15	60	75	20	3	25	
Side to Side Double		2.15	60	75	20	3	25	
Reverse Plank		2.15	60	75	20	3	25	
Mini Crunches		2.15	60	75	20	3	25	
Back Ups		2.15	60	75	20	3	25	
Push Ups		2.15	60	75	20	3	25	
Arms Down		2.15	60	75	20	3	25	
Swing Kicks		2.15	60	75	20	3	25	
Total		32.25						

Week seven and eight:
Sundays, Tuesdays and Thursdays

Content	Intensity (%)	Total Work and Rest (min)	Total Rest Between Exercises (s)	Total Exercise Time (s)	Rest Time (s)	Repetitions	Exercise Time (s)	Expected Pulse (beats / min)
Primer part								
Aqua jogging-in	50-60	2	60	60	20	3	20	100-120
Aqua jogging-out		2	60	60	20	3	20	
Punching Water		2	60	60	20	3	20	
Squat		2	60	60	20	3	20	
Jump Higher		2	60	60	20	3	20	

Total		10					
Main part							
Side Jump	90	2.5	60	90	20		30	180
Front Jumping		2.5	60	90	20		30	
Jumping Jacks		2.5	60	90	20		30	
Split Squat		2.5	60	90	20		30	
Knee Tucks		2.5	60	90	20		30	
Aqua Sprint		2.5	60	90	20		30	
One Leg Jump		2.5	60	90	20		30	
One Leg Jump with Knee Tuck		2.5	60	90	20		30	
Side to Side Double		2.5	60	90	20		30	
Reverse Plank		2.5	60	90	20		30	
Mini Crunches		2.5	60	90	20		30	
Back Ups		2.5	60	90	20		30	
Push Ups		2.5	60	90	20		30	
Arms Down		2.5	60	90	20		30	
Swing Kicks		2.5	60	90	20		30	
Total		37.5					

Study Tools

To achieve the research objectives, and after reviewing the educational literature, the researcher used several tools for conducting various tests. The tools used are as follows:

- Distance measuring tape for some tests.
- Casio stopwatch for timing.
- Fox whistle for signaling the start.
- Medical scale (Seca) for measuring mass.
- Stadiometer for measuring height.
- Swimming pool for conducting tests and implementing the training program, 25 meters long and 12.5 meters wide.

Study Tests

The researcher used the following tests in the study:

Physical Tests

- Agility Test (T-Test): The T-Test for agility by Pauole, K., et al., (2000) involves placing four cones on the ground in the shape of a "T" as shown in Figure 6. The starting point is at cone (A), where the test timing begins upon start. The distance between cone (A) and cones (B, C, D) is 10 yards (9.14 meters), and the distance between cones (B, C, D) is 5 yards (4.57 meters). The test starts with the signal to go, and the timer starts. The participant runs from cone (A) to cone (B) and touches the base of cone (B) with their right hand. Then they move sideways to the left to cone (C) and touch its base with their left hand. They then move sideways to the right to cone (D) to touch its base with their right hand, return to cone (B) to touch its base with their left hand, and finally return to the starting line at cone (A), stopping the timer upon crossing cone (A). Each participant is given three attempts, and the best attempt is recorded. Any attempt is not counted if the participant fails to touch the base of the cone or does not run sideways between cones (B, C, D).

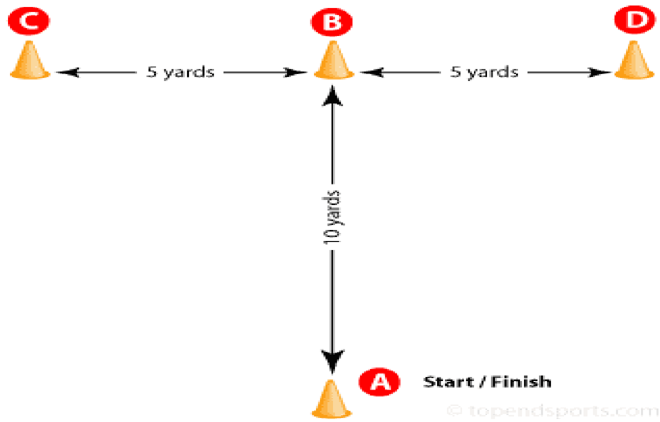

Figure 1: Agility Test.

