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The Relationship Between Leg Explosive Strength and Jumping Performance Among Female Rhythmic Gymnasts

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Abstract

The importance of this research lies in highlighting one of the modern training methods that may contribute to improving the athletic performance of handball players, whether on the physical or tactical level. From the perspective of physiological variables, repeated-sprint training at maximal and sub-maximal intensities is employed to enhance anaerobic capacity and increase the efficiency of the nervous system. The research problem emerged from the observation that many coaches focus heavily on offensive skills, neglecting the fact that an offensive mistake results in losing the ball, whereas a defensive error grants the opponent a scoring opportunity. Additionally, poor performance results may be attributed to the inability of the body's functional systems to withstand the demands of continuous and variable motor performance, as well as the noticeable delay in physical preparatory aspects such as speed of movement across the court, reaction time, and decision-making during defensive situations like intercepting or clearing the ball. Despite the importance of these aspects, training programs for players under 15 years of age still require further development in defensive performance and movement speed, which in turn influence physical abilities such as lower-limb explosive power and anaerobic functional variables.The study aims to: Design repeated-sprint training using maximal and sub-maximal intensities for handball players under 15 years of age, and identify the effects of this training on the alactic (phosphagen) anaerobic functional variable, lower-limb explosive power, and individual defensive movement among players in this age group. The researchers used the experimental method with a design of two equivalent groups (experimental and control). The research population consisted of players from the Specialized Handball School in Baghdad under

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the age of 15. The sample was intentionally selected and consisted of (20) players, randomly divided into two groups: (10) players in the experimental group and (10) in the control group. Results showed that repeated-sprint training had a significant positive effect on the development of lower-limb explosive power (right and left) and on improving the phosphagen anaerobic functional variable in the experimental group. The designed training also led to significant improvement in individual defensive movements, including ball interception and clearance. A lesser degree of improvement was observed in the control group compared to the experimental group.

Keywords: repeated speed, anaerobic functional variables, explosive power, individual defensive movement.

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Introduction

Handball is considered one of the team sports that requires a high level of physical performance characterized by a variety of rapid movements, sudden changes of direction, and repeated short sprints, particularly in defensive areas. Speed of transition, power of performance, speed endurance, and anaerobic capacity are major determinants of defensive success, which makes the physical and functional demands placed on the player complex and multifaceted.

Repeated Sprint Training (RST) is regarded as one of the modern training methods that combines short, high-intensity sprints with relatively short recovery periods. It focuses on improving players' anaerobic performance, increasing explosive and rapid leg power, and enhancing motor efficiency in individual defensive movements, thereby creating a training environment that closely resembles match conditions. Bishop, Girard, and Mendez-Villanueva (2011) defined repeated sprint ability (RSA) as the athlete's ability to perform a series of maximal and submaximal short sprints interspersed with short or incomplete recovery periods, while maintaining the highest possible performance in each repetition. The effectiveness of repeated sprint training lies in improving anaerobic performance and the ability to repeatedly sustain high-intensity efforts, a concept that is particularly important in sports that rely on repeated high-intensity actions such as handball, football, rugby, and others.

In light of recent developments in sports training methodologies, there has been a growing need to design specialized training programs that enhance the anaerobic functional capacities of handball players, improve recovery ability, and develop explosive and defensive power, which are considered fundamental elements in confronting fast offensive actions by opponents. Haddad (2013) and Machado (2007) indicated that both sports scientists and coaches agree that the ability to perform repeated sprints with short recovery intervals—known as repeated sprint ability—is an essential characteristic in various sports competitions and represents one of the basic components of physical fitness aimed at improving performance in activities that require repeated speed actions.

Despite the widespread use of such training methods in sports such as football and athletics, their effects within the context of handball, particularly on individual defensive performance, still require further investigation. Moreover, outstanding performance in handball is not limited to physical and skill-related aspects alone; it also extends to the functional aspects of the player, which reflect the efficiency of the body's systems in meeting physical workload demands and adapting to the variables that occur during the match and the motor tasks assigned to players, enabling the body to sustain performance throughout the entire duration of the game.

Al-Saqqa (2010: 91) stated that the playing rhythm in handball consists of rapid and short bouts of movement performed by the player to execute game tasks during offense or defense, with or without the ball. Although handball is predominantly an anaerobic endurance sport, the continuation of match duration for 60 minutes or more requires a certain level of aerobic endurance. The researchers believe that individual defensive movements represent a fundamental pillar of the team's defensive system and require the player to possess rapid response ability and effective maneuvering skills to repel opponents' attacks and prevent them from obtaining favorable shooting positions. This was supported by Kazem and Haddad (2021: 22), who emphasized that the development of physical abilities—especially those combining strength and speed—is essential for sports that require overcoming resistance and rapid transitions and movements. Such development is achieved through combined and varied exercises, in addition to jumping and lateral movements, which enhance muscular strength in the working muscle groups at intensities greater than those to which the players are accustomed. This, in turn, stimulates the working muscles and improves performance by increasing pushing force laterally and forward, while intramuscular and intermuscular coordination contributes to increasing movement speed.

