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Original Research

The Effects of 12 Weeks In-Water Training in Stroke Kinematics, Dry-Land Power, and Swimming Sprints Performance in Master Swimmers

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Abstract

Background: Master swimming is becoming increasingly popular, but research related to the training process and its effect on this population is scarce. The aim of this study was to investigate the effects of 12 weeks in-water training in stroke kinematics, dry-land power, and swimming sprints performance in master swimmers, and the relationships between these variables in this sports population. **Methods**: 15 healthy and physically active male master swimmers (age 32.3 ± 5.1 years, height 1.81 ± 0.04 m, body mass 77.0 ± 6.5 kg, training experience of 11 ± 4 years and average swimming training volume ~2.5 km/day, 3 times a week) participated in the study. Previously and after the intervention program, entirely water-based, swimmers were tested in a dry-land environment to assess their upper and lower body limbs (UL and LL) strength through power measurements, namely countermovement jumps (CMJ), seated 3 kg medicine ball throwing (MBT) and maximal isometric strength with handgrip (HG). In-water 50 m maximal front crawl swimming test was also completed. Swimming performance at 15, 25, and 50 m (T_{15}, T_{25}, and T_{50}) was determined, and the associated stroke kinematics. During the intervention program period, swimming training comprised three sessions per week (7.5 ± 0.9 km per microcycle), with low- to high-intensity aerobic and anaerobic swimming series and technical drills. **Results**: T_{25} significantly decreased after 12 weeks of training (18.82 ± 2.92 *vs.* 18.60 ± 2.87 sec, p = 0.02), the same was observed in the case of T_{50} (40.36 ± 7.54 *vs.* 38.32 ± 6.41 sec, p = 0.00). Changes in stroke rate (SR), stroke length (SL) and stroke index (SI) in swimming performance at 15 m were not observed, contrarily to 25 and 50 m, where SL and SI significantly increased. MBT and HG improved, but not CMJ, and improvements in T_{15}, T_{25} and T_{50} were mostly related to kinematic proficiency improvement. **Conclusions**: 12 weeks of in-water training in master swimmers significantly enhance performance time in 25 and 50 m front crawl swimming. SL and SI are also improved and are the variables that most influence T_{15}, T_{25} and T_{50} when compared to SR and dry-land power variables. Centering the training process not only in in-water tasks in master swimmers seem to be of relevant interest since age influences stroke kinematic and power variables.

Keywords: aging; aquatic sport; biomechanics; strength; speed

1. Introduction

The regular practice of sports is a growing phenomenon, and among these, swimming is one of the most popular sports, namely for master athletes. It is particularly suitable for older subjects since it is associated to little strain [1], enabling the participation of many individuals, including those who present limitations or orthopedic injuries [2]. Despite master athletes were defined as those older than 35 years [3], this definition might vary by sport disciplines. In swimming, Fédération Internationale de Natation (FINA) defines swimmers of 25 years in age or older as master swimmers. A significant part of these athletes were competitive swimmers in youth age-group training programs, who have the ambition to continue to be active (training 3–5 times a week in the swimming pool) and maintain a healthy lifestyle. The most traditional methodological strategy in master swimming clubs is that these athletes train together, however, in some cases, master athletes characterized by high-level performance with elite-level competitive performances regularly or occasionally train with the clubs' senior swimming team. This evidence is associated to the fact that teammates who were not competitive swimmers in the youth age-group training programs or in other cases who trained in other sports or even started to practice sports later in life. In most master's competitions, sport governing organizations arrange 5-year competitive age categories to provide equal chances for aging athletes and organize competitions which cater to their needs to increase the participation of middle-aged and elderly in sports [4].

Performance benefits were associated with the increasing popularity of competitive events for master swimmers over the years [5], associated to daily practices routines strived to maintain or even improve upon the performance achieved at younger ages, seeking to counter the normal decline associated with ageing [6]. Front crawl swimming is associated to bilateral coordination [7], and it was previously identified that front crawl sprint performance (i.e., 15 m, 25 m, 50 m) is reliant on stroke index (SI) in master swimmers of similar age (30–39 years) [8], this variable is determined as the product of swimming velocity and stroke length (SL, distance traveled by stroke, in meters - m), and relationships are usually investigated in swimming also with stroke rate (SR), other kinematic variables related to the number of strokes the swimmer performs per min.

