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Muscular Strength of Swimmers

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Abstract:

Muscular strength is one of the basic physical attributes that directly influences performance level of swimmers, due to its critical function in producing arm propulsive force and enhancing movement efficiency in the aquatic environment. It is through the muscles of the arms, shoulders, and trunk that mechanical force is generated and transmitted into forward acceleration, which minimises the influence of water resistance and positively reflects on the swimmer's pace and continuity of performance.

Explosive strength is also a vital component at the start phase, as it enables the swimmer to produce maximal force in a short time, delivering a time advantage from the very beginning of the race. Success in this phase depends on the efficacy of the neuromuscular system in activating fast-twitch muscle fibers and employing them effectively.

Through this study attempt, we wish to highlight the relevance of investigating these variables in a thorough, scientific manner, given their vital role in enhancing race timings and competitive performance among swimmers.

Keywords: Muscular strength; arm propulsive force; explosive strength…

1. Introduction and research problematic

The specific nature of sports training may require focusing on one physical component or somatic measurement over another. Muscular strength is considered one of the most important components of physical fitness, and the swimmer needs to improve and develop this component, particularly the muscular fitness of the arms, shoulders, back, and chest. Each sport has its own specific body characteristics; therefore, the importance of studying them emerges as necessary requirements for performance level in swimming, especially in short distances (Hatim Saber, 2013, p.16).

Swimming as a sport does not deviate from the principle of needing these requirements in relative form, based on the specificity of performance. Swimming activity is distinguished from other sports by the continuous effort of all parts of the body without exception or pause throughout the duration of performance or achievement, which requires special demands such as muscular strength, body measurements, and body composition.

The importance of muscular strength is attributed to its strong association with certain physical and motor components, such as speed-strength, dynamic transition speed, and endurance, in addition to general health status and psychological state (Kani Hamid, 2018, p.11).

Muscular strength has gained a prominent place within training programs for high-level swimmers worldwide. The annual volume of training dedicated to muscular strength and muscular endurance reaches about 200–300 hours, divided between land-based and water-based training.

Thanks to scientific research that has established numerous facts and pieces of information, strength-training programs specific to swimming have evolved. Studies have confirmed the absence of a relationship between developing muscular strength through general methods and swimming speed.

At the same time, swimming coaches have recognized the importance of speed-strength for swimmers; however, methods of developing it differ from one coach to another. Some rely on weights to develop speed-strength, while others use different methods.

During the 1950s, it was believed that weight training hindered swimmers' development, based on the assumption that muscles would become larger and joint range of motion would decrease. This old notion has faded with the increase in experimental and scientific research, and weights have come to be used to develop muscular strength of swimmers.

Swimming as a sport especially needs the development of muscular strength in the muscle groups of the arms, shoulders, back, and chest. Although swimming training contributes to the development of muscular strength, the resistances faced by the muscle groups in water are not sufficient for swimmer development, particularly regarding speed-strength. For this reason, the relationship between muscular strength development and improvement of swimmers' race times must be reinforced (Hatim Saber Qader, 2013, p.42).

The main propulsive force enabling the swimmer to raise performance level comes from the arms, through phases such as catch, pull, push, and release for both arms, which provide approximately 75% of the swimmer's speed. In addition, the legs direct the body and provide about 60% of its forward speed. The swimmer uses them to raise the requirements of muscular work to overcome water resistance to body movement (Amr Mohamed, Adel Mohamed, & Moamen Taha, 2016, p. 90).

Each arm cycle can be divided into two parts. ***The first*** part is the propulsive phase: "the phase that results in the swimmer's movement or progress in the water in the desired path." ***The second part*** is the recovery phase: "the initial phase that results in the arms returning to start the next main phase" (Rateb, 1999, pp. 56–57).

Merryn (1998) indicates that a swimmer who possesses high levels of energy uses each muscle in the body from time to time. Based on this, water training is considered one of the most effective methods because the main muscles involved in swimmer propulsion are the leg muscles, arm movements, and assisting muscles such as the chest, back, abdominal, and neck muscles. As a result, water-based training contributes to developing and improving muscular strength in particular and physical fitness in general (Heba Helmy, 2007, p.135).

Qasim Hassan and Yusuf Lazim (2011) state that the propulsive movement generated by the legs allows resistance forces to be directed forward against the feet and shanks when they move backward in the water. This depends on the movement of the legs relative to the body rather than to the water.

To highlight frontal resistance forces on the legs, the legs should move backward relative to the water so that the water stream passes over them forward in the direction of the swimmer's body movement (Qasim Hassan & Yusuf Lazim, 2011, p. 205).

To increase the benefit from leg kicks, the feet should be kept inside the water during movement, because moving the feet from outside to inside the water creates large vortices due to air entering at the moment the feet enter the water, which increases drag (Abdullah, 2013, p. 158).

According to Abu Al-Ela and Hazem Hussein (2011), the swimmer relies on strength in the initial push-off at the start and when swimming off the pool wall. In addition, the swimmer needs a high level of muscular endurance to maintain pulling force in the water effectively over long periods (Abu Al-Ela & Hazem Hussein, 2011, p. 148).

