Effectiveness of Weight Training Program on Maximal Muscular Power of the Arm, Some Biomechanical Properties and the Digital Record of 100m Freestyle Swimmers

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Abstract:

The current research aims to identify the effectiveness of utilizing weight training to improve maximal muscular power of the arm and the digital record and its effects on some biomechanical properties of the arm in 100m freestyle swimmers. The researcher used the experimental approach (one-group design) with pre- and post-measurements. Research community included swimmers of Alexandria Swimming Zone (n=58). The researcher purposefully recruited (20) swimmers as (10) were chosen as a pilot sample while the other (10) represented the experimental group. Results indicated that:

- The recommended weight training program had a significantly positive effect on the maximum muscular power of the arms of the swimmers (research sample).
- The recommended weight training program had a significantly positive effect on the digital performance level of the 100-meter freestyle swim.
- The recommended weight training program positively influenced the development of some mechanical properties of the arm in the 100-meter freestyle swim.
- Weight training overcomes the speed deficiency resulting from traditional training, in addition to its nature being closer to the actual performance during swimming.

Keywords*: Arm Muscular Power - Biomechanical Properties - Digital Record – 100m Freestyle*

Introduction:

Swimming training relies on developing the specific physical components of each of its types, alongside developing the essential skills for these types and the technical methods of performing them. **Meglischo** (2003, p. 88) highlighted the importance of dry-land training outside of water in the physical preparation of swimmers to achieve the highest level of motor performance in swimming through physical development. Developing muscular power is crucial for swimming, as it is needed for the rapid alternating and sequential movements of the arms and legs, especially in short-distance swimming. Swimmers also need it to push off strongly at the start and to perform turns (**Swaine**, 2000).

In swimming, particularly, there are muscles involved in the push and pull movements of the arms, and muscles involved in the push and pull movements of the legs. Hence, there are muscles that execute the movement, opposing muscles that relax when the working muscles

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contract, muscles that assist in completing the movement, and muscles that stabilize the joint in the direction of the movement. These include various muscles like the shoulder flexion muscles and the Pectoralis Major muscles. After several months of specialized training, this group of muscles becomes stronger than the opposing muscles and the muscles of the left limb, as well as the back muscles, leading to an imbalance in strength between the working muscles and the opposing muscles (**McLeod**, 2008).

The impact of swimming on the muscles involved in freestyle swimming is further clarified by what **Meclod** (2010, p.3) indicated that the fundamental difference between freestyle swimming and dolphin swimming is that the arms move as a single unit in dolphin swimming, whereas the movement is alternating in freestyle swimming.

When designing strength programs, it is crucial to select exercises that work on both sides of the joint. This way, the body and its levers become structurally stable on each side. The goal is to develop the player's muscle strength as evenly as possible because the swimmers' joints need to be surrounded by well-developed muscles in a balanced manner (Cools, et al, 2007). McLeod (2008) pointed out the necessity of following strength and stretching training programs to develop muscle balance to prevent injuries of the shoulder joints, trunk, ankle, and knee. The type of strength training used to improve the muscular balance of the muscles working around the scapula is related to the prevention and treatment of shoulder joint injuries (Guillermo, 2003).

Body position and mechanical aspects of technical swimming performance are among the most important factors affecting speed. To increase speed, it is crucial to reduce the resistance faced by the body during swimming by minimizing body resistance in the water. Body position can be observed using a video camera, followed by feedback to correct the body position (**Abu Al-Ala and Salem**, 2011, p. 49; **Maglischo**, 2003).

Biomechanics can be utilized in all sports during training and developing motor performance. The property of motor transfer is of utmost importance for motor performance, as it is one of the distinctive properties of sports movement, with a clear goal and a defined level. This means that it is not enough for the player to merely possess the ability to perform; the performance must be at a level that meets the standard rates for these movements. This is one of the tasks that kinesiology aims to achieve: to reach the highest level of movement permitted by human abilities and capacities (**Al-Fadli**, 2010, p. 153).

