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The Benefits of Dry-Land Training for Swimmers: A Systematic Review

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ABSTRACT. Introduction: In competitive swimming, dry-land training has routinely become an important aspect of the training programme for swimmers. In contrast, traditional swimming training remains the main method emphasised, focusing heavily on the development of endurance and speed, which are characteristic of the sport. **Aim:** The aim of this study is to conduct a systematic review to observe the effects that strength training can have on a swimmer's training cycle, specifically whether there is a positive correlation between it and swimming performance. **Research methods:** Using the Prisma platform methodology, 354 articles published between 2013 and 2024 were retrieved from the PubMed, ScienceDirect, Medicine & Science in Sport & Exercise, American Physiological Society databases, of which a sample of 50 articles were used after meeting the criteria. **Results:** From this review, they suggested that the inclusion of physical training in the training programme of swimmers can have a positive effect on performance over different distances by improving force transmission in the biomechanics of swimming style. **Conclusions:** The swimmers' dry-land training focused on the development of abdominal muscular endurance, along with strength and power as the most important qualities. The training included specific core strengthening exercises as well as weightlifting sessions. This approach had a positive impact on the swimmers, preparing them for their respective trials and successful competitions.

Keywords: *swimmers, dry-land training, swimming performance, strength training.*

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INTRODUCTION

The importance of strength training for swimming performance has been discussed since the early 20th century. It is particularly associated with Robert Kiphuth, who was probably one of the first swimming coaches in the 1920s and 1930s to introduce out-of-pool (land-based) training in an attempt to develop swimming-specific musculature (Wirth et al., 2022).

Swimming as a competitive sport is popular worldwide and has been part of the Olympic programme since the first modern Olympic Games in 1896. Today, competitive swimming comprises 16 Olympic pool events ranging from 50 to 1500 metres and lasting from approximately 21 seconds to 15 minutes (Fone and Tillaar, 2022). Swimming is one of the most popular competitive sports in the world, requiring a combination of motor skills such as strength, speed and endurance to achieve peak performance due to the wide range of distances and intensities in swimming events (Mavroudi et al., 2023; Pérez-Olea et al., 2018). These qualities are supported by a combination of energy systems (lactacid, alactacid and aerobic). The swimmer's speed is also important and is determined by water resistance and the propulsive force of the movement. When swimming, the head, hips and heels should be in approximately the same horizontal line (Storck, 2017).

Swimming performance can be divided into four key phases: start, freestyle, turns and finish (Thng et al., 2019). The time spent on the turns accounts for between 19-20% of the total race time in 100 m events, rising to 36% in the 1500 m freestyle in long-distance events. This influence is obviously higher in short course events, with values between 44-45% in the 100 m breaststroke (Hermosilla et al., 2021). Therefore, coaches have started to prescribe land-based fitness training to develop motor skills.

L. Rodriguez Gonzalez et al. (2022), in a study of physical training in competitive swimming, argue that the motor quality that currently receives the most attention in swimming is endurance, at the expense of other skills. One aspect that is often neglected in preparation for the sport is strength, a physical quality that has numerous physiological and sporting benefits (González et al., 2022). In the context of strength training for swimmers, when talking about the development of athletic fitness, we can distinguish between two types: strength-speed and speed-strength.

As mentioned earlier, strength development is an important factor in swimming performance. Muscle strength can be measured in a number of ways, but to measure maximum muscle strength, a one-repetition maximum test is usually performed, and to measure muscular endurance, a test is used in which subjects perform as many repetitions of an exercise as possible, with a time of

30 seconds typically used (Hasan et al., 2016; Coyne et al., 2015). Muscles are made up of muscle fibres and are divided into two groups, slow-twitch and fast-twitch fibres. Muscle fibres are specifically trained for a particular type of activity, either speed or endurance.

In fact, the development of strength should be promoted from young athletes (10-11 years of age by starting the development of lumbo-pelvic stability and the biomechanics of technical elements) in order to support the development of motor skills, to improve fitness and performance, but also to improve health indicators and quality of life, and one of the most important aspects is the reduction of injuries.

The human neuromuscular system is capable of developing high forces in a short period of time. Approximately 1.50 ms is required to achieve high force levels [>70% of maximum voluntary force (MVF)] during a single joint explosive concentric voluntary contraction (Del Vecchio et al., 2018). Force is often measured at specific time intervals from contraction onset or characterised by the slope of the joint time-motion curve [i.e. rate of force development (RTD)] during the first 2.00 ms of force generation (Del Vecchio et al., 2018). Over the last few decades, there has been a growing interest in strength development, particularly for improving athletic performance.