From the foregoing, the two researchers consider it important to study this physical variable—muscular strength of swimmers—as a general basic variable under which specific variables fall, namely, arm propulsive force and explosive strength during the start. These are closely linked to the improvement of swimmers' performance level. They are considered fundamental pillars in the training process that help coaches lead athletes to the highest sports levels. Accordingly, the researchers pose the following question

To what extent does muscular strength contribute to the development of arm propulsive force and explosive strength during the start of swimmers?

2. Key research terms

2.1 Muscular strength

Linguistically:

It is the opposite of weakness; strength is a source of power, effectiveness, development, and movement.[ppl-ai-file-upload.s3.amazonaws]

In technical terms:

It is the capability of the muscle to overcome or confront an external resistance (Alaa, Khaled, & Hisham, 2021, p.106).

Strength has great weight as it is one of the attributes and Names of Allah Almighty. It is mentioned in the Noble Qur'an 43 times, and the word "Al-Qawiyy" (the Strong) is mentioned 11 times. Muscular strength plays a major role in existence in general, but its importance increases for the athlete, as it is one of the most important components of physical fitness (Hatim Saber, 2013, p.31).

Shtiller defines it as "*the ability of muscles or a muscle group to overcome a resistance or several external resistances regardless of whether they are static or moving*" (Ketchouk, p.78).

Procedurally:

It means the efficiency of the muscles in overcoming a given load, measured using evaluative tests.

2.2 Explosive strength:

Risan Khuraibit (1995) defines it as "the individual's efficiency in overcoming resistances through rapid muscular contraction," while Abd al-Jabbar and Bastawisi (1987), and from Hara's perspective, consider explosive strength as the individual's ability to overcome resistances using high movement speed (Hatim Saber, 2013, p.38).

It is also defined as the muscle's ability to confront maximal resistance with speed and force simultaneously, which appears clearly in performing the starting dive in races and in applying push-off during turns. It has a clear impact on the speed of executing short distances (50 m, 100 m, and 200 m), and its effect decreases as race distance increases (Hussein Ali & Liqa' Ali, 2016, p.210).

From Ouel's perspective, explosive strength is the strength used to perform a specific action, and it is also the strength that the muscle must produce to maintain balance in a given transfer. It is "the force or tension that a single muscle or a group of muscles can produce against a resistance at peak voluntary contraction." Maximal force produced by the muscle is determined by recording the maximum weight lifted with a specific performance for one repetition or by the magnitude of the resulting intensity (Saad Hamad, 2014, p.25).

Procedurally: Explosive strength is defined as the muscle's ability to produce a large amount of force in a short period, such as starting from a stationary position.

2.3 Arm propulsive force

Propulsion is the driving force that pushes you forward through water. In swimming, propulsive force comes from leg kicks and arm pulls (and all related elements such as body roll, undulation, and arm recovery).

According to Qasim Hassan and Yusuf Lazim, propulsive forces are the forces exerted on the moving body within fluids at a small angle of attack.

The direction of these propulsive forces is perpendicular to the direction of water flow around the hand, which is considered a tapered shape suitable for generating propulsive forces in water and is felt by the swimmer as pressure forces acting on the palm (Qasim Hassan & Yusuf Lazim, 2011, pp.202–203).

Procedurally: It is the muscular ability of the arms and shoulders to generate the force needed to propel the body forward in water during swimming. It is evaluated theoretically by studying the movement phases of the arms, the propulsive angle, and the efficiency of transferring force from the muscles to the water during swimming.

3. Previous studies

First study (2025)

Al-Alali Maysa, Hazzhazi Kamal, and Merabet Jemali, titled "A proposed strength-training program and its influence on some physiological variables, arm propulsive force, and explosive power at the start of swimmers."

Study iutcomes: The results of this study, which assessed a proposed muscular-strength training program for swimmers, showed that the training application did not lead to statistically significant improvements in physiological variables. In contrast, the results revealed a noticeable and statistically significant improvement in arm propulsive effectiveness and explosive strength during the start, indicating that the proposed muscular-

strength training program was effective in enhancing motor performance and explosive capabilities of swimmers.

Second study (2025)

Katerina Santos et al., titled "Study of the association between squat strength and swimmers' start kinetics at the beginning of the race".

Study results: The study of the relationship between squat strength and swimmers' start (2025) indicated that land-based tests such as the squat are significantly correlated with horizontal and vertical start forces, demonstrating the impact of muscular strength on explosive performance capability at the beginning of the race.

Third study (2025)

Namra Rabie, Ben Saada Maamar Badr-Eddine, and Ghazali Abdelkader, titled "The influence of recommended plyometric training on increasing various characteristics of muscular strength, turn time, and 100 m freestyle performance level in young swimmers".

Study results: Plyometric experiments (2025) indicated that explosive training leads to gains in acceleration and start capability, which is reflected in turn time and overall performance. This confirms the relevance of muscular strength in increasing swimmers' technical performance.

Fourth study (2025)

Romanoli, Bonaiuto, and Gatta, titled "Propulsive force arising from arm movements in front crawl and its assessment using advanced devices".