- Explosive Leg Power Test (Vertical Jump Test): The Sargent Jump Test by Sargeant, A., (1987) was used, modified by De Salles et al. (2012). The participant stands next to a wall with a measuring tape fixed on it. They hold a piece of chalk in their hand and make a mark at the highest point they can reach without lifting their heels off the ground, ensuring their shoulders are level when raising the arm holding the chalk. The participant then bends their knees and jumps as high as possible to make a second mark on the wall with the chalk. The distance between the first and second marks (in centimeters) represents the explosive leg power. Each participant is given three attempts with a rest period of at least 45 seconds between attempts, and the best attempt is recorded. Figure 2 illustrates the test.

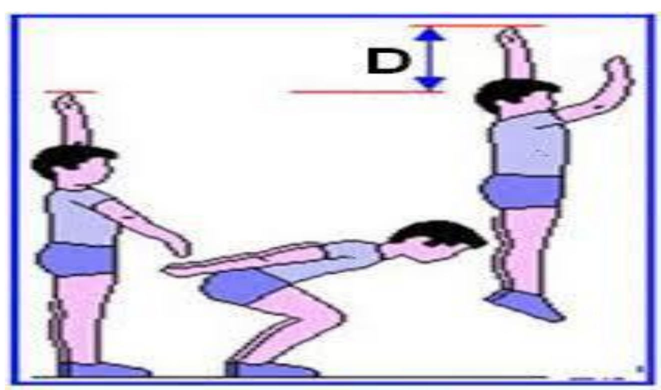

Figure 2: Sargent Jump Test for Measuring Explosive Leg Power.

Scientific Transactions of Study Tools

- Test Validity: After reviewing many studies and references related to various topics in swimming, the researcher selected a set of tests to measure the study variables. To verify the validity of the tests, the researcher presented them to a group of experts in the field of swimming. The experts confirmed the appropriateness of the tests and their ability to measure the intended variables.

- Test Reliability: To ensure the reliability of the physical and skill tests under study, the Test-Retest method was used. The tests were applied to a pilot sample of six swimmers not included in the main study sample. The interval between the first and second test applications was five days. Pearson Correlation Coefficient was used to determine the relationship between the two applications, as shown in Table 3.

Table 3: Reliability and Construct Validity Coefficients for the Physical and Skill Tests Under Study.

Physical and Skill Variables	R Value	Construct Validity	Significance Level
Explosive Leg Power (Standing Long Jump Test)	0.94	0.969	0.000**
Explosive Arm Power (Medicine Ball Throw Test)	0.96	0.979	0.000**
Agility (Barrow Test)	0.94	0.969	0.000**
Arm Strokes from Horizontal Floating Position on Stomach	0.97	0.984	0.000**
Leg Strokes from Horizontal Floating Position on Stomach	0.93	0.964	0.000**
25-Meter Freestyle Swimming without Jump	0.95	0.974	0.000**
25-Meter Breaststroke Swimming without Jump	0.94	0.969	0.000**

Statistically significant relationships at the significance level ($\alpha \leq 0.01$).

The results of **Table 3** indicate statistically significant relationships at the significance level ($\alpha \leq 0.01$) between the first and second applications for all physical and skill variables under study. The Pearson correlation coefficient values ranged from 0.93 to 0.97, and the construct validity values ranged from 0.964 to 0.984. This indicates that the tests used in the study have a high degree of reliability and meet the study's objectives.