There is ample evidence in the literature of the effectiveness of dry-land training in improving swimming performance. In the research by Dr Dnyanesh Patil & al. (2013), as expected by the authors, specialised core strength development training, which also included an area-specific functional strength test, led to significant improvements in a 50m crawl swimming event.

The purpose of this systematic review is to analyse the existing literature to synthesise studies conducted by other sport science authors that have evaluated the effects of physical training on swimmer performance. The main hypotheses include: are there additional benefits of combining strength training with swimming compared to traditional swimming training; what types of exercises are more effective in monitoring progress. This review will provide a comprehensive understanding of the current state of knowledge in this area and may identify gaps or needs for future research.

MATERIALS AND METHODS

Considering the main aspects of the problem, a systematic review of the scientific literature was carried out. The PRISMA statement was taken into account in the selection of the articles to be reviewed in order to properly structure this systematic review (Page et al., 2021) and for this aspect we find all the data in **Figure 1**.

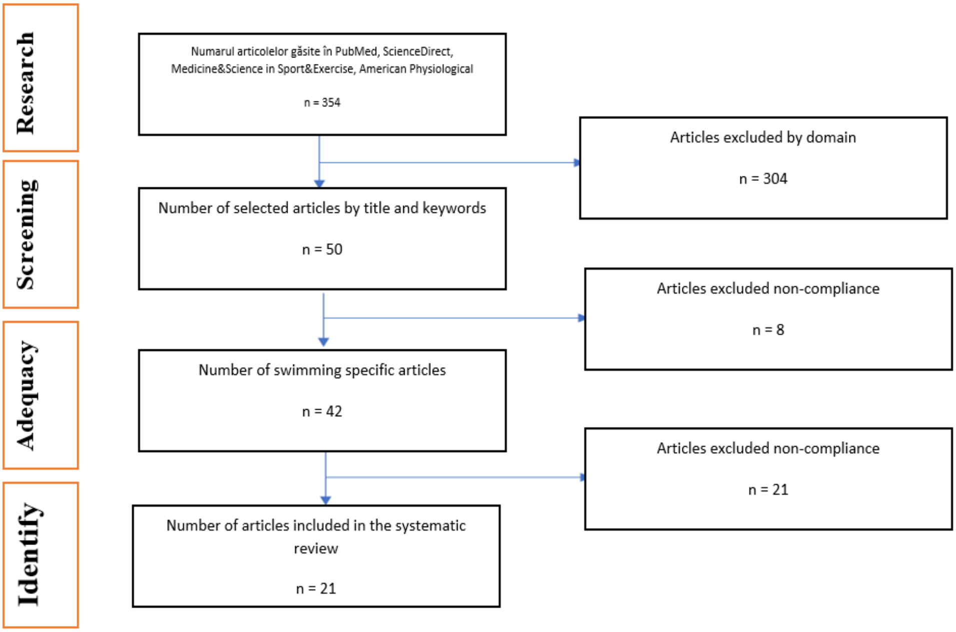

Fig. 1. Representation of the item selection process

1. Research strategy

Articles for this review were searched between January and March 2024 using the PubMed, ScienceDirect, Medicine&Science in Sport&Exercise and American Physiological Society databases, including only articles published between 2013 and 2024. The search terms used were “swimming”, “dry-land”, “strength training” and “velocity”.

The first search returned 354 articles. This was followed by a selection of articles based on keywords and titles, resulting in 50 articles. The matching process was then applied to include only swimming articles, leaving 42 articles. **Figure 1** shows the entire selection process. In this collection, the titles and abstracts of each article were read and only those that met the following criteria were selected:

- Articles written in English and not older than 2013;
- Contain the words “swimming”, “strength training”, “speed and power”, “dry-land” in the title, keywords or abstract;
- The sample consists of amateur, semi-professional and/or professional swimmers;

- The intervention in the study is focused exclusively on improving swimming performance through strength training as part of a programme that also includes in-water training;
- The results contribute to knowledge in the field.

2. Eligibility criteria

The following inclusion criteria were used to extract information: (a) year of publication; (b) study sample; (c) methodology; (d) study; (e) objective(s); (f) instruments; (g) outcomes.

Exclusion criteria were as follows: (a) swimmers from different sport-specific branches: triathlon, aquathlon, open water swimming, frozen water swimming; (b) Paralympians; (c) studies older than 2013.

Data were extracted from eligible articles: author, year of publication, sample size and athlete characteristics (age, gender, weight) in **Table 1** and **Figure 2**.