Study results: The study by Romanoli, Bonaiuto, and Gatta (2025) found that muscular strength in the arms and forearm supports an estimated 8.5% increase in propulsive force in front crawl when the forearm is included with the hand, thereby enhancing the swimmer's ability to generate effective propulsion in water. The muscular power of the arms + forearm is thus vital in enhancing propulsion in freestyle swimming.

Fifth study (2024)

Noor Jawad and Ali Zahir Ghalib, titled "Using a propulsive-force gadget to determine duration and distance of peak arm force and its association with performance in 50 m freestyle swimmers".

Study results: In sprint events, the study using the propulsive-force device (2024) showed that increased maximal arm propulsive force is associated with improved 50 m freestyle time; that is, the greater the swimmer's ability to generate maximal arm propulsive force within a short time, the better the overall race time.

Sixth study (2022)

Ben Sheikh Youssef and Shibani Abdel-Latif, titled "The effect of strength and morphological dimensions on performance time in 50–100 m freestyle".

Study results: The decline in performance level was attributed to weak arm strength of swimmers, as well as insufficient muscular strength in the lower limb, and failure to consider the physical dimensions required for the 50–100 m freestyle events.

Seventh study (2017)

Mazari Fatah, Dahmani Jamal, and Haddash Abdullah, titled "Proposed special exercises to develop arm strength in freestyle swimming among students of the Institute of Physical and Sports Activities Sciences and Techniques".

Study results: The study showed a positive effect of the proposed exercises on improving arm muscular strength. The content of the modern training program and the exercises and specific tools it contained also led to improvement and development of the study variables (physical and skill variables in addition to muscular strength).

Eighth study (2016)

Riyad Al-Rawi and Taha Al-Atari, titled "Developing muscular strength of swimmers and its relationship to performance time".

Study results: The training program had a positive effect on developing muscular strength and raising swimmers' performance level. Explosive strength in upper-limb muscles had a major impact on improving forward arm thrust, and explosive strength in the arms affected performance time in these events that are carried out with high force and speed.

In addition, explosive strength in lower-limb muscles had a physical effect in this event because they participate in the performance achieved with high force and great speed, including the initial jump. Developing static strength also had an effect in improving performance level and kinematic variables.

Reading in the previous studies:

Based on our earlier study, which showed the effectiveness of a strength-training program designed for muscular strength in enhancing motor performance and explosive capabilities of swimmers, and relying on the findings of the cited studies, the two researchers consider this paper a theoretical addition in this research domain. It is grounded in field results that present a theoretical proposal that can be adopted as a theoretical basis and a qualitatively valuable contribution in the field for specialists.

4. Muscular strength

4.1 The concept of muscular strength

Muscular strength is one of the main components of physical fitness, as it is the comprehensive principle of both general and specific physical training, from which superior performance in the practiced physical activity results according to one's specialization. It is also an accurate and practical measure of fitness for the non-athlete.

Kani Hamid (2018) defines muscular strength as follows: muscular strength is associated with any achievement performed by the active or inactive individual. This clarifies the relationship between muscular contraction and the muscular strength component. Muscular contraction differs depending on three elements: required speed, level of force produced, and duration of contraction. Muscular strength is related to other dynamic physical elements such as speed-strength, movement speed, and strength endurance, as well as health status and psychological well-being. Accordingly, muscular strength is classified into:

1. Muscular strength
2. Muscular strength with speed (speed-strength)
3. Strength endurance

The muscular strength component is considered one of the most important physical attributes upon which the swimmer relies to develop race performance level. It strongly affects the development of speed and endurance. Developing and enhancing a swimmer's muscular strength necessarily leads to the development of speed-strength and strength endurance.

The basis of speed and endurance of swimmers is the continuity of performance against water for a specified period; thus, there is a strong correlation among the three physical components for swimmers (strength, speed, and endurance) (Kani Hamid, 2018, p.20).

From the foregoing, the researchers deduce their perspective on the general concept of muscular strength: it is the ability to produce bodily force or the ability to withstand or resist specific forces and to execute movements effectively using muscles with low effort.

It is essential in all sports activities, as it helps in performing tasks that require muscular strength, such as lifting weights, jumping, and swimming. Muscular strength depends on the intensity of muscular contractions and muscular endurance. It appears in different forms such as dynamic strength and static strength, and can be developed through regular exercises and training according to the practiced sport specialization.

4.2 Muscular strength of swimmers

Muscular strength has gained great importance in training programs for high-level swimmers in most countries worldwide. The volume of training dedicated to muscular strength and muscular endurance can reach approximately 200–300 hours per year, divided between land and water training.

Scientific research has revealed several facts that contributed to the development of muscular-strength training programs specific to swimming. Studies have shown no relationship between developing muscular strength using general methods and swimming speed. For this reason, Maglishio (1982) proposed three main principles for muscular-strength and endurance training of swimmers (Hatim Saber, 2013, p.41):

1. The method of performing exercises should resemble swimming performance as closely as possible.
2. Exercises should be applied with the same rhythm and tempo as swimming.
3. There must be sequential progression in increasing the resistances encountered by the swimmer during swimming.

Although swimming coaches agree on the importance of explosive strength for swimmers, they disagree on how to develop it. Some recommend weight training, while others prefer different methods.