Statistical Methods

To achieve the study's objectives and answer its questions, the Statistical Package for the Social Sciences (SPSS) version 28 was used for the following analyses:

- Shapiro-Wilk Test to ensure the homogeneity of all sample members in terms of age, mass, and height data.
- Repeated Measures Analysis using Hotelling's Trace to determine differences between repeated measurements of the study variables.
- Sidak Post-hoc Test for pairwise comparisons of means for repeated measurements of the study variables.
- Partial Eta Squared to determine the effect size of plyometric training in an aquatic environment on the change curve of the study variables. Effect size was determined according to Cohen's criteria (Cohen, 1988): (less than 0.20) very small effect, (0.20 - less than 0.50) small effect, (0.50 - less than 0.80) medium effect, (0.80 - less than 1.10) large effect, (1.10 and above) very large effect.
- Means, standard deviations, and percentage change (%) were calculated using the formula (post-test mean - pre-test mean ÷ pre-test mean × 100) for each study variable.

Study Results

The current study aimed to identify the effect of aquatic plyometric exercises at the pool level on the curve of change in explosive power and agility in swimmers. To achieve this, the study answered two research questions and presented their results, as follows:

- First: Results related to the first question: What is the effect of aquatic plyometric exercises at the pool level on the curve of change in the explosive leg power in swimmers?

To answer this question, Hotelling's Trace analysis was used for repeated measures, and partial eta squared values were extracted to determine the effect size of aquatic plyometric exercises on explosive power. The results are shown in Table 4.

Table 4: Hotelling's Trace Values for the Effect of Aquatic Plyometric Exercises on the Curve of Change in Explosive Power in Swimmers (N=20)

Physical Variables	Hotelling's Trace	F Value	df Numerator	df Denominator	Significance Level	Effect Size	Effect Size Category
Explosive Leg Power (m)	41.39	234.53	3	17	0.000*	0.97	Large
Agility (Barrow Test; s)	33.18	187.99	3	17	0.000*	0.97	Large

Statistically significant differences at the significance level ($\alpha \leq 0.05$).

The results in Table 4 indicate statistically significant differences at the significance level ($\alpha \leq 0.05$) among the repeated measurements for explosive leg power in swimmers. This indicates a statistically significant effect of aquatic plyometric exercises at the pool level on the curve of change in explosive power in swimmers, with effect size values for the variables being 0.97.
To determine the sources of differences between repeated measurements of explosive leg power variables, the Sidak post-hoc test was used for pairwise comparisons between mean values, and the percentage of change was calculated for each physical variable. The results are shown in Table 5. The results, in terms of the sequence of physical variables, are as follows:
Explosive Leg Power in the Standing Long Jump Test:

Table 5: Means, Standard Deviations, and Percentage Changes for Explosive Leg Power in the Standing Long Jump Test for Swimmers (N=20).

Measurements	Mean	Standard Deviation	Percentage Change (%)
First	2.9	0.11	-
Second	2.94	0.1	1.37
Third	2.98	0.1	1.36
Fourth	3.01	0.09	1.01
Total Percentage Change			3.79

The results in Table 5 show that the total percentage change in explosive leg power between the first and fourth measurements was 3.79%

Table 6: Sidak Test Results for Comparing the Mean Values of Explosive Leg Power in the Standing Long Jump Test for Swimmers (N=20).

Measurements	Mean	First	Second	Third	Fourth
First	2.9	-	-0.04*	-0.08*	-0.11*
Second	2.94		-	-0.04*	-0.07*
Third	2.98			-	-0.03*
Fourth	3.01				-

Statistically significant differences at the significance level (α ≤ 0.05).

The results in Table 6 indicate statistically significant differences at the significance level (α ≤ 0.05) in the effect of plyometric water exercises at the pool level on the variable of explosive leg power in the standing long jump test for swimmers. The differences are in favor of the fourth measurement compared to the first, second, and third measurements; the third measurement compared to the first and second measurements; and the second measurement compared to the first measurement. This is also illustrated in **Figure 3.**