Table 1. Study and sample data

Authors	Participants
Lopes & colab. (2020)	n = 20 (n = 14 male and n = 6 female) swimmers, age: 20.55 ± 1.76 years, body mass: 68.86 ± 7.69 kg, height: 1.77 ± 0.06 m, 100 m crawl: 71.08 ± 6.71 m, 50 m crawl: 31.70 ± 2.45 s, two groups: experimental (EG: 11) and control (CG: 9).
Sadowski & colab. (2020)	n = 26; age 15.7 ± 0.5 years, height 174.6 ± 6.6 cm, weight 68.4 ± 8.2 kg. Two groups: experimental (E) (n = 12, age 15.8 ± 0.4 years, height 175.7 ± 5.9 cm, weight 67.8 ± 7.9 kg) and control (T) (n = 14, age 15.6 ± 0.6 years, height 173.4 ± 7.1 cm, weight 69.1 ± 8.4 kg).
Gatta & colab. (2015)	n = 20, Masters, males, were allocated to the strength training (ST, n = 10) and swimming training (SW, n = 10) groups. Age (years) 38.7±8.6 32.0±6.9 Body mass (kg) 77.2±8.6 74.9±9.2 Height (cm) 176.2±4.4 176.4±5.8 BMI (kg/m2) 24.8±2.4 24.1±2
Karpiński & colab. (2020)	n = 16, male (21.6 ± 2.2 years). Two groups: experimental (EG, n = 8) and control (CG, n = 8).
Sammoud & colab. (2019)	n = 26, males, two groups: experimental PJT (PJT; n = 14; age = 10.3 ± 0.4 years) and control CG (n = 12; age = 10.5 ± 0.4 years).
Amaro & colab. (2017)	n = 21, males, age 12.7 ± 0.7 years, three groups: control (n = 7) and experimental GR1 and GR2 (n = 7 for each group).
Amara & colab. (2023)	n = 22, males, specialised in butterflies, two groups: experimental (EG, n = 11; age: 14.1 ± 0.30 years; height: 170 ± 9.8 cm; body mass: 68.7 ± 4.3 kg) and control (CG, n = 11; age: 14.5 ± 0.32 years; height: 171 ± 8.4 cm; body mass = 68.1 ± 3.8 kg).

Authors	Participants
JI Mu-Yeop & colab. (2021)	n = 30, two groups: basic training (n = 15; age 13.00±0.88; BMI 19.47±1.13) and traditional training (n = 15; age 13.06±0.88; BMI 19.76±1.85) (CTG and WTG, respectively).
Amara & colab. (2021)	n = 22, males, two groups: experimental (CRTG: n = 11, age = 16.5 ± 0.30 years; height: 174 ± 9.80 cm; body mass = 72.7 ± 5.30 kg) and control (CG: n = 11, age = 16.1 ± 0.32 years; height: 175 ± 9.70 cm; body mass 73.6 ± 5.25 kg).
Pérez-Olea & colab. (2018)	n = 12, males, age 19 ± 3 years, 180 ± 6 cm, 75 ± 10 kg, 15 ± 3% fat mass.
Junior E.B. & colab. (2016)	n = 21, males, three groups: n = 7 swimmers who trained with an elastic band in the water (RW); n = 7 traditional strength programme (ST); and n = 7 control group (CG).
Keiner & colab. (2019)	n = 14, males, age 16-20 years; weight 70.21 ± 4.88 kg; height 1.81 ± 0.05 m.
Patel & colab. (2019)	n = 60, young swimmers (age not specified), two groups: experimental (strength + swimming) and control (swimming only).
Morais & colab. (2016)	n = 27; n = 12 boys, age 13.55 ± 0.72 and n = 15 girls, age 13.16 ± 0.93), divided into 3 groups according to anthropometric and performance measurements (fast, average, poor).
Thng & colab. (2020)	n = 72; n = 38 boys, age 21.0 ± 3.2, height 1.83 ± 0.08 m, body weight 76.7 ± 10.2 kg and n = 24 girls, age 19.2 ± 4.1, height 1.73 ± 0.06 m, body weight 64.8 ± 8.4 kg).
Garcia-Ramos & colab. (2016)	n = 15, boys, age 17.1 ± 0.8 years, height 181.2 ± 6.5 cm, weight 74.1 ± 8.0 kg.
Kanelov and Gotsi (2024)	n = 16, n = 8 females (age 16.63 ± 0.52 years, weight 62.76 ± 3.41 kg, height 165.8 ± 4.20 cm, arm span 175.8 ± 6.36 cm and body fat 16.20 ± 1.4%) and n = 8 males (age 16. 38 ± 0.52 years, weight 65.40 ± 3.36 kg, height 172.1 ± 2.90 cm, arm span 181.3 ± 2.61 cm and body fat 12.6% ± 2.03).
Khiyami & colab. (2022)	n = 18, male, two groups: experimental n = 9, age: 13 ± 2 years, height: 158.8 ± 17.3 cm, weight: 48.3 ± 14.2 kg, swimming experience 2.8 ± 0.4 years and control n = 9, age: 13.11 ± 2.6 years, height: 160.4 ± 11.9 cm, weight: 49.1 ± 11.3 kg, swimming experience 2.9 ± 0.7 years.
Morais & colab. (2018)	n = 27, n=11 boys: 13.5 ± 0.75 years, 54.12 ± 7.81 kg weight, 165.22 ± 8.45 cm height; n=16 girls: 13.2 ± 0.92 years, 51.64 ± 7.22 kg weight, 159.96 ± 6.42 cm height.
Popovici and Suciu (2017)	n = 24, female, age 13-14 years, completed three tests over 3 years in 2012, 2013 and 2014.
Storck (2017)	n = 13, females n=4, age 18±1.41 years; males n=9, age 18±1.11 years.