Swimming is characterized by some specificities, namely, and opposite to other sports activities where minimal differences in efficiency are observed among subjects with different technical abilities, the efficiency of swimming is greatly induced by training in a specific environmental, the water. Considering this, it must be highlighted that the number of master swimmers and their performance level considerably increased in the last years, with regular participations in European and World Championships [9]. Very recently, it was found that 8 weeks of dry-land training involving bench press and training with medicine ball throwing (MBT) did not change kinematic variables SL and SI in the 50 m front crawl ($p > 0.05$) in university swimmers of national-level [10]. All the participants (control and experimental group) performed 27 water training units (3.4 sessions per week of ~90 min), a total of 80.4 km, corresponding to a mean value of 10.05 $\pm$ 1.53 km per week and 3.00 $\pm$ 0.31 km per training unit. In addition to the usual swimming sessions, the experimental group performed one session per week of strength training, with 1 h duration. The authors concluded that complementing in-water training with strength training seems to be relevant to improve upper body strength and to optimize 50 m and 100 m swimming performance, adapting technical patterns used during all-out swimming.

Also Grourgoulis *et al.* [11] previously showed that 11 weeks of in-water training resistance with water parachute increased by 2.18% the velocity of the 50 m, while the SR and SL remained unchanged ($p > 0.05$) in 12 female competitive swimmers (age: 13.08 $\pm$ 0.9 years, 6 height: 1.58 $\pm$ 0.05 m, mass: 48.3 $\pm$ 6.9 kg). Control and experimental groups (6 + 6) followed a standardized specific training program contained, on Mondays and Thursdays, 3 maximal sets of 6 $\times$ 15 m with 60 sec rest between the repetitions and 5 min rest between the sets and, on Tuesdays and Fridays, 2 maximal sets of 4 $\times$ 25 m with 90 sec rest between the repetitions and 5 min rest between the sets. On Wednesdays and Saturdays swimmers performed only the common swimming training program and on Sundays they had free day. The experimental group performed this standardized specific training program pulling an added resistance that was provided by a water parachute with a chute of 40.64 cm, which was tethered with a 2 m long tube on a belt that was fastened around each swimmer's waist. On the other hand, 4 weeks of in-water resistance training (always with 5 training sessions) were not associated to changes in stroke kinematics (SR and SL) during 25 m front crawl ($p > 0.05$) in senior competitive swimmers [12].

Dry-land training programs for competitive swimmers has been an area of great interest in research [13]. In young competitive swimmers (age: 12.08 $\pm$ 0.76 years) it was found a tendency to enhance sprint swimming performance due to dry-land strength improvements [14] and it was also previously reported that a combined program of swimming and dry-land strength lead to significant gains in swimming sprinting performance in national-level competitive swimmers (age: 21.8 $\pm$ 3.9 years) [15]. Dry-land training was indicated as an integral part of the programs used by youth, adolescent, and collegiate swim programs, although, the authors referred to the master swimmers as the least likely to use dry-land training because of limited practice time [16]. Nonetheless a study highlighted that hand grip strength (HG) was the best predictors in short-distance events comparatively to age and height in master swimmers [17]. However, no study examining how in-water swimming training may influence dry-land power variables has been conducted in master swimmers.