Front crawl (freestyle) ranks first among the four swimming styles due to its wide popularity and speed in achieving the best economic results in energy usage and time taken to cover distances. According to the international regulations of Olympic swimming in 2009, this type of swimming, known as freestyle swimming, is characterized by a horizontal body position, always on the stomach, to reduce frontal resistance faced by the swimmer. It also features alternating movements of the arms and legs in the water to perform their function effectively. The kinetic analysis of arm movements in the 100-meter freestyle swimming involves advancing in water by pushing water backwards. Arm movements contribute approximately with 70-80% to the total rate of progress. Arm movements rely on two main phases: the propulsive phase and the recovery phase (Zaki et al., 2002, p. 84).

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The problem of this research lies in the fact that the 100-meter freestyle swimming heavily relies on continuous arm movements in a short time, controlled by certain mechanical properties, including (angular velocity of the upper arm, angular velocity of the forearm, resultant arm momentum, resultant arm power). However, traditional strength training methods do not provide the arm muscles with the appropriate contraction speed for these types of variables.

Therefore, the researcher believes that the importance of this research lies in its attempt to study the effectiveness of weight training on maximal muscular power, some mechanical properties of the arm, and the digital performance level in the 100-meter freestyle. The research problem is the necessity of a scientific diagnosis of the movement represented in an Ideal athlete performing the 100-meter freestyle through biomechanical analysis of the race. This includes the arm movement position, resulting mechanical properties, and the verification of the relationship between the synchronization of arm movements and the final race result, which reflects the athlete's success in meeting the biomechanical requirements of ideal performance.

Aim:

The current research aims to identify:

1. The effectiveness of utilizing weight training to improve maximal muscular power of the arm and the digital record in 100m freestyle swimmers.
2. The effects of utilizing weight training on some biomechanical properties of the arm in 100m freestyle swimmers.

Hypotheses:

1. The recommended weight training program has positive effects on the maximal muscular power of the arm and the digital record in 100m freestyle swimmers.
2. The recommended weight training program has positive effects on some biomechanical properties of the arm in 100m freestyle swimmers.

Methods:

Approach:

The researcher used the experimental approach (one-group design) with pre- and post-measurements.

Participants:

Research community included swimmers of Alexandria Swimming Zone (n=58). The researcher purposefully recruited (20) swimmers as (10) were chosen as a pilot sample while the other (10) represented the experimental group. Swimmers were chosen according to their 100m

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freestyle digital records and other variables that show homogeneity of participants' data as seen in table (1).

Table (1): Mean, SD, Median and Squewness of Participants on Growth and Physical Variables and Digital Record (n= 20).

Variables		Measurement	Mean	SD	Median	Squewness
Growth variables	Age	Year	17.07	1.90	21.00	0.11
	Height.	Cm	175	4.35	178	−0.68
	Weight	Kg	70.30	2.86	71.00	0.31
Physical variables	Shoulder–level weight throwing (900 g)	M	27.77	1.87	28.06	−0.46
	Overhead two–hand pushing of a medicine ball (2 kg) from sitting	M	8.85	0.93	9.06	−0.67
	Two–hand pushing of a medicine ball (3 kg) from sitting	M	6.11	0.68	6.30	−0.83
	One–hand pushing of a medicine ball (3 kg).	M	11.65	1.19	11.20	1.13
	Digital record	Sec	1.12	0.42	1.21	−0.43

According to table (1), all Squewness values for all variables under investigation were between (±3). This indicates data normality for participants.

Data Collection Tools:

Measurement Tools:

- A restameter for measuring heights
- A medicine balance for measuring weights
- A measuring tape
- A stop-watch
- Medicine balls (2 – 6kg)
- A multi-unit weight training device (Smith Barbell).

Motion Analysis Tools:

- A disk-top computer
- "Motion Track" software
- Sticky markers
- Video camera (60 Cadre/ Sec).
- A tripod

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- A 1x1 m scale

Physical Tests:

According to review or related literature, the researcher chose (4) tests to measure maximal muscular power, in addition to 100m freestyle digital record. These tests are:

1. Shoulder-level weight throwing (900 g)
2. Overhead two-hand pushing of a medicine ball (2 kg) from sitting
3. Two-hand pushing of a medicine ball (3 kg) from sitting
4. One-hand pushing of a medicine ball (3 kg).