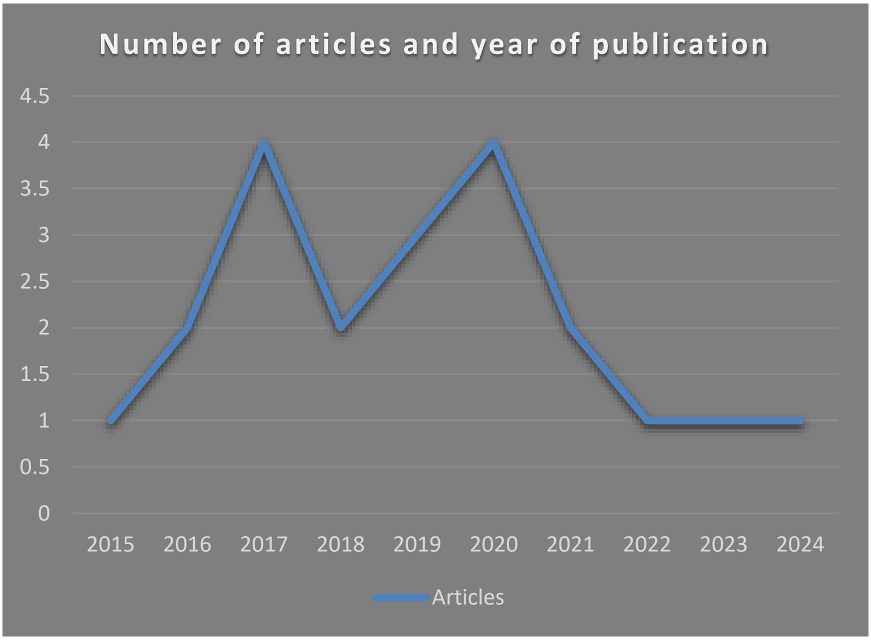

Fig. 2. Presentation of the theme according to the year of publication

RESULTS

Of the 50 studies (publication year 2013-2024) in the PubMed, ScienceDirect, Medicine&Science in Sport&Exercise and American Physiological Society databases, 42 were selected as swimming-specific and 21 were included according to the knowledge criteria based on the results. The aim of the 21 studies was to demonstrate the benefits of land-based training for swimmers.

It can be seen that the importance of this aspect of athletic performance is increasing year by year, as evidenced by the number of studies conducted on this topic in **Table 2**.

Table 2. Swimming performance results after integrating dry-land training

Study	Objectives	Methods	Results
Lopes & colab. (2020)	To evaluate the effect of eight weeks of combined swimming and resistance training on swimming performance.	In water evaluation: 50 m freestyle 100 m freestyle Strength evaluation: 1RM Squat	Experimental training improved performance in the 50 m (29.65→ 28.47 s, $p = 0.013$) and 100 m freestyle (67.04→64.13 s,