Based on the above, the importance of this study lies in highlighting one of the modern training methods that may contribute to the development of handball players' athletic performance, both physically and tactically. From a functional perspective, repeated sprint exercises at maximal and submaximal intensities contribute to enhancing anaerobic capacity, increasing neuromuscular efficiency, and improving the body's ability to remove lactic acid, which positively reflects on players' performance during matches that may extend to extra periods.

The research problem emerged from observing the considerable attention given by coaches to developing offensive skills, while neglecting the fact that an error in offense leads to loss of possession, whereas an error in defense grants the opponent a direct goal. Poor defensive results may also be attributed to the inability of the body's functional systems to tolerate variable and continuous motor performance during the match, in addition to deficiencies in physical preparation, such as transition speed on the court, reaction speed, and decision-making when intercepting or deflecting the ball. Accordingly, there is a clear need for training programs that focus on developing defensive performance and the physical and functional capacities that support it, such as explosive leg power and anaerobic efficiency.

From this perspective, the research problem is formulated in the following question:
Do repeated speed exercises have an effect on explosive power, anaerobic functional capacity, and individual defensive movement in handball players under 15 years of age?

1.2 Research Objectives

1. To design repeated speed exercises at maximal and submaximal intensities for handball players under 15 years of age.
2. To identify the effect of repeated speed exercises on anaerobic functional variables (phosphagen system), explosive leg power, and individual defensive movement in handball players under 15 years of age.

1.3 Research Hypotheses

1. There are no statistically significant differences between the pre- and post-test results of the control and experimental groups in the anaerobic functional variable (phosphagen system), explosive leg power, and defensive movement of handball players under 15 years of age.
2. There are no statistically significant differences in the post-test results between the control and experimental groups in the anaerobic functional variable (phosphagen system), explosive leg power, and defensive movement of handball players under 15 years of age.

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1.4 Research Scope

1. **Human scope:** Players of the National Center for Sports Talent Care in handball under 15 years of age, totaling 20 players, for the 2024–2025 sports season.
2. **Time scope:** From 12/10/2024 to 5/5/2025.
3. **Spatial scope:** The National Center for Sports Talent Care in Handball, Ministry of Youth and Sports, Al-Rusafa, Baghdad.

2. Methods and Procedures

2.1 Research Design

The researchers employed the experimental method using a two equivalent-group design (experimental and control groups) with pre- and post-tests. This design was selected as it is appropriate to the nature of the research problem and suitable for achieving the study objectives.

2.2 Research Population and Sample

The research population consisted of handball players from the Specialized Handball School in Baghdad under 15 years of age. The research sample was selected intentionally and initially included 30 players registered in the Iraqi Handball Federation records and regularly participating in training and competition. Five players were excluded because they were goalkeepers due to the differences in their training programs, and another five players were excluded based on recommendations from the coaching staff at the center because of frequent absences from training and the presence of injuries. Accordingly, the final sample comprised 20 players, who were randomly assigned into two groups: 10 players in the experimental group and 10 players in the control group. The sample represented 66.66% of the total population.

To avoid the influence of individual differences on the experimental results, homogeneity among the sample participants was established for the variables of body mass, height, chronological age, training age, and body mass index. These characteristics are presented in Table (1).

Table1. *Statistical characteristics of the variables (chronological age, training age, total body height, and body mass)*

Variable	Unit	Mean	Standard Deviation	Median	Skewness
Chronological age	year	14.86	0.64	14	−0.50
Training age	year	2.22	1.55	2	0.54
Total body height	cm	162.67	4.84	161	0.32
Body mass	kg	50.15	4.82	40	0.17

As shown in Table (1), the skewness values ranged within ±1, indicating a clear homogeneity in these variables among the members of the research sample.

2.3 Instruments, Tools, and Means of Data Collection

- Arabic and foreign references and sources.
- Internet resources.
- Tests and measurements.
- Questionnaire forms related to functional variables, explosive power, and individual defensive movements.
- Adhesive tape and a 50 m metallic measuring tape (1).

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- Training ladders and elastic resistance bands of various lengths.
- Cones of different heights (10).
- Hurdles with a height of 30 cm (10).
- Platform with a height of 40 cm (1).
- Laptop computer (HP) (1).
- Medical scale for measuring body mass and a metallic measuring tape for height.
- Numbered board to identify the player number and the performed trial.

2.4 Description of the Tests for Functional and Physical Variables and Individual Defensive Movements in Handball

First: Explosive Leg Power

Test name: Triple hop test for the right and left legs (Al-Badri & Al-Sudani, 2011).

Purpose: To measure speed–strength (explosive power) of the right and left legs.

Equipment: Flat surface, measuring tape, whistle.