(Ismail, 2016; El-Nimr & El-Khateeb 2005; Hassanain 2003, 2004)

The Recommended Weight Training Program:

The researcher considered important principles of designing the training program in terms of intensity, volume, and selecting ballistic exercises that are similar in their temporal and geometric paths to the force produced by the working muscles during the performance of the 100m freestyle swim. The researcher prepared a set of exercises using various devices and tools such as "medicine balls, kettlebells, multi-weight machines like the Smith machine." The researcher also took into account the ability of participants to perform ballistic exercises and relied on the theory of using resistance that matches the strength, speed, and elasticity of the muscles to achieve the program's goal of developing maximal muscular power of the arms as a means to improve the mechanical efficiency of the arms, aiming for a better digital record.

Duration of the Training Program:

Muscular strength does not develop quickly, and training for several weeks contributes to its development. A period of eight weeks is sufficient to reach a measurable level of muscular strength. The duration of a training session ranged from 60-90 minutes, which is adequate considering the total number of program weeks (Ismail, 2016; Al-Nimr & Al-Khatib, 2005; Hassanin, 2004; Hassanin, 2003; Baker, 2001).

The number of training units should not exceed three per week to allow muscles and joints sufficient recovery before the next session due to the high intensity and nature of the exercises (Fleck & Kramer, 2004, p.19; Fox, 1997, p.103). Based on this, the researcher determined an eight-week application period with three training units per week, resulting in a total of 24 training units, with each unit lasting between 75 and 90 minutes.

The researcher emphasized developing maximum muscular strength before starting the training program through a set of weight training exercises, which is essential for achieving the purpose of ballistic exercises. This ensures that the muscles can handle sudden changes in force and speed simultaneously (Chu, 2000, p.42).

Training Loads Intensity:

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The intensity of load in training ranges from 30% to 40% of maximum intensity, which represents the maximum weight that can be lifted once (1RM) in weight training to avoid overburdening the body and negatively affecting muscle contraction speed, which can cause injuries.

For free weights (medicine balls, kettlebells), the intensity can be determined by the weight of the tool itself, with medicine balls weighing between 2 to 6 kg and kettlebells between 5 to 10 kg (Fleck & Kramer, 2004; Baker, 2001).

The appropriate volume in weight training should be 10-12 repetitions, with 3-5 sets and rest periods of 2-3 minutes between sets. For free weights, repetitions range from 10-15, with 1-3 sets and rest intervals between sets from 2-3 minutes (Fleck & Kramer, 2004).

Parts of Training Session:

- **Warm-Up:** This part aims to prepare the muscles and cardiovascular and respiratory systems for the type of muscular work to be performed in the training session, focusing on flexibility and stretching exercises and general warm-up exercises. This part lasts between 15-20 minutes, with weight training intensity during the warm-up ranging from 20% to 30% of the main part's intensity.
- **Main Part:** This part of the training session contains ballistic exercises that achieve the unit's goal, contributing to the development of maximum muscular power and some mechanical properties of the arm outside the water. This part generally represents 75% of the training session's duration.
- **Conclusion:** This part includes relaxation in-water exercises, with a duration of 5-10 minutes.

Pilot Study:

The researcher conducted a pilot study on a sample of 10 swimmers to assess the suitability of the recommended training program for the research sample, ensure the validity of the filming procedures for motion analysis, and all used tools. The study also aimed to verify the tests used to measure maximal muscular power, calculating the scientific coefficients for the tests (validity and reliability). To calculate validity, the researcher used differential validity between two groups, one distinct from the research community and outside the main sample (10 swimmers), and the other non-distinct from the research community and outside the main sample (10 swimmers), as shown in tables (2) and (3).

Table (2): Difference Significance Between the Distinct and Non-distinct groups on the Physical Tests Under Investigation (for Validity) (n1 = n2 = 10)

Physical tests		Measurement	Distinct		Non–distinct		(t)
			Mean	SD±	Mean	SD±	
1	Shoulder–level weight throwing (900 g)	M	27.63	1.86	22.54	2.53	3.06*

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2	Overhead two-hand pushing of a medicine ball (2 kg) from sitting	M	9.05	1.03	6.23	0.89	4.11*
3	Two-hand pushing of a medicine ball (3 kg) from sitting	M	6.10	1.59	3.55	1.22	3.39*
4	One-hand pushing of a medicine ball (3 kg).	M	11.53	1.68	8.13	2.04	6.83*

(t) table value on P ≤0.05 = 2.26

Table (2) indicated statistically significant differences on P ≤0.05 between the distinct and non-distinct groups on all research variables. This proves the validity of tests.