During the 1950s, swimmers were prohibited from weight training due to the belief that muscles would enlarge and joint range of motion would decrease. However, this theory is no longer valid given new research, and weights are now used to develop muscular strength of swimmers.

Swimmers need muscular strength more than many other athletes, especially in the muscle groups of the arms, shoulders, back, and chest. Although swimming training

contributes to developing muscular strength, the resistances facing muscle groups in water are not sufficient for swimmer development, particularly explosive strength.

Therefore, we reiterate the importance of the relationship between the growth of muscular strength and the development of swimmers' performance level (Hatim Saber, 2013, p.42).

Kani Hamid (2018) confirms that the muscular strength component is one of the most important physical attributes upon which the swimmer relies to develop race performance level. It strongly affects the development of speed and endurance.

Developing muscular strength of swimmers leads to improvements in speed-strength and strength endurance. The basis of speed and endurance of swimmers is their ability to maintain performance against water resistance for a certain period; there is a strong correlation among the three physical components of swimmers (strength, speed, and endurance) (Kani Hamid, 2018, p.20).

Abu Al-Ela and Haitham Abdel-Hamid (2019) state that strength is one of the most important physical attributes and is often trained with other capacities. There are misconceptions and incorrect theories that strength training leads to poor athletic performance and negatively affects endurance and flexibility.

However, contemporary theories have rejected these notions and confirmed that combining strength and endurance training does not adversely affect the development of aerobic or muscular capacity. Strength-training programs also do not negatively affect flexibility, which applies to endurance elements in endurance events. Therefore, combined training programs are used to develop both strength and endurance, as well as sports requiring both strength and flexibility (Abu Al-Ela & Haitham Abdel-Hamid, 2019, p.519).

This is corroborated by the study of Riyad Al-Rawi and Taha Al-Atari, titled "growing muscular strength of swimmers and its link to performance time", which revealed that the training program had a beneficial effect on growing muscular strength and boosting swimmers' performance level. Explosive strength of upper-limb muscles had a large impact on enhancing forward arm thrust, and explosive strength of the arms affected performance time in events that are conducted with great power and speed.

Additionally, explosive strength in lower-limb muscles had a physical effect in this event since they engage in the performance completed with tremendous force and great speed, including the initial jump. Developing static strength also had an influence in boosting performance level and kinematic variables.

From the researchers' perspective, physical strength of swimmers is the ability to use muscles effectively to produce movement and force in water. Muscular strength plays a significant role of swimmers' performance, particularly in their speed and efficiency in water. It arises from specific training targeting the key and most-used muscles in swimming, such as the muscles of the arms, legs, and back.

Common workouts to build muscular strength of swimmers include weightlifting and exercises specialised to the muscles utilised in swimming, such as pulling and pushing movements. Swimming training programs depend on the swimmer's level and speciality (stroke type).

In addition, balance and coordination among muscle groups have a vital part on swimmers' muscular strength, alongside enhancing swimming methods, increasing efficiency in water, and minimising injury risk.

Conversely, any shortage in muscle strength among swimmers may result in several undesirable repercussions that directly impair the level of physical and skill performance:

1. Weak efficacy of motor performance
2. Reduced effectiveness of arm and leg propulsive force
3. Decline in performance level in starts and turns
4. Increased rate of tiredness and muscle exhaustion
5. Poor stability and body control in water
6. Higher likelihood of muscule and joint injuries
7. Impaired neuromuscular coordination, leading to diminished harmony among movements during swimming

This is what was indicated in the results of **the study by Ben Sheikh Youssef and Shibani Abdel-Latif**, titled "The effect of strength and morphological dimensions on performance time in 50–100 m freestyle," which confirmed that the decline in performance level was due to weak arm strength of swimmers, insufficient muscular strength in the lower limb, and failure to consider the physical dimensions required for the 50–100 m freestyle events.

5. Main types of muscular strength

5.1 Maximal muscular strength

It is "the muscle's capacity to provide the greatest possible amount of muscular force through voluntary contraction." The characteristics of maximal muscular strength are:

- Muscular contraction results from activating the maximum number of muscles fibers within the muscle (Zemouri, 2020, p. 53).
- Contraction speed increases considerably, as the muscle contracts as quickly as possible.
- Contraction duration ranges between a fraction of a second and one second.

5.2 Speed-strength

It is the neuromuscular system's capacity to provide rapid force, requiring a high level of coordination in combining strength and speed in one place. This means that speed-strength is a dual physical component and is essential in sport, especially in single-movement events that require rapid execution such as push-off, take-off, or fast start.

5.3 Strength endurance (muscular endurance)

It is the individual's ability to perform continuous contractions for a long time using several muscle groups at a constant force, which creates a load on cardiovascular and respiratory functions. It provides the athlete with the ability to overcome fatigue during continuous training with relatively high resistances. The most important characteristics of muscular endurance are:

- The resulting muscular contraction uses a relatively small number of muscles fibers.
- Contraction speed is moderate.

- Muscular contraction is continuous, and its duration is approximately 45 seconds to an extended period (Zemouri, 2020, p.54).