Study	Objectives	Methods	Results
		1RM Bench press	p = 0.023), as well as in the squat (70.30→ 79.95 kg, p = 0.022) and bench press (74.55→85.67 kg, p = 0.001).
Sadowski & colab. (2020)	To compare the effects of specific land-based strength training using an ergometer with traditional land-based strength training over a 12-week period.	Assessment of 25m swimming performance.	Transfer rates were significantly higher in the experimental group than in the control group, resulting in a significant increase in swimming speed (by 4.32%, $p<0.001$; ES (mean effect size) =1.23 and 2.78%, $p<0.003$, ES=0.31, respectively).
Gatta & colab. (2015)	To test a training method, Cometti, based on a mixed phase "on dry land with loading followed by a series of fast swims", over a period of 6 weeks.	It was used a accelormeter Maximum-Mechanical-External-Power for evaluation, over a distance of 15m of crawl swimming.	The strength training (ST) group had increases in power (+5.73%), strength (+11.70%) and a slight decrease in speed (-4.99%), while the swimming only (SW) group had decreases in power (-7.31%), strength (-4.16%) and speed (-3.45%).
Karpiński & colab. (2020)	Evaluate a 6-week training programme designed to strengthen the core muscles.	- 50 m freestyle - Distance to enter the water - Entry speed (m/s) - Reaction time - Flight phase - Time 5m after turning - Average swimming speed 5m after return	The experimental group significantly improved the 50 m freestyle time (25.24→24.94 s, p = 0.01), the 5 m time after the turn (0.43→ 0.34 s, p = 0.001) and the average speed after the turn (11.77→ 15.34 m/s, p = 0.001).
Sammoud & colab. (2019)	Comparison of the effects of an 8-week plyometric training programme combined with swimming and swimming training on	- 15m, 25m, 50m crawl - 25m water start without pushing off the wall - 25m kick stroke with start in water without pushing off the wall - CMJ	The experimental group showed significant improvements in both the counter movement jump (CMJ: 19.7→21.7 cm) and the long jump (134.3→148.4 cm), as

Study	Objectives	Methods	Results
	muscle strength indicators.	- Long jump	well as in water performance, reducing the times for the 25 m crawl (18.2→17.52 s) and the 50 m crawl (40.0→39.1 s).
Amaro & colab. (2017)	Evaluation of 3 training regimens in which the control group underwent 10 weeks of swimming only training, GR1 underwent a 6-week strength development programme plus a 4-week swimming only training programme, and GR2 underwent a 6-week explosiveness programme plus a 4-week swimming only training programme.	- 50 m Freestyle - Power during an accelerometer sprint (participants perform 10 seconds of moderate effort followed by 30 seconds of maximal effort) - CMJ - 1kg medicine ball throw (speed and distance measured)	GR2 showed the greatest improvement, with a significant reduction in 50 m freestyle time (33.43 to 31.65 s, p = 0.003) and improved CMJ (29.70 to 31.91 cm, p = 0.018) and medicine ball throw (4.07 to 5.18 m, p = 0.0001) performance, whereas GR1 showed progress in CMJ, but no significant change in swimming, and the control group (CG) showed no relevant improvement.
Amara & colab. (2023)	Evaluation of the effect of 8 weeks of HIIT training combined with maximal training.	1RM Bench pressontal 1RM Leg extension 100 m Butterfly	The experimental group showed significant improvements in 1RM bench press (45.18 kg, p = 0.001), 1RM leg extension (48.73 kg, p = 0.001) and 100 m butterfly (61.85 s, p = 0.001), whereas the control group did not show significant improvements.
JI Mu-Yeop & colab. (2021)	To investigate the effect of adapting land-based abdominal muscle training on swimming performance and fitness.	- 1 RM Deadlift - 1 RM Pullover - Maximum and average power produced on a cycle ergometer (within 30 seconds) - Plank - Throw medicine ball (2kg) forward from supine position with knees bent at 90° (FAPT)	The CTG group showed significant improvements, increasing 1RM deadlift, 1RM pullover, max power from, plank from, FAPT and SAPT.