Table (3): Difference Significance Between the Test and Re-test on the Physical Tests Under Investigation (for Reliability) (n = 10)

Physical tests		**Measurement**	Test		Re-test		(R)
			Mean	SD±	Mean	SD±	
1	Shoulder-level weight throwing (900 g)	M	27.63	1.86	27.69	1.78	0.885*
2	Overhead two-hand pushing of a medicine ball (2 kg) from sitting	M	9.05	1.03	8.97	1.55	0.856*
3	Two-hand pushing of a medicine ball (3 kg) from sitting	M	6.10	1.59	6.17	1.71	0.778*
4	One-hand pushing of a medicine ball (3 kg).	M	11.53	1.89	11.61	1.68	0.826*

(R) table value on P ≤0.05 = 0.632

Table (3) indicated statistically significant differences on P ≤0.05 between test and re-test on all research variables. This proves the reliability of tests.

Determining the Phases of Performance Under Investigation:

According to the capabilities of the motion analysis unit used, the researcher studied the arm strokes' motor performance in the 100m freestyle swimming from the moment of water entry. This phase will be divided into time moments that are easier to study.

Filming Procedures:

The researcher filmed participants according to the requirements and needs of the motion analysis program and the research objectives, ensuring that the swimmer is clearly visible in the camera frame throughout the technical phases and time moments to be studied. Consequently, guiding markers were placed on the arm joints, and cameras were placed underwater. After verifying the validity of all the previously mentioned procedures in the pilot study, all procedures became ready and valid for the main experiment.

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Main Study:

Pre-Measurements:

Pre-measurements of mechanical variables and digital performance levels were conducted. The researcher ensured the application of all scientific conditions in the filming procedures. Each swimmer performed three legal attempts, and the best attempt was digitally analyzed. Thus, the number of attempts analyzed was 10.

Physical measurements for maximal muscular power of the arms were conducted the day after filming the research experiment to ensure all swimmers had sufficient rest before the physical measurement.

Application of the Training Program:

The recommended training program was applied to participants (n=10). The researcher ensured the program was implemented during the preparation period to benefit from performance mastery. The researcher also ensured that the weekly training units for all swimmers were consistent to avoid fatigue and isolate all external variables that could affect research results.

Post-Measurements:

After completing the training program, the researcher conducted post-measurements following the same protocol of the pre-measurements. After obtaining all the raw data, it was tabulated and prepared for statistical analysis.

Statistical Treatment:

The researcher used SPSS software to calculate the following:

Mean – SD – Median – Squewness – Correlation Coefficient (R) – (t) test – Improvement percentage (%).

Results and Discussion:

Maximal Muscular Power and Digital Record:

Table (4): Difference Significance Between the Pre- and Post-measurements on the Physical Tests Under Investigation and the Digital Record of Participants (n = 10)

Physical tests		Measurement	Pre–		Post–		(t)	Improvement (%)
			Mean	SD±	Mean	SD±		
1	Shoulder–level weight throwing (900 g)	M	27.83	1.36	31.14	2.03	7.52*	10.62
2	Overhead two–hand pushing of a medicine ball (2 kg) from sitting	M	8.91	0.84	10.22	0.87	3.70*	17.81

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3	Two-hand pushing of a medicine ball (3 kg) from sitting	M	6.17	0.85	7.87	1.43	4.03*	22.00
4	One-hand pushing of a medicine ball (3 kg).	M	11.70	1.05	13.53	1.87	3.96*	13.52
Digital Record		Sec	1.12	0.11	1.01	0.09	2.75*	9.82

(t) table value on P ≤0.05 = 2.26

Table 4 shows statistically significant differences between the pre- and post-measurements in favor of the post-measurement for participants in all physical tests and the digital record.

The researcher attributes these differences to the effective and positive role of training in developing the maximal muscular power of the arms for participants, as it combines strength and speed in its performance method and closely resembles the nature of freestyle swimming skills.

These results consistent with the study by Suzuki et al. (1999), which found that the first experimental group, aimed at studying the impact of flexibility training, showed statistically significant improvement after the program. In contrast, the second group, aimed at studying the impact of training on muscle stiffness, showed no negative statistical significance on the muscles using the latest CT imaging devices.