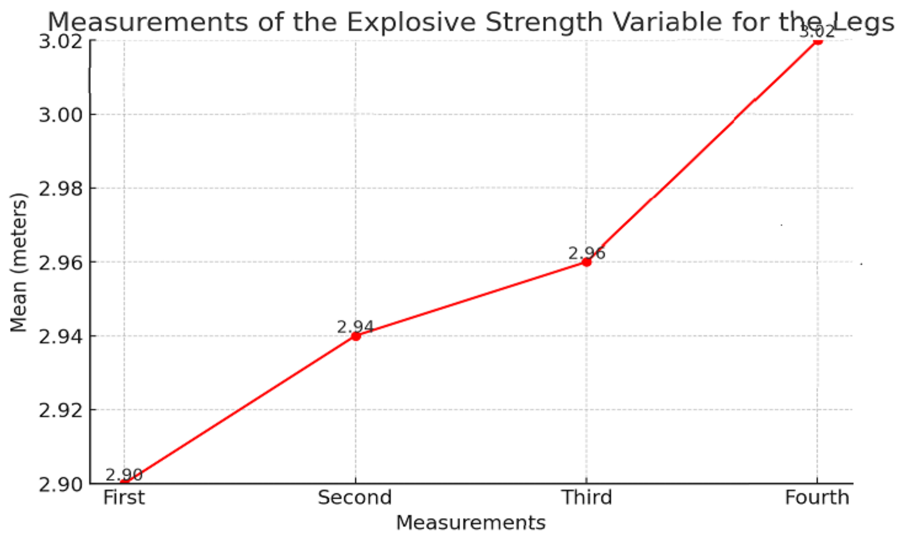

Figure 3: The effect of aquatic plyometric training on the change curve of the leg explosive power variable for the swimmers.

Secondly: Results related to the second question which reads:
What is the effect of aquatic plyometric training at the pelvic level on the change curve of agility in swimmers?

Table 7: Arithmetic Means, Standard Deviations, and Percentages of Change for the Agility Variable in the Barrow Test for Swimmers (n=20).

Measurements	Arithmetic Mean	Standard Deviation	Percentage of Change %
First	6.53	0.24	-
Second	6.45	0.23	-1.22
Third	6.4	0.22	-0.77
Fourth	6.35	0.21	-0.78
Total Percentage of Change			-2.75

The results in Table 7 indicate that the overall percentage change in agility between the fourth and first measurements was (-2.75%) seconds.

Table 8: Sidak Test Results for Comparing the Arithmetic Means of Agility Variable Among Swimmers (n=20).

Measurements	Mean	First	Second	Third	Fourth
First	6.53	-	0.08*	0.13*	0.18*
Second	6.45		-	0.05*	0.10*

Third	6.4			-	0.05*
Fourth	6.35				-

Statistically Significant Differences at Significance Level (α≤ 0.05)

Table 8 shows statistically significant differences at the significance level (α≤ 0.05) in the effect of plyometric water exercises at the hip level on the agility variable in the Barrow test among swimmers between the (first) measurement and the (second, third, and fourth) measurements in favor of the (first) measurement, and between the (second) measurement and the (third and fourth) measurements in favor of the (second) measurement, as well as between the (third) and (fourth) measurements in favor of the (third) measurement. This is illustrated in **Figure 4**.

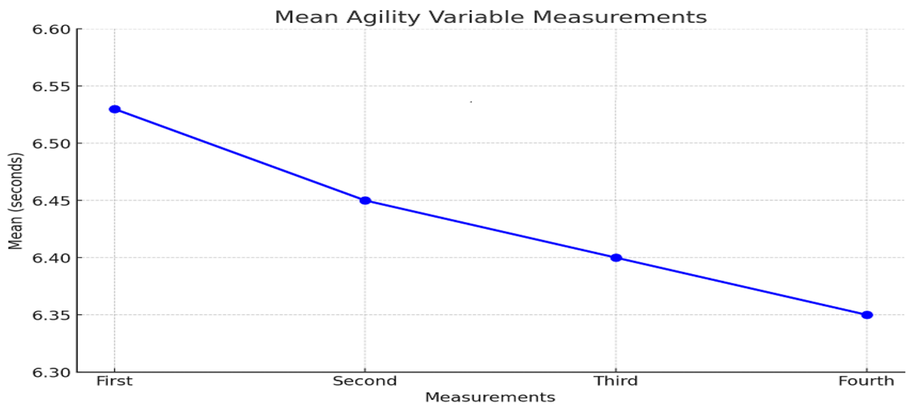

Figure 4: The Effect of Plyometric Training in Water on the Agility Variable Change Curve in the Barrow Test for Swimmers.