6. Training methods used to develop muscular strength

In recent years, there has been major development in the field of sports, and several training methods have been created specifically to develop muscular strength in its different forms. This has led to increased levels of muscular strength among athletes in various sports:

- Continuous loading method
- Interval training method
- Repetition training method
- Evaluation and competition method
- Pyramid training method
- Electrical training method
- Reciprocal contraction training (lengthening and shortening) (Mohamed, 2017, p.510)

From the perspective of Abdel-Zaher Mohamed Mahmoud (2014), strength-training methods and forms are largely tied to the athletic goals to be achieved, where primary objectives are directed toward developing neural capacity and energy output, particularly when the content of strength training corresponds primarily to beginners' levels.

Conversely, Martin (1991) indicated that strength-training goals for high-level athletes tend toward performance specialization to expand and achieve specific muscular-strength training objectives. This demonstrates the possibility of eliciting strength forms in accordance with the sport's specific physical profile for developing specialized strength.

Additionally, selection of different strength-training methods is determined based on the performance diagnostic profile of the specific sport. In this context, it becomes important to understand the theoretical framework of the musculoskeletal system, as well as to diagnose strength capacities using field tests, through reliance on scientific training methods such as those used to identify and measure strength deficits (Abdel-Zaher, 2014, p.273).

Abu Al-Ela Abdel-Fattah (1997) notes that the method of execution in many strength-training exercises relies on using both limbs together—for example, squats, leg press, bench press from supine, or overhead presses. It has been found that performing these exercises with both limbs leads to lower muscular forces compared to performing the same exercises with each limb separately.

This is accompanied by decreased bilateral performance and reduced electromyographic activity in the working muscles. This bilateral deficit is more evident in non-athletes than in trained athletes, as the muscle protects itself involuntarily through a reflex response mediated by sensory organs in the tendons (Abdel-Zaher, 2014, p.274).

7. Specific and more precise goals of strength training

Motor strength is divided into:

- Maximal strength
- Speed-strength
- Strength endurance

It must be taken into consideration that this division does not represent three separate abilities; there is a strong correlation between each ability and the others.

It should also be noted that this classification is based primarily on a particular training perspective, while the practical methods used to train each of these abilities differ.

Although many express doubts about this classification, it facilitates training planning, as each of these capacities includes manifestations of muscular strength that are similar in content and very close to one another. Any improvement in one capacity leads to partial development in the others, making it possible to direct training to achieve multiple training goals simultaneously: a main goal and several secondary goals (Al-Sayyid, 2009, p.96).

8. Methods of measuring muscular strength

8.1 Resistance tests

These tests measure the maximal load or weight that the athlete can lift once, known as the one-repetition maximum (1RM). Weights or body weight are used in this measurement. There are also numerous modern devices and tools that serve the same purpose of measuring muscular strength in a specific sport. It is important that the individual can exert maximal muscular contraction (lifting the weight) comfortably and without risk of muscular or joint injury (Imad Al-Din, 2015, p.50).

8.2 Isometric muscle tests

Muscular contraction that does not change muscle length is considered a static contraction. This type of test requires special devices that measure skill performance in various sports. Maximum strength is measured based on maximal static contraction. In this type of muscular strength, tests do not rely on movement speed, which is considered zero. Instead, they focus on the joint angle being evaluated, as well as the athlete's motivation and ability to perform.

8.3 Isotonic (dynamic) muscle tests

The term "isotonic" refers to continuous tension, strength, or torque. It is used in weightlifting training because the weight does not change while being lifted through the joint range of motion. It is also called dynamic muscular contraction (Imad Al-Din, 2015, p.51).

8.4 Isokinetic muscle tests

These tests refer to maximal muscular contraction performed at a constant speed throughout the full range of motion of the joints. The term consists of two parts: "iso," meaning "similar," and "kinetic," meaning "movement."

Concentric contractions, in which muscle length shortens toward its center, and eccentric contractions, in which the muscle lengthens under increased tension, are part of isokinetic contractions that resemble movement. The term is applied to concentric and eccentric contractions executed at constant speed, as well as movements performed at constant velocity (Imad Al-Din, 2015, pp.51–52).

9. Muscular strength testings of swimmers

9.1 Evaluation in competitive swimming

Continually monitoring the swimmer's status needs ongoing assessment of their physical and functional condition to find strengths for further development and deficiencies

to avoid. aids to controlling physical preparation during the season according to swimmers' progress and the planned goals.

9.2 Evaluating muscular strength

When conducting evaluation tests, care must be devoted to ensuring that test procedures mirror the muscular effort performed in swimming as nearly as possible, so that the specific component being tested is evaluated with a high degree of validity.

9.3 Maximal strength

Maximal strength is used to quantify static or dynamic muscular performance. For static performance, a dynamometer or dynamograph is utilised. Muscular strength can be tested at any step of static performance in a method that resembles muscular performance in swimming. An isokinetic dynamograph can also be used to record force during any phase of movement and to establish the swimmer's maximal strength (Al-Qatt, 2002, p.178).

9.4 Explosive strength

Some in-water tests used to evaluate this type of strength include:

1. Swimming 10 m from a wall push-off.
2. Measuring the time from the starting dive to 7 m of swimming.
3. Measuring turn speed, defined as the period from 7 m before the turn to 7 m after the turn (Al-Qatt, 2002, pp.178–179).