Performance description: The participant stands at the starting line on one leg (the leg used for hopping) and performs three consecutive hops, aiming to cover the maximum possible distance.

Conditions:

- The take-off must be performed from a stationary position.
- The performance should be executed as quickly as possible.
- Measurements are recorded to the nearest centimeter.
- Two trials are allowed for each leg, and the best attempt is recorded.
  Scoring: The score is the distance (to the nearest centimeter) measured from the starting line to the point reached after the third hop.

Second: Phosphagen Anaerobic Capacity Test

(Radwan, 1998, p. 162)

Test name: Step Test (10 s)

Purpose: To measure phosphagen anaerobic capacity.

Equipment: Step box (40 cm height), stopwatch, body-weight scale, whistle.

Performance description:

The participant (player) stands in front of a step box with a height of 40 cm, placing one foot on the box and the other on the ground, with body weight initially supported by the free leg (on the ground), while the other leg is placed on the box. At the start of the test, the participant lifts the body upward by stepping onto the box. In all cases, the free leg remains extended, and the trunk is kept upright; the free leg assists in upward propulsion. The arms are used only to maintain balance during the test and must not contribute to propulsion through swinging. The movement rhythm follows two counts (one–two): "one" for stepping up and "two" for stepping down.

Scoring:

The total number of steps is recorded (upward and downward). A step is counted when the participant stands up straight on top of the box with the free foot away from the box. The duration of the test is 10 s.

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Calculation of phosphagen anaerobic capacity:

$$\text{Phosphagen power} = 1.33 \times \frac{\text{Body mass (kg)} \times 0.4\,\text{m} \times \text{Number of steps in 10 s}}{10\,\text{s}}$$

Third: Individual Defensive Movement Test in Handball

Test name: Intercepting and deflecting the ball among three attacking players in handball *(Hamel, Saad, 2020, p. 6)*

Purpose: To measure a defender's ability to intercept and deflect the ball among three attacking players.

Equipment: Whistle, stopwatch, measuring tape, colored adhesive tape, half a handball court, four handballs, three attacking players.

Test setup and performance:

An equilateral triangle is centered at the midpoint of each side of which is also 4 m long, with the apex being at the mid-point between two points on a line that's 7 m long and the base just barely overhanging in to a box that's 9 by 18 m.

- Each attacking player stands at one vertex of the triangle; one player holds the ball before the start signal.
- Balls are distributed equally among the attackers and placed near each of them.
- A circular mark with a diameter of 1 m is drawn at the center of the triangle, where the defender stands.
- After the referee's whistle, the attackers begin passing the ball quickly among themselves for 30 seconds, while the defender moves to seize suitable opportunities to intercept or deflect the ball.

Test conditions:

- Attackers are instructed to use overhead passes only.
- The referee positions himself at a distance that allows clear observation without interfering with performance.
- When the defender successfully intercepts or deflects the ball, the referee stops the time until play resumes; this procedure continues until the allotted time expires.
- A successful attempt is not counted if the defender does not initiate movement from the marked circle (at least one foot must be in contact with the circle).
- In the event of errors or interruptions (e.g., cramps, sprains, external interference), the participant performs the next attempt after confirming readiness. If the error recurs, the participant is not tested on that day and is preferably retested on another day.
- The attacking passers remain the same until all participants complete the test.
- Each participant is given two attempts; each attempt lasts 30 seconds, and the better attempt is recorded.

Scoring method:

The total number of successfully intercepted and deflected balls is counted for each attempt.

2.5 Field Procedures

2.5.1 Pilot Studies

The researchers conducted several pilot studies. The first pilot study was carried out on Monday, 21/10/2024, at 3:30 p.m. in the hall of the National Center for Sports Talent Care in Handball. It involved tests of speed–strength (explosive leg power), phosphagen anaerobic functional capacity, and individual defensive movement, using a sample of three handball players under 15 years of age. The purpose was to verify the players' physical and functional capabilities during test application, identify potential difficulties, determine appropriate solutions compatible with their abilities, estimate the time required for the tests, identify possible obstacles prior to the

main experiment, and confirm the validity of the tools used to measure functional variables. To determine the required training intensity, a second pilot study was conducted for the exercises used by determining maximal heart rate in the same sample. This study was implemented on Wednesday, 23/10/2024, at 3:30 p.m. Training load components were regulated by administering maximal physical exercises to determine maximal heart rate. These exercises included:

- A 30 m sprint from a standing start.
- A 30 m hopping exercise, divided into 15 m hopping on the right leg and 15 m hopping on the left leg.

To control exercise intensity during training sessions, resting heart rate was measured for each player before maximal exercises and immediately after completion via the carotid artery during the first 6 seconds, with the result multiplied by 10 to obtain beats per minute, as this method is considered the most accurate (Al-Qatt, 1999, p. 43).