DISCUSSION OF RESULTS WITH HYPOTHESES

Results Related to The First Study Question:

Which stipulates: What is the level of some elements of physical fitness among female soccer players in Palestinian clubs? To answer this question, the arithmetic means and standard deviations of the results of the physical tests of the young soccer players were extracted, and the results of Table 2 show that. Hypothesis One: The researcher hypothesized that there is a statistically significant effect of plyometric water exercises at the hip level on the change curve in explosive leg strength among swimmers. The results of Table 9 indicated statistically significant differences at the significance level (α≤ 0.05) between the repeated measurements in explosive leg strength, indicating a statistically significant and substantial effect of plyometric water exercises on the change curve in explosive leg strength among swimmers, with effect sizes of the variables being (0.97) respectively.

The results of Table 4 showed statistically significant differences between the repeated measurements in favor of the fourth measurement. The researcher attributes this result to the nature of the plyometric exercises in the aquatic environment used in the training program, which combines strength and speed through the mechanism of these exercises that rely on an eccentric elongation contraction leading to a sudden stretch in the muscles, followed by a concentric shortening contraction that increases explosive strength in the muscles, thereby enhancing the explosive force generated by muscle contraction.

In this context, Dell Antonio [26] emphasize the role of plyometric exercises in the aquatic environment in improving muscle strength through the stretch-shortening cycle mechanism in plyometric exercises. Similarly, Cassidy, W., et al. [16] highlight the importance of muscle contractions resulting from aquatic jumping exercises in improving muscle strength. Abu Altaieb, M., et al. [17] indicate that plyometric water exercises, which included many jumping exercises over a period of (10) weeks, twice a week, improved explosive strength in soccer players. The researcher adds that plyometric water exercises are among the best exercises that bridge the gap between strength and speed, requiring maximum force in the shortest time possible, as shown through deep jump exercises, which are a form of plyometric water exercises allowing athletes to benefit from the stretch-shortening cycle to produce and develop explosive strength.

This aligns with the findings of Sandip, G., Raju, B. [27] and Jurado, L., et al. [28], who confirmed the role and importance of plyometric water exercises in developing explosive leg strength. The results are consistent with those of Pryse, M., et al. [29] and Fonseca, R., et al. [14], who verified the effectiveness of plyometric water exercises in developing explosive leg strength. These results align with Sandip, G. & Raju [27] and Atanaskovic, A., et al. [20], who confirmed that plyometric water exercise programs have proven their ability to improve explosive strength in athletes, supporting their use for enhancing athletic performance.

Elfakharany, M. & Elnaggar [30] add that aquatic plyometric training (APT) leads to an increase in the strength of the quadriceps muscles, which are crucial during jumping, thereby enhancing the strength and performance of these muscles, which play a significant role in improving explosive strength. Nicholas, H., et al. [12] highlighted the role of plyometric water exercises in developing the strength of the lower limb muscles (sartorius muscle, adductor muscle, gluteus maximus muscle) and their importance in improving speed, maximum strength, and explosive leg strength. The study's results align with those of Sofhie, E. [31] who emphasized that aquatic plyometric training involves explosive jumping movements in water in various forms, generally aimed at improving athletic performance by developing muscle strength and speed. Hubret, M., et al. [7] also noted that plyometric water exercises improved muscle strength and vertical jump height, with Soprri, D., et al. (2018) affirming the importance of aquatic plyometric training in improving vertical jump height among athletes.