This is what was applied in the study by Al-Alali Maysa, Hazzhazi Kamal, and Merabet Jemali, titled "**A proposed strength-training program and its effect on some physiological variables, arm propulsive force, and explosive strength during the start of swimmers**", where the test measuring time from the starting dive to 7 m in water was used to evaluate explosive strength during the start. The results indicated a noticeable and statistically significant gain in explosive strength, indicating that the proposed muscular-strength training program was beneficial in boosting explosive skills among swimmers.

Similarly, the study by **Katerina Santos et al., titled "Study of the relationship between squat strength and swimmers' start kinetics at the beginning of the race"**, showed that land-based squat tests had statistically significant relationships with horizontal and vertical start forces, indicating the impact of muscular strength on explosive performance at the beginning of the race.

Another **study by Namra Rabie, Ben Saada Maamar Badr-Eddine, and Ghazali Abdelkader, titled "The effect of proposed plyometric training on developing some aspects of muscular strength, turn time, and 100 m freestyle performance level in young swimmers",** showed that explosive plyometric training leads to improvements in acceleration and start ability, which is reflected in turn time and overall performance. This confirms the relevance of muscular strength in increasing swimmers' technical performance.

From the researchers' perspective, explosive power in the lower limbs plays a vital role in swimming since it adds substantially to boosting performance and efficiency in water. A good start from the starting platform depends on the ability to create big, fast force with the lower limbs.

A fast start translates to increased speed when entering the water, providing swimmers with a vital competitive edge. Enhancing this strength helps swimmers obtain a

powerful start, effective turns, and strong underwater propulsion in minimal time, which positively influences overall performance in competitions.

Zemouri Belkacem (2020) suggests that explosive strength is the neuromuscular system's potential to generate quick force, requiring a high level of synchronisation in combining strength and speed in one area. This means that speed-strength is a dual physical component and is vital in sport, especially in single-movement events demanding rapid execution such as push-off, takeoff, or fast start. It originates from the combination of muscular strength and speed and means creating maximal force in minimal time (Zemouri, 2020, p.54).

According to Abu Al-Ela and Hazem Hussein (2011), the swimmer relies on strength in the initial push-off at the start and when swimming off the pool wall. In addition, the swimmer needs a high level of muscular endurance to maintain pulling force effectively over long periods in water (Abu Al-Ela & Hazem Hussein, 2011, p.148).

Although swimming coaches agree on the importance of speed-strength for swimmers, they disagree on how to develop it. Some recommend weight training to develop speed-strength, while others prefer different methods. During the 1950s, swimmers were prohibited from weight training based on the belief that muscles would enlarge and joint range of motion would decrease.

However, this theory is no longer accepted given new evidence and research, and weights are now used to develop muscular strength of swimmers. Swimmers require muscular strength more than many other athletes, especially in the muscle groups of the arms, shoulders, back, and chest.

Although swimming training contributes to the development of muscular strength, the resistances that muscle groups confront in water are not sufficient for swimmer development, particularly speed-strength. Therefore, we reiterate the importance of the relationship between the growth of muscular strength and the development of swimmers' performance level (Hatim Saber, 2013, pp. 41–42).

From the researchers' perspective, physical strength of swimmers is the ability to use muscles effectively to produce movement and force in water. It has a key influence on swimmers' performance, especially in their speed and efficiency in water. This strength comes from specialized training targeting the primary muscles involved in swimming. Training regimens focus on swimmers' levels and specializations.

Additionally, balance and coordination among muscle groups perform a major part of swimmers' muscular strength, alongside increasing swimming tactics and rising efficiency in water.

Abdel-Zaher (2014) emphasises that an athlete's capacity to perform sport-specific movements is not obtained by relying on a single muscle; rather, executing specialized sport movements involves the participation of a relatively large number of muscles or muscle groups. These muscles must exhibit a high level of coordination, which contributes to raising the level of produced force (Abdel-Zaher, 2014, pp.255–256).

Qasim Hassan and Yusuf Lazim (2011) underline that the propulsive action generated by the legs permits resistance forces to be directed forward against the feet and

shanks when they travel backward in water. This depends on leg movement relative to the body rather than to the water. To highlight frontal resistance forces on the legs, the legs should move backward relative to the water so that the water current flows over them forward in the direction of the swimmer's movement (Qasim Hassan & Yusuf Lazim, 2011, p.205).

To improve the advantage from leg kicks, the feet must remain within the water during movement, because changing the feet from outside to inside the water causes enormous vortices created by air entering at the moment the feet enter the water, increasing drag (Abdullah, 2013, p.158).

From the researchers' perspective, explosive strength among swimmers is a crucial component in creating large acceleration within fractions of a second, enabling swimmers to reach high speed quickly upon leaving the starting platform. A fast start offers swimmers with a critical time advantage, especially in short races where differences are assessed in fractions of a second.

This results to a rapid start and powerful starting momentum that lets swimmers enter the water at favourable angles with minimal resistance.

- ✓ Explosive strength also adds to enhancing leaping and start technique by boosting jump distance and dispersing energy uniformly, therefore eliminating oscillations and preserving body balance.
- ✓ Additionally, it boosts swimmers' self-confidence, positively boosting their psychological performance and competitive abilities.