In coordination with the coaching staff, the researchers also conducted a pilot training unit involving repeated maximal-intensity speed exercises to achieve the required training intensity, determine exercise duration and repetitions prior to the main experiment. The purposes were to:

- Determine the number of exercises used for each physical and motor ability within a training unit.
- Verify the duration of the training unit.
- Regulate training load components, including maximal repetitions and maximal-intensity exercises, to determine the required intensity.
- Assess players' acceptance and understanding of the exercises and their level of difficulty.

2.6 Main Experiment

2.6.1 Pre-tests

After completing the research procedures and pilot studies, the researchers conducted the pre-tests on the research sample at the hall of the National Center for Sports Talent Care in Handball, Baghdad, at 3:30 p.m. on Monday, 28/10/2024, in the presence of all members of the experimental and control groups, according to the following sequence:

Physical ability tests were administered, including the speed–strength test for the right and left legs, the anaerobic functional variable test represented by the 10 s step test, and the individual defensive movement test (intercepting and deflecting the ball among three attacking players). Adequate rest was provided between tests in the form of turn-waiting rest periods ranging from 10 to 15 minutes, which was sufficient for heart rate to return to its normal warm-up level (110–120 beats/min). This ensured that players were prepared to perform each subsequent test with maximal

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effort. Test results were recorded by the coach and the assisting team (Appendix 4), with support from the researchers.
The pre-test results were used to establish equivalence between the research groups, as shown in Table (2).

Table2. *Equivalence between the control and experimental groups*

Test	Unit	Control group (Mean ± SD)	Experimental group (Mean ± SD)	t-value	Sig.	Significance
Triple hop (right leg)	m	3.393 ± 0.458	3.284 ± 0.219	0.678	0.50	Not significant
Triple hop (left leg)	m	2.493 ± 0.338	2.394 ± 0.363	0.544	0.43	Not significant
Step test (10 s)	count	53.600 ± 3.717	55.800 ± 3.259	1.407	0.17	Not significant
Interception & deflection test	count	2.600 ± 0.516	2.300 ± 0.483	1.342	0.19	Not significant

2.6.2 Preparation and Implementation of Repeated Speed Exercises

After reviewing the relevant sources and studies in the field of sports training science, the researchers determined the content and principles for designing repeated speed exercises at maximal intensity. These exercises were incorporated into the training program of the experimental group, starting on Saturday, 2/11/2024, and ending on Wednesday, 25/12/2024. The program included the following components:

- The exercises were implemented during the main part of the training session within the prescribed training curriculum of the sample. The program was applied for a duration of **8 weeks**, with **three training sessions per week** on **Saturday, Monday, and Wednesday**, resulting in a total of **24 training sessions**. The total duration of each training session was **120 minutes**, while the main part lasted **90 minutes**. The repeated speed exercises were performed for a period ranging between **25 and 35 minutes** within the main part of the session.
- A variety of training methods were employed within the program and its main section, including **high-intensity interval training** and **repetition training**, with intermittent recovery periods. Training intensity ranged between **80% and 100%** of the player's maximum performance.
- To avoid excessive fatigue, considering that the musculoskeletal system of young players is still in a developmental stage, **high-intensity exercises were kept very short** (e.g., **5–15 seconds of maximal effort**), followed by adequate recovery periods with **work-to-rest ratios of 2:1 or 3:1**. To prevent repeated severe fatigue, the program began with **submaximal intensity** and gradually progressed to **maximal intensity**. The number of repetitions ranged from **3 to 5 repetitions**, with **2 sets**, and rest intervals between sets were determined according to exercise duration and intensity.
- Training load levels were divided into **moderate, high, and maximal** throughout the duration of the training program.

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- Training intensity was determined based on the player's **maximum heart rate**, calculated according to the following equation (Al-Bashtawi & Al-Khawaja, 2005, p. 66):

$$\text{Maximum heart rate} = 220 - \text{age}$$

$$\text{Target heart rate} = \frac{\text{Maximum heart rate} \times \text{Required intensity}}{100}$$

Heart rate is considered one of the most important and easily applicable physiological indicators in practical settings. It allows for the determination of training load intensity and provides coaches with rapid and reliable feedback on the responses of functional systems during training, thereby guiding the regulation of training load (Al-Basati, 1998, p. 44).

Post-tests

After standardizing the conditions related to the pre-tests—such as location, timing, and execution procedures—to ensure consistency, the researchers conducted the post-tests on **Friday, 27/12/2024**, at **3:30 p.m.**, under the same temporal, spatial, and instrumental conditions as those of the pre-tests. All tests applied in the pre-test phase were repeated to ensure accuracy and comparability of the results.

3. Presentation and Discussion of Results

3.1 Presentation and Discussion of the Pre- and Post-Test Results for the Experimental and Control Groups

Table (3) presents the arithmetic means, standard deviations, mean differences and their standard deviations, *t*-values, and significance levels for the pre- and post-test results of all research variables for the **experimental group**.