Study	Objectives	Methods	Results
		- Throw medicine ball (2kg) diagonally from supine position with knees bent at 90° (SAPT)	
Amara & colab. (2021)	The effect of a training programme aimed at developing strength, both on land and in the water, simultaneously, over a period of 9 weeks.	- 1 RM Bench press - 25m crawl - 50m crawl	The experimental group showed significant improvements in 1RM bench press (50.36±2.94 kg, p=0.001), 25 m crawl (12.24±0.55 s, p=0.002) and 50 m crawl (26.17±0.92 s, p=0.009).
Pérez-Olea & colab. (2018)	The main aim of this study was to analyse whether performance in common land based exercises such as pull-up and counter movement jump (CMJ) could predict swimming performance.	- Two high jump tests were carried out: 1. Five jumps were performed with a 1 minute rest between jumps, the highest and lowest were eliminated and the 3 were averaged (CMJ H). 2. 30 jumps were performed with a 2-second rest between them, and all were averaged (CMJ MH). - There were also two tests for the upper body, including chin-ups: 1. 5 pull-ups with a 1 minute rest, recording the speed of execution, eliminating the fastest and the slowest, averaging the 3 (PUv), the absolute and relative force (PU AF, PU RF), the absolute and relative power (PU AP, (PU RP) and the peak speed (PU PV). 2. After 15 minutes, the participants performed the maximum repetitions (PUF) - 50 m freestyle (50 F) - 50 m kick with water start	Regarding the upper body fatigue endurance indices, a strong correlation was found between 50m crawl and PUF V (0.57 ± 0.15 m-s -1) and PUF VL (26.4 ± 6.7%), with no significant correlations between CMJ H (36. 8 ± 4.4 cm), CMJ MH (30.1 ± 3.4 cm) with 50 F or with 50 L. However, a strong correlation (r = 0.78; 90% CI = 0.45 to 0.92; R 2 = 0.60; p = 0.03) was found between 50 F and 50 L (40.59 ± 5.18 s).
Junior E.B. & colab. (2016)	The aim of this study was to compare the effects on swimming performance of a traditional strength training programme, a	- 25m crawl - 50m crawl	The resistance band group showed the greatest improvement in the 25 m crawl and the weight training group had a slight

Study	Objectives	Methods	Results
	programme using an in-water resistance band, and in-water only training (no additional strength training aids).		improvement., and in 30 crawl those groups had slight improvements.
Keiner & colab. (2019)	The aim of this study was to determine the relationship between strength and various specific indices of swimming performance, also analysing start and turn performance.	- 1 RM Squat; - 1 RM Bench press; - Counter movement jump (CMJ); - Squat jumps (with weight)	Maximum force, particularly in the upper body, significantly influences swimming performance, including starts and turns. Therefore, strength training should be an essential part of a swimmer's training programme.
Patel & colab. (2019)	The aim of this study was to compare the effects of 6 weeks of strength training between two groups.	1. Arm frequency using the formula: SR= 60X 3/t SR (SR=arm frequency, t SR=time of 3 arm cycles). 2. 50m kick with water start 3. Core test: - plak 60 sec - Raise left arm for 15 sec - Raise right arm for 15 sec - Raise left leg for 15 sec - Raise right leg for 15 sec - Raise right arm and left leg for 15 sec - Raise left arm and right leg for 15 sec - plank for 30 sec	Significant improvements were observed in the experimental group in terms of arm frequency, 50 m kick time and core test results, indicating the effectiveness of the intervention ($p = 0.0001$), whereas the control group showed no progress and some even regressed.
Morais & colab. (2016)	The objectives of the study were carried out over a whole season in three groups: G1- the effect of a physical training programme combined with swimming training G2- Effect of swimming training programmes G3- Effect of classical periodisation	- Squat jump (SJ) - Counter movement jump (CMJ) - Medicine ball throwing velocity (VT) - 100m crawl (PERF)	G1 performed consistently better than the other groups across all three stages (M1–M3), achieving superior results in jump performance (SJ and CMJ), velocity (VT) and swimming time (PERF). Despite a slight decline in some parameters at M3, G1 remained the top-performing group. In contrast, G2 and, in

Study	Objectives	Methods	Results
			particular, G3 showed limited progress.
Thng & colab. (2020)	The primary objective was to determine lower body strength as a predictor of swimming start and the secondary objective was to observe gender differences in these predictors.	TEST – Squat jump: - A warm-up is performed - with the hands on the hips, the participants perform a triple-joint flexion for 3 seconds, followed by the propulsion part. - Participants are asked to perform 3 jumping squats with 30 seconds rest in between. - The highest jump squat is recorded. Test start swim 5m, 15m: All 72 participants (crawl n=50, butterfly n=12, breaststroke n=10) perform the 5m start, and for the 15m breaststroke is excluded due to the requirement to perform a single underwater kick.	Lower body strength is a strong predictor of swim start performance, with higher correlations at 15 metres for both males and females ($R^2 > 0.80$, $p < 0.001$).
Garcia-Ramos & colab. (2016)	a) To analyse the evolution of the genuflexion during the jump and the start of the swim. b) To correlate the height of the jump and the start between the pre- and post-training periods. c) To correlate the percentage change in the genuflexion and the percentage change in the start after the training camp	- start performance: 5m, 10m, 15m - Squat Jump with and without weight (maximum load equal to body weight)	After testing, significant improvements in performance were observed: Squat jump increased and start performance times were reduced, e.g. for 5 m ($p = 0.01$).
Kanelov and Gotsi (2024)	To analyse the effect, positive or negative, of the application of combined strength training in speed and plyometrics - medicine ball throwing (MBP).	- Half-squat against the stopwatch (HS); - High jump (VJ); - 50m crawl	Improvements were seen in the medicine ball throw, high jump and 50 m crawl times for boys and girls. The boys also performed better in the half-squat test, indicating an increase in overall strength and performance.