This is what was measured in our study, titled "**A proposed strength-training program and its effect on some physiological variables, arm propulsive force, and explosive strength during the start of swimmers",** where the results showed a noticeable and statistically significant improvement in explosive-strength variable during the start, indicating that the proposed muscular-strength training program was effective in enhancing motor performance and explosive capabilities among swimmers.

From the content of the muscular-strength training program, identified many elements stemming from the influence of explosive-strength training on the start of swimmers:

- Providing a fast start (reaching maximal acceleration and earning a time advantage)
- Enhancing platform propulsive force (strong and effective push, achieving an ideal entrance arc))
- Improving leaping and start technique (precise body control)
- Maintaining body homeostasis (balanced energy distribution, reduced oscillations)
- Enhancing confidence and psychological performance (increased confidence in capabilities, motivation for high performance)

- ✓ Thus, muscular-strength training programs can be considered a core component in improving swimmers' performance at all levels, which is positively reflected in their performance in competitions and in achieving best results.

9.5 Strength endurance

Some in-water tests used to evaluate this element include:

1. Swimming in place at maximal speed for 30–35 seconds while continuously recording pulling force. Strength endurance is determined by the pulling force recorded during

30 seconds relative to maximal pulling force, determined according to the formula: Strength endurance = pulling force / maximal pulling force.

2. Swimming at maximal speed in a 25 m pool, excluding the first 5 m, and continuing performance for 40 seconds, using the same method as the first test to determine strength endurance.
3. Performing the first test but with 50% of maximal pulling force instead of maximal pulling force. Strength endurance is measured by calculating the time during which the swimmer can continue to maintain the same force.

Experts believe that the first and second tests suit short-distance swimmers, while the third test suits long-distance swimmers (Al-Qatt, 2002, p.179).

10. Propulsive forces involved in swimming events

To discuss the forces and reaction forces generated by the swimmer's movements in water, these forces must be examined in relation to water as the surrounding medium. To identify these forces, attention must be paid to the nature of water flow over the moving body parts.

10.1 Interaction of the arms with water in body propulsion

There are two forces produced by the movements of the arms and hands in water:

- Resistance forces
- Propulsive forces

The first type represents the forces resisting the swimmer's movement, while the second type represents the forces assisting the swimmer's movement. The direction of resistance forces is opposite to the direction of movement of body segments. When resistance forces are directed forward against a backward-moving body segment, this is called "propulsive drag force" (Force) (Qasim Hassan & Yusuf Lazim, 2011, p.201).

In this context, propulsive forces are the forces acting on the moving body within fluids at a small angle of attack (Qasim Hassan & Yusuf Lazim, 2011, pp.202–203).

10.2 Interaction of the legs with water

The propulsive movement produced by the legs allows resistance forces to be directed forward against the feet and shanks when they move backward in water, depending on leg movement relative to the body rather than to the water. To highlight frontal resistance forces on the legs, the legs should move backward relative to the water so that the water flow passes over them forward in the direction of the swimmer's movement (Qasim Hassan & Yusuf Lazim, 2011, p.205).

10.3 Interaction of the body with water in propulsion

In all swimming events, the hands and legs work individually to move the body as a whole forward. Because these muscles need a central mass for stability, the trunk is the most stable and least mobile part in water, except for some lateral flexion and longitudinal rotation resulting from alternating arm and leg movements or breathing to one side (Qasim Hassan & Yusuf Lazim, 2011, p.206).

11. Forces acting in swimming

11.1 Differences among swimmers

There are large differences in swimming skill level depending on the purpose of practice, and this difference extends to variation among swimmers themselves. One swimmer may be faster than another primarily because of differences in how swimmers interact with the water through which they move. To benefit from hydrodynamic principles, one must first understand the forces acting on the swimmer in water.

There are four forces acting with or against the swimmer's body, similar to forces acting on an airplane. Vertically, the weight of the swimmer's body is countered by the vertical buoyant force of the water. Horizontally, there are two opposing forces: propulsion and drag. Drag appears in two forms: pressure drag and friction drag from water contact with the skin. Swimming through water generates disturbances and vortices that increase pressure drag; therefore, the swimmer must adopt a streamlined horizontal position with the water surface to reduce drag.

On the other hand, friction drag from water contact with the skin increases with a more extended horizontal position because the surface area in contact with the water increases. However, this drag is weak compared to pressure drag, so a streamlined horizontal position reduces overall drag (Abdullah, 2013, pp. 156–157).

11.2 Arm movement

Generally, arm movement provides the greatest effectiveness for propelling the body forward in water, and differences among swimmers lie in how they use this movement to increase propulsive force. The best swimmers are those who perform arm movements similar to a fan rather than a simple backward pull to push water as it might appear to some.

In this situation, propulsive forces are the forces acting on the moving body in fluids at a small angle of attack. The direction of these forces is perpendicular to the direction of water flow around the hand, which is considered a tapered, suitable shape for generating propulsive forces in water and is felt by the swimmer as pressure forces acting on the palm (Qasim Hassan & Yusuf Lazim, 2011, pp. 202–203).

Generally, arm movement provides the greatest effectiveness for propelling the body forward in water, and differences among swimmers lie in how they use this movement to increase propulsion.