The study results are consistent with those of Arazi, H., & Asadi, A. [18] and Arazi, H., et al. [19], who confirmed the effectiveness and importance of plyometric water exercises in developing explosive leg strength. The researcher also notes that anaerobic energy systems, particularly the phosphagen system (ATP-PC), play an important role in plyometric water exercises, improving their efficiency through various training programs, including plyometric exercises. Rajesh, K., & Akhila, G. [6] emphasized the role of plyometric exercises in improving anaerobic efficiency by developing the phosphocreatine energy system, allowing for maximum energy storage in muscles before explosive contraction, undoubtedly giving swimmers a quick start at the beginning of the race.

Hypothesis Two: The researcher hypothesized a statistically significant effect of plyometric water exercises at the hip level on the change curve in agility among swimmers. The results of Table 7 indicated statistically significant differences at the significance level ($\alpha \leq 0.05$) between repeated measurements in agility among swimmers, indicating a statistically significant and substantial effect of plyometric water exercises on the agility change curve, with effect sizes of (0.97). The results of Table 8 also showed statistically significant differences between repeated measurements in favor of the fourth measurement. The researcher attributes this result to the nature of plyometric exercises in the aquatic environment used in the training program, which directly affects the main factors that improve agility, including muscle strength, speed, and balance. These exercises, combined with water resistance, enhance these factors, leading to improved agility.

The researcher adds that a swimmer's ability to change body positions in water requires significant physical strength, underscoring the importance of muscle strength in relation to agility. Sheaff (2023) emphasizes the swimmer's reliance on various physical abilities, highlighting the crucial role of muscle strength in swimming performance and achievement. Waddingham, DP., et al. [32] noted that swimmers' performance and achievement are closely linked to physical and physiological performance outcomes, with increased strength leading to better movement and performance in water.

The researcher also highlights the importance of static and dynamic balance in improving swimmers' agility. Plyometric water exercises increase a swimmer's ability to maintain balance during stillness and movement, enhancing agility. This is consistent with Elnaggar, R. et al. [34], who noted that aquatic plyometric training (APT) improves the ability to control body position and movement.

Improved speed in swimmers also plays a crucial role in enhancing agility. Plyometric water exercises provide the necessary resistance to improve muscle strength and speed, thereby improving agility. Rajesh, K., & Akhila, G. [6] noted the importance of these exercises in developing muscle strength, speed, explosive power, flexibility, and agility, as well as improving athletes' reaction time and neuromuscular coordination, all crucial for enhancing swimmers' performance. Hubret, M., et al. [7] and Datta, N. & Bharti, R. [33] highlighted the role of these exercises in improving agility, balance, and coordination by enhancing muscle strength and power, which require significant effort in water to maintain body balance and stability.

This aligns with the findings of Hubret, M., et al. [7], who noted that plyometric water exercises improved agility among volleyball players, consistent with the results of Fonseca, RT., et al. [14] and Fattahi, A., et al. [15], who confirmed the importance of plyometric water exercises in improving agility and nimbleness among athletes.

The researcher also notes that agility is an anaerobic ability that requires maximum strength and speed, meaning that improving anaerobic capacity enhances agility. The researcher emphasizes that plyometric water exercises play a significant role in improving anaerobic capacity, consistent with Raju, B & Sandip [35], who found that a 14-week plyometric water exercise program improved athletes' anaerobic capacity compared to land-based plyometric training.

GENERAL CONCLUSION AND RECOMMENDATIONS

The use of aquatic plyometric training (APT) at a water level reaching the hip, including exercises performed in place or with movements in different directions (forward, lateral, backward), applied to a sample of swimmers over an eight-week training program, three times a week, with an intensity ranging between (70-90%), led to improvements in explosive leg strength and agility among the swimming team. This study indicates the importance of these exercises in improving these variables, which are essential for overall swimming performance. Based on the study results and conclusions, the researcher recommends the following:

- Use plyometric water exercises at a water level reaching the hip to reduce the risk of muscle and tendon injuries.
- Use plyometric water exercises at a water level reaching the hip to improve both explosive leg strength and agility.
- Conduct studies on the physiological benefits of plyometric water exercises.
- Disseminate the study results to professionals in the field of swimming in educational institutions and sports federations.

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