Table 4 also shows significant improvement in the four tests measuring the maximal muscular power of the arms, with improvement rates ranging from 10.62% to 22.00%, indicating the positive effect of the recommended training program on the muscular power level of participants. The results also indicate that the training improved the digital record by an increase of 2.05 meters, a 4.9% improvement.

Biomechanics is the science that provides the correct basis for coaches and teachers when it comes to teaching and training sports skills by finding solutions to questions about performance and athletic achievement in various movements, including pushing, pulling, and stretching. Understanding biomechanics leads to a comprehension of the fundamentals related to the anatomical, physiological, and mechanical aspects of an athlete's movements, which undoubtedly helps in learning and teaching skills and improving precise motor performance (Al-Fadli, 2010, p. 36).

Additionally, using training methods that closely mimic the nature of freestyle swimming performance is one of the advantages of this type of training (Olsen & Hopkins, 2003, p. 291).

From the above, the first hypothesis is confirmed: "The recommended weight training program has positive effects on the maximal muscular power of the arm and the digital record in 100m freestyle swimmers."

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Biomechanical Variables:

Pull Phase:

Table (5): Difference Significance Between the Pre- and Post-measurements on the Biomechanical Variables of the Arm During Pull Phase for Participants (n = 10)

	Variables	Measurement	Pre–		Post–		(t)	Improvement
			Mean	SD±	Mean	SD±		(%)
1	Upper Arm Angular Velocity	Degree/sec	197.22	10.49	252.78	9.11	5.12*	21.8
2	Forearm An=gular Velocity	Degree/sec	175.46	17.54	221.32	21.41	1.94	20.7
3	Arm Resultant Momentum	N/M/Sec	3.11	0.316	3.73	0.154	2.62*	16.6
4	Arm Resultant Power	J/Sec	134.29	7.97	171.23	11.33	0.954	21.5

(t) table value on P ≤0.05 = 2.26

Table 5 shows significant statistical differences between the pre- and post-measurements participants in the variables of the angular velocity of the upper arm and the resultant arm momentum, favoring the post-measurement. The improvement rates ranged from 16.6% to 21.8%.

The results of Table 5 indicate statistically significant differences in the variables of the angular velocity of the upper arm and the resultant arm momentum during the pull phase. The angular velocity of the upper arm reached 21.8% in the post-measurement. The researcher attributes this improvement to the positive effect of the training program on the biceps brachii, shoulder, and chest muscles, increasing the muscles' pulling capacity, which positively impacted the increase in the resultant arm momentum at the same moment. In the post-measurement, it was 221.32% Newton/meter/second, with an improvement rate of 16.6%.

Considering that the arm requires pulling and movement within the water around the shoulder joint, the results of Table 6 showed that the angular velocity of the upper arm increased by 21.8% in the post-measurement, reaching 252.78 degrees/second. This confirms the positive impact of the recommended training program on increasing the movement speed of the arm joint and some other mechanical variables during the pull phase.

Using rotational speed (angular velocity) around any joint provides the advantage of a higher linear speed if the radius length does not reduce the angular speed (Hossam El-Din et al., 2019, pp. 162-163).

Additionally, the strength in the handgrip movement is three times stronger than the hand extension movement in the wrist joint. Many scientists attribute this difference in several cases to the relationship between muscle size and the effective operation of the muscle's bone lever system,

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where the working muscle groups can produce greater torque than the opposing joint muscles (Noffal, 2003).

Push Phase:

Table (6): Difference Significance Between the Pre- and Post-measurements on the Biomechanical Variables During of the Arm Push Phase for Participants (n = 10)

Variables		Measurement	Pre−		Post−		(t)	Improvement
			Mean	SD±	Mean	SD±		(%)
1	Upper Arm Angular Velocity	Degree/sec	351.86	12.38	408.60	17.99	3.54*	13.9
2	Forearm An=gular Velocity	Degree/sec	3.33	0.195	4.19	0.484	3.1*	20.5
3	Arm Resultant Momentum	N/M/Sec	119.80	23.18	160.20	13.05	0.052	25.2
4	Arm Resultant Power	J/Sec	13841.2	470.75	16878.6	612.22	6.62*	17.9

(t) table value on P ≤0.05 = 2.26

Table (6) shows statistically significant differences between the pre- and post-measurements in favor of the post-measurement for participants in all mechanical variables, with improvement rates ranging from 13.9% to 25.2%.