Table.3. *Means, standard deviations, mean differences, t-values, and significance between pre- and post-tests for all research variables in the experimental group*

Test	Unit	Pre-test Mean	SD	Post-test Mean	SD	Mean diff.	SD diff.	t-value	Sig.	Significance
Triple hop (right leg)	m	2.285	0.219	4.028	0.286	1.743	0.444	10.283	0.01	Significant
Triple hop (left leg)	m	2.934	0.326	3.891	0.980	0.885	0.361	11.131	0.002	Significant
Step test (10 s)	count	55.800	3.259	62.850	5.366	7.050	4.290	5.197	0.00	Significant
Interception & deflection among three attackers	count	2.300	0.483	4.100	0.567	1.800	0.632	9.000	0.00	Significant

Significant when the error level ≤ significance level (0.05).

Table (4) presents the arithmetic means, standard deviations, mean differences and their standard deviations, *t*-values, and significance levels for the pre- and post-test results of all research variables for the **control group**.

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Table 4. *Means, standard deviations, mean differences, t-values, and significance between pre- and post-tests for all research variables in the control group*

Test	Unit	Pre-test Mean	SD	Post-test Mean	SD	Mean diff.	SD diff.	t-value	Sig.	Significance
Triple hop (right leg)	m	2.193	0.458	3.263	0.434	1.076	0.753	8.825	0.00	Significant
Triple hop (left leg)	m	2.493	0.338	3.118	0.187	0.625	0.184	7.762	0.01	Significant
Step test (10 s)	count	53.600	3.717	58.1795	6.0124	4.579	4.846	2.988	0.01	Significant
Interception & deflection among three attackers	count	2.600	0.516	3.500	0.527	0.900	0.875	3.250	0.01	Significant

Significant when the error level ≤ significance level (0.05).

Discussion of Results

Based on the results presented in Table (3), a statistically significant improvement was observed in the explosive leg power variable, represented by the triple hop test for the right and left legs, in the experimental group in favor of the post-test. This finding confirms the effective impact of repeated maximal-intensity speed exercises on developing and enhancing the explosive power of the leg muscles. These exercises enabled the players to utilize this power efficiently during repeated forward hopping when performing the test, indicating that the implemented exercises were designed according to sound scientific principles that allowed players to generate maximal force in the shortest possible time.

The researchers intentionally designed the exercises to emphasize repetitions characterized by rapid and powerful muscular contractions in order to increase muscle elasticity and maximize energy utilization to support forward propulsion. The researchers believe that this improvement in speed–strength resulted from the development of the muscle groups involved in performance under intensities greater than those to which the players were previously accustomed, thereby creating a favorable interaction between strength and speed. This is consistent with the findings of Hussein and Naseef (1987, pp. 95–96), who stated that the development of speed–strength occurs through two primary methods: improving muscular strength and increasing the rate of muscular contractions. This indicates enhanced development of the working muscle groups and an increased contraction speed among the experimental group.

Rey (2019, p. 25) also confirmed that performing repeated sprint training twice per week over a period of 7–10 weeks improves sprint performance, acceleration, sprint time, repeated sprint ability, high-intensity running, and change-of-direction performance in sports. In addition, Kazem, Widad, and Hisham (2018, p. 11) emphasized that speed–strength is closely associated with skill performance; the greater the speed–strength possessed by the player, the higher the level of skill performance. This type of strength is particularly essential for handball players in general and for defensive movements in particular. Therefore, speed–strength occupies a considerable proportion of training time and is closely linked to the degree of technical skill mastery (Abu Al-Ala, 1997, p. 133).

Regarding the phosphagen anaerobic functional variable, represented by the 10-second step test, Table (3) shows statistically significant differences between the pre- and post-tests for the experimental group in favor of the post-test. These marked inexpensive deltas arise from the multiplicity of repeated speed efforts at maximum and sub maximum paces, employed in a well-organized scientific manner. These exercises constituted multi-directional-runs/sores/hurdles/get-ups and variable -speed movements that had a greater effect on anaerobic functional variables.

Handball skills, especially under the modern amendments to the laws of the game that emphasize fast-paced performance, require rapid movements and frequent high-intensity actions. The researchers believe that the nature of training exercises and match movements demands high-speed transitions across the court; as the workload on the body's functional systems increases, reliance on anaerobic energy systems also increases. Consequently, players are able to sustain high-level performance efficiency throughout numerous offensive and defensive situations during the match.

Bishop (2011, p. 756) indicated that performing sprinting actions with changes in direction or executing high-intensity efforts over short durations requires a high level of anaerobic capacity, as anaerobic power is directly associated with muscular strength in accomplishing work within a limited time. Furthermore, the improvement observed in physical abilities—particularly speed–strength—among the experimental group positively influenced their performance in the 10-second step test. This is also something that the scientists put down to the creation of hypoxia within muscle groups which work under high-intensity and transient intervals. The application of maximal along with submaximal intensities, a gradual progression from the submaximal to the maximal loads and the provision of suitable intermittent recovery periods, allowed an extended working muscles' stimulation. Moreover, sport-specific drills which mimicked actual game movement when both ball and opponent were present (i.e., with the ball in and without a defender) took up a large amount of the primary portion of training…worked quite well at increasing players' efficiency in task performance.