Study	Objectives	Methods	Results
Khiyami & colab. (2022)	Evaluation of swimming performance following a program aimed at developing abdominal strength.	- 50m crawl - Muscle tension on the external oblique (EO) - Muscle tension on the erector spinae (ES) - Muscular tension on the latissimus dorsi (LD)	The experimental group showed significant improvements in 50 m crawl times and reductions in muscle tension, indicating enhanced performance and better muscle condition compared o the control group ($p \leq 0.05$).
Morais & colab. (2018)	The aim of this study was to determine the interaction between dry-land training, arm entry biomechanics and swimming performance over a 34-week period.	- Medicine ball throw (1 kg and 0.72 m circumference - 100m crawl	Participants demonstrated significant improvements in swimming velocity and 100 m crawl time, indicating enhanced physical and technical capabilities. These results demonstrate the effectiveness of the training programme in enhancing swimming performance ($p < 0.001$).
Popovici and Suciu (2017)	The aim of this study was to test the neuromuscular coordination and control of movement to a given force in swimmers.	- 50m butterfly Biometer Isokinetic Trainer test (30 sec): - Average force (N) - Average power (W) - Average speed (m/s)	Significant improvements in swimming performance and strength were observed from 2012 to 2014. These improvements were evidenced by faster 50 m butterfly times and increased force and power in the isokinetic test. This confirms the effectiveness of the training programme.
Natalie Storck (2017)	The aim of this study was to evaluate the correlation between bench press, pull-ups and 400m freestyle in elite swimmers.	1RM bench press. - Pull-ups, maximum repetitions for 30 seconds. - 400m freestyle (V4 speed test), starting from the water and blood lactate level close to 4 mmol/l.	Men demonstrated greater strength and speed than women. Moderate negative correlations between strength measures and V4 speed suggest that greater strength is linked to faster performance.

DISCUSSION

The purpose of this review was to examine the effects of dry-land programmes on swimming performance, and recent studies in competitive swimming highlight the importance of specific training to improve athlete performance. Optimisation of performance in short distance events is associated with higher levels of maximal upper body strength. It also emphasises the importance of developing lower body strength and power to improve start and return performance in swimming. Correct technique and biomechanics are also critical factors in determining swimming efficiency, and specific training can make a significant contribution to injury prevention and improved athlete performance.

Analysis of the included studies shows that land-based strength training has a significant positive effect on performance, such as the 50m and 100m breaststroke events. For example, the study by Lopes et al (2020) showed a significant time reduction in the 50m event for the experimental group (29.65 ± 2.94 s to 28.47 ± 2.25 s; p = 0.013) and a similar improvement in the 100m (67.04 ± 8.06 s to 64.13 ± 6.46 s; p = 0.023). In addition, the increase in muscular strength, as assessed by tests such as 1RM in squats and bench press, was significant within the experimental groups, highlighting the effectiveness of these methods. Gatta et al (2015) also showed that the group that combined strength training with intense swimming sessions achieved significant increases in muscle strength and power, in contrast to the group that focused on swimming alone.

Probably the strongest correlation between strength training (bench press and pull-ups) and swimming performance (400 m freestyle) was demonstrated by Natalie Storck (2017). The correlation between maximum number of repetitions in bench press and performance in 400m freestyle was moderate. The correlation between the number of repetitions in the 30-second pull-up and performance in the 400-metre freestyle was strong (Storck, 2017).

Over the course of a competitive year, the body and musculature of athletes adapt to dry-land training, increasing both muscular strength and the hypertrophy effect, and these variables depend on the frequency, volume and type of training (interval, set or continuous).

In competitive swimming, optimising performance in short-distance events depends on a higher level of maximal upper body strength. Indeed, dry-land training has been found to be very important in improving maximal strength in competitive swimmers. Water resistance training has also been reported in several studies (Arsoniadis et al., 2022).