Abdullah (2013) notes that the best swimmers are those who perform fan-like arm movements rather than straight backward pulling to push water as it might appear.

It was once believed that straight paddling was the main determinant in generating propulsive force, but scientific evidence has shown that pushing a large volume of water over a short distance is more effective than pushing a small volume over a long distance.

It is essential to observe swimmers' arm movements, which produce arcs that push what are called "relatively fixed water surfaces," generating the greatest resistance and thus increasing water reaction force to propel the body forward (Abdullah, 2013, p.157).

This is what was indicated in the study by Romanoli, Bonaiuto, and Gatta, titled "Propulsive force resulting from arm movements in front crawl and its measurement using advanced devices", which found that muscular strength in the arms and forearm contributed to an estimated 8.5% increase in propulsive force in front crawl when the forearm was included with the hand. This enhances the swimmer's ability to generate effective

propulsion in water; therefore, muscular strength in the arms plus forearm is important in improving propulsion in freestyle swimming.

We also find **the study by Mazari Fatah, Dahmani Jamal, and Haddash Abdullah, which supports the importance of arm muscular strength in improving swimmers' performance times, titled "Proposed special exercises to develop arm strength in freestyle swimming",** where the **results showed** a positive effect of the proposed exercises on improving arm muscular strength. The modern program content and its exercises and special tools led to improvement and development of study variables (physical and skill variables in addition to muscular strength).

Noor Jawad and Ali Zahir Ghalib, in their **study titled "Using a propulsive-force device to determine time and distance of maximal arm force and its relationship with performance in 50 m freestyle swimmers",** concluded that in sprint events, increased maximal arm propulsive force is associated with improved 50 m freestyle time; that is, the greater the swimmer's ability to generate maximal arm propulsive force within a short time, the better the overall race time.

From the researchers' perspective, muscular-strength training programs are among the crucial aspects for improving swimmers' performance, notably in raising the effectiveness of arm propulsive force. These programs target the arm muscles and upper body, helping improve the muscular strength needed to create higher propulsion during swimming, hence enhancing swimmers' speed. They also increase technical performance through more precise motions with reduced energy consumption, which helps to enhancing total movement efficiency underwater.

Muscular-strength training not only helps develop strength but also increases endurance, helping swimmers to maintain great performance for longer periods in water, while lowering injury risk and enhancing self-confidence. Benefiting from different exercises and supported nutritional regimens boosts swimmers' overall efficiency. Therefore, integrated training programs can be the key to making remarkable progress in competitive qualities and reaching new levels of sporting brilliance.

This is what was concluded in the study by Al-Alali Maysa, Hazzhazi Kamal, and Merabet Jemali, titled "A proposed strength-training program and its effect on some physiological variables, arm propulsive force, and explosive strength during the start of swimmers", where the results showed a noticeable and statistically significant improvement in arm propulsive effectiveness, indicating that the proposed muscular-strength training program was effective in enhancing motor performance and explosive capabilities among swimmers.

11.3 Leg kicks

The primary effectiveness of leg kicks is to maintain the body in alignment with the water surface, in addition to another effectiveness, which is forward propulsion. The swimmer benefits relatively little from leg kicks in terms of propulsive force, and the degree of benefit varies depending on stroke type, except in breaststroke, where leg effectiveness in generating propulsive force is high.

To increase the benefit from leg kicks, the feet must remain inside the water during movement, because moving the feet from outside to inside the water produces large vortices due to air entering at the moment the feet enter the water, which increases drag. Therefore, performance differences in leg kicks must be taken into account when comparing swimmers (Abdullah, 2013, pp.158–159).

Conclusion:

From the theoretical presentation and analysis in this article, it can be confirmed that muscular strength is one of the fundamental pillars on which motor performance and athletic achievement of swimmers are based, due to its direct effect in improving movement efficiency in water, increasing the ability to overcome water resistance, and achieving economy in exerted effort.

It also became clear that arm propulsive force represents the main factor in generating and maintaining horizontal speed, whereas explosive strength during the start is a decisive element in determining the swimmer's advantage from the earliest moments of the race.

This article showed that the relationship between general muscular strength, arm propulsive force, and explosive strength is an integrative one, as each variable forms a basic support in improving competitive level and race times. Any deficiency or weakness in one of these components negatively affects overall performance, whether in terms of speed, motor effectiveness, or performance continuity.

Accordingly, it can be said that developing muscular strength is not a secondary training option but rather a scientific and practical necessity for reaching high performance levels in swimming.

Recommendations:

The researcher recommends the following:

- ✓ The necessity to focus on growing muscular strength within training regimens for swimmers, as it is a base for boosting motor performance and race times.
- ✓ Designing specialized training programs that target the development of arm propulsive force through particular exercises that imitate the swimming movement route.
- ✓ Emphasizing the development of explosive strength, especially during the start phase, due to its direct impact on race time and final outcome.
- ✓ Observing the principle of gradual loading and physiological adaptation when growing muscular strength, to avoid tiredness and injuries, especially in younger age groups.
- ✓ Calling for future field and experimental investigations to validate the efficiency of the proposed programs and to link theoretical features with actual application.

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