With respect to individual defensive movements, represented by the test of intercepting and deflecting the ball among three attacking players, Table (3) indicates statistically significant differences between the pre- and post-tests for the experimental group in favor of the post-test. The enhancement is believed to be a result of the nature of the exercises we designed that aimed at enhancing specific defensive actions for several repetitions under maximal and submaximal speed with-in one exercise and among different vitality levels. This approach enhanced performance efficiency both without the ball and in the presence of an attacking opponent, thereby increasing players' motivation, competitiveness, and engagement during training sessions.
Individual defensive movements represent a preparatory phase for offense and are often associated with rapid transition to defense immediately after ball loss. This was supported by Al-Badri (2013, p. 48), who stated that a player characterized by a high level of motor anticipation is better able to select the appropriate timing to step out, intercept passes, gain ball possession, and deflect the ball effectively.

Regarding the control group, Table (4) shows improvements in all investigated variables; however, these improvements were of a lesser magnitude compared with those observed in the

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experimental group. The researchers attribute this development to the diversity of exercises implemented by the coach, without reliance on a single training method, as well as the emphasis on distributing training loads in a manner appropriate to the exercises and the working muscle groups. The training program included varied offensive and defensive movements, speed execution with and without the ball, and drills performed in confined playing areas, which contributed to enhancing players' physical and functional fitness.

The observed improvement in post-test performance is considered a natural outcome of the regular training methods adopted by the coach, whose primary objective was to improve players' performance levels to sustain match play. As the efficiency of the body's functional systems improves, the contribution of the energy systems utilized in handball increases, enabling players to maintain performance efficiency. Ismail (1996, p. 24) defined speed–strength as the individual's ability to overcome resistance using high and varied movement speed to achieve the highest possible movement frequency, such as short-distance sprinting.

Moreover, the coach's reliance on practical experience in designing training units that incorporated physical exercises with varying intensities—including bodyweight resistance, added weights, lateral jumps, and forward–backward movements with and without the ball—contributed to the development of both defensive and offensive performance throughout the training period.

These exercises were applied according to the principle of repetition and involved varied situations with teammates or opponents, which positively reflected on players' responses to different game situations. This supports Mahmoud's (1994, p. 54) assertion that continuous training plays a vital role in enabling players to reach high levels of technical performance in terms of accuracy, integration, stabilization, and mastery of advanced technical skills. This was clearly reflected in the significant differences between the pre- and post-tests in favor of the post-test results.

Presentation and Discussion of the Post-Test Results for the Experimental and Control Groups

Table (5) presents the arithmetic means, standard deviations, calculated *t*-values, and significance levels for the **post-test results** of all research variables for both the **experimental** and **control** groups.

Table5. *Means, standard deviations, t-values, and significance between the experimental and control groups in the post-tests for all research variables*

Test	Unit	Experimental Group (Mean ± SD)	Control Group (Mean ± SD)	t-value	Sig.	Significance
Triple hop (right leg)	m	4.028 ± 0.286	3.263 ± 0.434	4.44	0.00	Significant
Triple hop (left leg)	m	3.891 ± 0.980	3.118 ± 0.187	3.41	0.01	Significant
Step test (10 s)	count	62.850 ± 5.366	58.1795 ± 6.0124	1.833	0.04	Significant
Interception & deflection among three attackers	count	4.100 ± 0.567	3.500 ± 0.527	2.449	0.02	Significant

Significant at the 0.05 level when Sig. ≤ 0.05.

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Discussion of Results

Based on the results presented in Table (5), statistically significant differences were observed in the post-test results between the two groups in all studied variables, in favor of the experimental group.

With regard to explosive leg power, represented by the triple hop test for the right and left legs, the researchers attribute this superiority to the repeated speed exercises designed to develop hopping and running in multiple directions, both without an opponent and in the presence of an opponent with the ball. In addition, the use of training aids such as cones and elastic resistance bands, applied with appropriate durations and intermittent rest periods, was well suited to developing this essential ability in handball. Al-Moussawi and Talib (2021, p. 165) showed that moving at high speed helps improve strength, speed and range of movement therefore training with elastic bands is an effective way of achieving the development of speed–strength. This type of training may develop further speed and fatigue resistance in the flexor arm and leg muscles, while providing more training time suitable for high velocity play and intense motor skills.