Sofiene Amara et al, in their study (2021) focusing on upper body strength development in adolescent swimmers, argue that this is consistent with the principle of training specificity, which states that training-related adaptations are greater when training characteristics (e.g. exercise type, contraction mode and movement speed) are matched to the activity being trained and tested. Study results were improved by 3.22-7.26% at a load of 60-80% of 1RM (Amara et al., 2021). Furthermore, the study by Amara et al (2023) confirms that combined HIIT and maximal strength training can significantly reduce times in the 100m butterfly event (64.13 ± 1.41 s reduced to 61.85 ± 1.22 s; $p = 0.001$), suggesting that explosive strength directly contributes to performance.

Most studies focus on increasing upper body strength, but improving lower body performance is also an important factor in determining swimming performance. Morouço et al (2015) showed that the relative contribution of leg movement was 29.7% for male and 33.4% for female swimmers. However, lower body strength and power are two very important variables that determine start and return performance in swimming (Amara et al., 2022). The extensor muscle group (mainly the quadriceps) of the lower limbs contributes predominantly to the swim turn from the moment the swimmer's foot makes contact with the wall to the momentum (Jones et al., 2018).

Sammoud et al. (2019) showed that the development of the long and high jump, adapted in a swimmer's training, has a positive impact on swimming performance, namely the times of 15, 25, 50 m breaststroke and 25 m standing breaststroke. For the same index involving the start, namely 15 m, Michael Keiner et al. (2019) showed that 1 RM squat and 1 RM bench press accounted for 50% of the performance over this distance, and the lower body momentum from the technical elements: high jump and jump squat, accounted for 30-42% of the 5 m start performance in the craul process.

Core exercises are an integral part of many strength training programmes, as greater stability of the abdominal girdle can provide a foundation for greater strength production in the upper and lower body (Tsoltos et al., 2023).

Roshani S. Patel et al (2019) come up with a very plausible hypothesis in which they explain that a well-developed body in terms of strength can have a much more efficient transfer in the process of water traction through a strong core. If the core muscles are weak, energy expenditure is much higher, especially during leg movements.

In addition to developing muscular endurance, body mass index, flexibility and prevention, a physical training programme has been shown to increase stroke frequency, improve swimming efficiency and improve the hydrodynamic momentum at the moment the stroke enters the water (Morais et al., 2016; Morais et al., 2018).

It is interesting to note that many athletes and coaches do not accept the use of strength training to improve swimming technique and timing. In general, however, it is clear that the stronger the athlete, the better their performance in addition to their swimming ability (Junior E.B. et al., 2016).

The percentage of injuries to professional swimmers is determined by injuries to the hip (37%), knee (28%), ankle and foot (19%), with the remainder being upper limb and trunk injuries (Patel et al., 2019). Brian J. Krabrak along with his collaborators in a study (2013) specified the investigation of other authors regarding the association between dry-land training and injuries in American college swimmers, and dry-land training contributed to 38%-44% of the injuries/pain experienced by the athletes. In conclusion, as the title of the study suggests (Comparison of Dry-Land Training Programs Between Age Groups of Swimmers), each athlete should follow a personalised programme according to their age and level of training or competition.

FUTURE CONSIDERATIONS

Based on the design of dry-land training, we can provide physiological adaptation to further improvements. Some authors have described the effects on the energy systems, which are at the centre of several scientific teams, and there is a temptation to maintain this in the coming years, as is common in other sports. However, to the best of my knowledge, there has not been an update on the progress of strength training by assessing the lactate threshold during work and optimising sessions so that athletes are in good physical condition throughout the training period, providing a good transition between strength training and swimming so as not to overload.

Sebastian Keller et al (2023) studied 19 adolescent swimmers (age 14.8 ± 1.3 years, n = 7 boys, n = 12 girls), 716 FINA points, for neuromuscular development related to swimming performance and metabolic changes over a 12-month period. They were tested 3 times: T1- before the start of training, T2- during the competition period and T3- at the end of the season. Some of the results were significant, an improvement in strength and VO2 max had a positive effect on swimming performance, and another variable of interest was the positive correlation between the improvement in upper body strength and the anaerobic lactate threshold (LT2) during training.

CONCLUSIONS

Core endurance, strength, and power were the most targeted physical performance factors. Bench press and squats were the most commonly prescribed exercises, along with core strengthening to improve lumbo-pelvic stability in swimmers.

The evidence summarised in this systematic review supports the hypothesis that dry-land training contributes to improved performance in swimmers, especially when combined with specific training in the water. These findings emphasise the importance of incorporating strength training into swimmers training programmes.

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