The push phase of the arm joint in swimming is one of the most important performance phases in freestyle swimming, as it is responsible for pulling the body forward. Its strength is crucial for success in freestyle swimming.

Results in Table (6) indicate that the mechanical measurements show the positive effect of the training program during the push phase, with significant statistical differences in the variables of the angular velocity of the forearm in favor of the post-measurement, which reached 17.99 degrees/second. Since the arm in this phase works on both the shoulder and elbow joints, an increase in the angular velocity of the upper arm at this moment will increase the angular velocity of the forearm, as it is the lighter part. This is confirmed by the results, where the resultant momentum of the arm in the post-measurement increased to 4.19 m/s², with an improvement rate of 3.1%, positively affecting the increase in the resultant momentum of the arm.

Any change in the momentum of a body necessarily requires force, as momentum is the amount of movement that can increase or decrease by increasing or decreasing speed (Hossam El-Din et al., 2019, pp. 139-140).

Developing muscular endurance requires a high level of training load intensity, including the continuous pumping of blood through capillaries within the muscles to reach the adaptation stage, in addition to combining strength, speed, and endurance training (Doyle, 2010, p. 115).

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Table (7): Difference Significance Between the Pre- and Post-measurements on the Biomechanical Variables of the Arm During Push Phase for Participants (n = 10)

Variables		Measurement	Pre–		Post–		(t)	Improvement
			Mean	SD±	Mean	SD±		(%)
1	Upper Arm Angular Velocity	Degree/sec	193.74	13.62	237.31	19.52	3.26*	18.35
2	Forearm An=gular Velocity	Degree/sec	185.87	8.01	222.46	14.40	3.03*	16.4
3	Arm Resultant Momentum	N/M/Sec	4.46	0.348	5.54	0.612	6.22*	17.8
4	Arm Resultant Power	J/Sec	263.73	16.85	354.21	11.19	2.82*	25.5

(t) table value on P ≤0.05 = 2.26

Table (7) shows statistically significant differences between the pre- and post-measurements in favor of the post-measurement for participants in the mechanical variables under investigation. The improvement rates ranged from 16.4% to 18.65%.

Results of Table (7) indicate the positive effect of the recommended training program during the push phase, with the angular velocity of the upper arm and forearm in the post-measurement reaching 19.52 and 14.40 degrees/second, respectively, with improvement rates of 18.35% and 16.4%, respectively. This indicates a direct relationship between angular velocity and linear variables; as the angular velocity increases, the linear velocity also increases accordingly (Hossam El-Din et al., 2019, pp. 162-163).

These results are consistent with the study by Newton et al. (1999), which found that all measured strength variables during the two previous tests using a force platform showed positive improvement for the eight athletes in the experimental group.

Strength training tailored to the age group significantly increases the range of motion in joints. Many studies agree with the researcher's interpretation of the relationship between muscular strength and digital performance level (Hong-Sun et al., 2014).

Accordingly, it is evident that the second hypothesis of the research is confirmed, which states, "The recommended weight training program has positive effects on some biomechanical properties of the arm in 100m freestyle swimmers."

Conclusions:

According to this research aim, hypotheses, methods and results, the researcher concluded the following:

1. The recommended weight training program had a significantly positive effect on the maximum muscular power of the arms of the swimmers (research sample).

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2. The recommended weight training program had a significantly positive effect on the digital performance level of the 100-meter freestyle swim.
3. The recommended weight training program positively influenced the development of some mechanical properties of the arm in the 100-meter freestyle swim.
4. Weight training overcomes the speed deficiency resulting from traditional training, in addition to its nature being closer to the actual performance during swimming.

Recommendations:

In light of these conclusions, the researcher recommends the following:

1. Using weight training for short-distance swimmers due to its importance in developing the maximum muscular power of the arms and improving the mechanical properties of the arm.
2. Referencing the content of the recommended weight training program when designing similar training sessions using different tools and standardizing the training loads for this type of training.
3. Referencing the quantitative values of the mechanical variables of the arm during the pull, push, and release moments in the 100-meter freestyle as one of the benchmarks for mechanically evaluating similar performance samples.
4. Ensuring the provision of sufficient tools and equipment necessary for weight training, in line with modern standards and safety requirements.

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