The researchers believe that the exercises applied to the experimental group led to increased efficiency of the leg muscles, which was reflected in improved neuromuscular coordination through the recruitment of an optimal number of motor units during muscular contractions. Some scholars (Shaiky, 1986, p. 74) have confirmed that the results of research demonstrate that various jumping and running exercises improve neuromuscular efficiency, enabling the performance of fast and powerful jumps. Mohamed (2014, p. 26) also emphasized that intramuscular and intermuscular coordination is among the most important factors associated with speed–strength. This improvement can be attributed to the stimulation of the working muscle groups under higher-than-usual intensities, which increases their contraction velocity. Moreover, the researchers note that players' commitment to the training sessions and their competitive and engaging execution of the exercises, without boredom, had a positive effect on the development of their physical abilities. This is consistent with Abdel-Khaleq (2005, p. 138), who stated that the development of speed abilities requires muscular contractions at relatively high velocities or contractions against appropriate resistance.

Regarding the phosphagen anaerobic functional variable, represented by the 10-second step test, the researchers attribute the significant post-test differences in favor of the experimental group to the positive effects of the training program implemented throughout the training units. The presence of an opponent, the use of the ball, maximal and submaximal training loads, and intermittent recovery periods—within a high-intensity interval and repetition training framework—contributed to the development of players' functional variables. Hussein and Qasim Hassan (1998, p. 562) observed that not only are short duration speed exercises useful for neural adaptation in the face of their complexity but also they stimulate motor units and creatine reactions which is a component of fundamental energy systems.. Bishop (2011, p. 756) further emphasized that the ability to sprint with changes of direction or to perform high-intensity efforts over short durations requires a high level of anaerobic capacity, as anaerobic power is closely linked to muscular strength in accomplishing work within a limited time.

In individual defensive actions which divided into interception and deflection test, it was found that; Post-test results were statistically significantly difference between the two group ($p<0.05$), in favor of experimental group as shown in Table (5). The researchers speculate that this can be attributed to the similarity of defensive movements performed during handball training and competition (mirror game-related activity). These exercises constituted plyometric activities in the development of speed or conditioning which allowed players to move from side to side, backward and forward on a continuous basis. To assert an effective defense the player must have a capability and readiness to make the right movements preventing his or her opponent gaining certain advantage. This was confirmed by Aliya Ali and Qasim (2022, p.10) who underscored that the training environment should be as close, or even higher level than the match for optimum training effect to take place. Coaches may cause players to be exposed to different training stimuli, since variation of training units appears as basis for adaptations that develop skill execution more proficiently.

Finally, while acknowledging the effectiveness of the training program designed for the experimental group, the researchers do not underestimate the role of the coach and the training curriculum applied to the control group. The exercises implemented aimed to develop both individual and collective aspects of offensive and defensive performance, which resulted in a relative improvement among control group participants; however, this improvement remained less pronounced when compared with the experimental group.

Conclusions

1. Repeated speed exercises demonstrated a positive and statistically significant effect on the development of speed–strength of the legs (right and left) in the experimental group, indicating the effectiveness of these exercises in improving the ability to generate maximal force in the shortest possible time, as well as increasing muscle elasticity and energy output.
2. Repeated speed exercises effectively contributed to improving the phosphagen anaerobic functional variable in the experimental group.
3. The designed exercises led to a significant improvement in individual defensive **movement**, including ball interception and deflection, in the experimental group. This improvement is attributed to repeated training under maximal and submaximal speeds and game-like situations with the presence of an opponent, which enhanced performance efficiency and increased players' motivation.
4. A lesser degree of improvement was observed in the investigated variables in the control group compared with the experimental group, which can be attributed to the diversity of the coach's exercises aimed at improving general performance and physical and functional fitness.
5. Post-test comparison between groups showed statistically significant toward the experimental group for all variables (leg speed-strength, phosphagen anaerobic capacity and individual defensive movement), demonstrating that RSE was more effective than isolated exercises to provide improvement of those abilities.

Recommendations

1. From its overall effects, we suggest that RST should be included in the training programmes of handball players at all youth age levels, especially in under-15 players.
2. Coaches should develop training exercises that incorporate short, high intensity sprints with shorter recovery periods, considering the growth characteristics of the musculoskeletal system in young players to avoid excessive fatigue.
3. training exercises more game-like in nature, characterized by competition and challenge, to increase athletes' motivation and focus, as well as work on their efficiency in performing actions widespread when playing defense or stealing the ball.
4. Subsequent studies should explore the impact of RSE with REGARD on other components of handball performance (offensive performance or game-related variables) and others age categories.
5. scientific monitoring of players' functional and physical variables is required to maintain the effectiveness of training programmes and make necessary changes according to players' demands.

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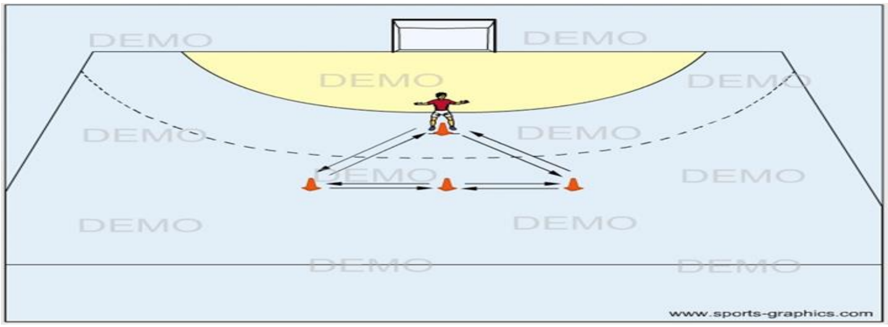
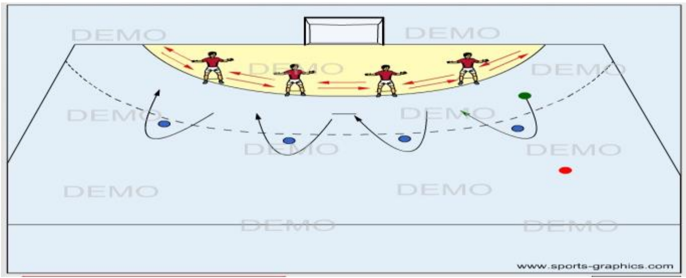
Appendix (1)

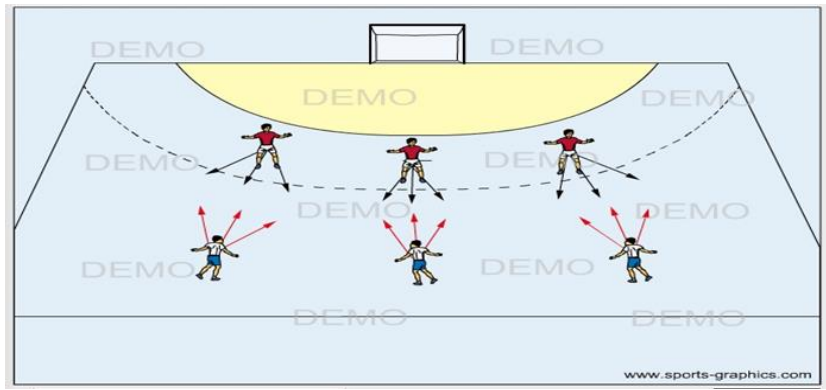
Sample of Repeated Speed Exercises
Exercise (3)
Method of Performance:
The player performs a series of varied defensive movements starting from point A to point C, then returns to the same point. Next, the player moves laterally to point B, retreats backward to point D, then advances forward to point C, and returns backward to the same point. After that, the player sprints to point B, and the sequence is repeated continuously in the same manner.



Exercise (5)
Method of Performance:
Four defenders perform lateral defensive movements along the 6-meter line while using an elastic resistance band. Upon the coach's signal, the players move forward, circle around a medicine ball, and then return to lateral defensive movements along the same line.



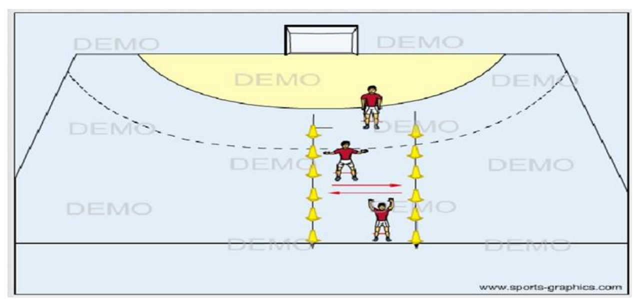
Exercise (9)
Method of Performance:
A 1×1 confrontation drill is performed within a confined space not exceeding 3 meters, without the ball. The attacker attempts to pass the defender by moving in different directions, while the defender maintains close proximity, using proper footwork and body positioning to prevent the attacker from breaking through.



Exercise (17)

Method of Performance:

Twelve training poles (cones) are arranged in pairs in front of the player, with a distance of 3 meters between each pair. Upon the start signal, the player moves forward and performs a lateral sliding movement with both legs together, using an elastic resistance band, progressing between the arranged poles.



Appendix (2)

Sample Weekly Training Units

Day	Date	Exercise No.	Unit Intensity Level	Weekly Intensity Level	Training Volume	Rest Between Repetitions	Sets	Rest Between Sets	Total Exercise Time (min)	Total Unit Time (min)
Saturday	2/11	4	85%	86.66%	10 s × 3	20 s	2	90 s	6.0	27.66
		3			12 s × 3	24 s		90 s	7.8	
		17			8 s × 4	24 s		90 s	6.19	
		9			10 s × 5	20 s		90 s	7.67	
Monday	4/11	3	85%		10 s × 4	20 s		90 s	7.0	30.3
		11			15 s × 3	30 s		90 s	7.5	
		12			10 s × 5	20 s		90 s	8.0	
		20			12 s × 4	24 s		90 s	7.8	
Wednesday	6/11	5	90%		15 s × 3	30 s		90 s	7.5	29.43
		10			8 s × 5	24 s		90 s	8.33	
		6			10 s × 4	20 s		90 s	7.0	
		7			12 s × 3	24 s		90 s	6.6	

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