Contrarily, research was previously performed regarding kinematic variables in master swimmers. It was indicated that the energy cost of swimming increases with age, and suggested that when training master swimmers, attention should be taken not only to preserve the physiological factors that determine maximal metabolic power but also to preserve, as much as possible, the factors that affect the energy cost of this form of locomotion, namely technical skill, and dynamic asset in water [18]. Also Ferreira *et al.* [19], underlined that biomechanical parameters tend to decrease with age and that it is challenging to designing effective training programs for master swimmers, suggesting that the training sessions in this age categories should include a higher percentage of technical drills to enhance the technical performance of the swimmers. More recently, Zaleski Trindade *et al.* [20] suggested that master swimmers training should be developed beyond metabolic training, focusing also in technical quality because swimming kinematics is central in the production of propulsive forces and drag decrease. Moreover, Breen *et al.* [21] examined master athletes pacing strategies from 4272 performances in World and European masters swimming championships, through categorization by stroke, gender, age, and performance level. The research team highlighted that master athletes exhibited different pacing patterns across strokes, whereas lower ranked athletes also displayed less even pacing and a faster relative start compared with higher-ranked athletes.

Studies with master swimmers are scarce compared to younger cohorts, more specifically aiming to understand swimming performance development along the training process [22]. To the best of our knowledge, no studies to date have analyzed the effects of 3 months in-water training in stroke kinematics, dry-land power, and swimming sprints performance in master swimmers. Hence, the aim of this study was to investigate the effects of 12 weeks in-water training in stroke kinematics, dry-land power, and swimming sprints performance in master swimmers, and the relationships between these variables in this sports population. The population analysed as well as the effects of a long period of swimming training in dry-land power and strength measurements and also in swimming performance and stroke mechanics encompasses the novelty of this study comparing with the existing literature.

2. Materials and Methods

2.1 Participants

15 healthy and physically active male master swimmers (age 32.3 ± 5.1 years, height 1.81 ± 0.04 m, body mass 77.0 ± 6.5 kg, 25.02 ± 2.47 kg/m^2) were recruited at a local swimming club using the following inclusion criteria: (i) Male; (ii) Aged 35–50 years old; (iii) Engaged in a systematic swimming training program for at least two competitive seasons; (iv) Not engaged in dry-land strength or power training outside the master swimming club program; and; (v) Competing in masters national swimming events. Swimmers who were absent in one training session/week in the month previous to data collection or had a musculoskeletal injury, pathology or physical impairment were not involved in the study. Subjects had a training experience of 11 ± 4 years, and their average training volume was ~2.5 km/day, 3 times a week.

2.2 Training Characteristics

During the intervention program period, three weekly in-water swimming training sessions occurred (7.5 ± 0.9 km per microcycle), composed by low- to high-intensity aerobic and anaerobic swimming training sets and technical drills. 87.5 ± 3.2% *vs.* 12.5 ± 3.1% of the total swimming volume was performed at exercise intensities corresponding to aerobic *vs.* anaerobic paces throughout the mesocycle, this characterization and differentiation between aerobic and anaerobic training zones was carried out considering specialized literature [22,23]. Participants were instructed not to be involved in other regular sports activities during the intervention period.

2.3 Experimental Design

The intervention program was entirely water-based, no specific routine dry-land training was performed by all subjects in addition to regular warm-up outside of the swimming pool before the start of each in-water training session, fundamentally based on approximately 10 min of joint mobility and dynamic stretching aiming to increase body temperature and blood flow to working muscles, along with cognitive activation for in-water training. All measurements were completed during the preparatory period of the winter training cycle. There were no dropouts from the experiments and no injuries occurred during the experimental training or testing sessions. All procedures were in accordance with the Declaration of Helsinki [24], before starting the research, the objectives of the study were explained to the club officials, coaches and master swimmers, and authorizations were guaranteed. The study was approved by the Ethics Committee of the Polytechnic Institute of Leiria (CE/IPLEIRIA/22/2021).

2.4 Data Collection

In the swimming training session before the evaluations in pretest and posttest, all swimmers performed a low intensity training to avoid fatigue. All measurements were conducted in the swimming pool at the end of the day (between 19:00 and 20:30) to prevent circadian rhythm disruption. Subjects were fully familiarized with testing procedures since they performed one specific familiarization session of the dry-land tests prior to the pretest and were regularly engaged in swimming training, which provided them the skills to perform the in-water tests. In the data collection days, the participants were instructed to maintain their nutritional routines previous to testing and to arrive at the swimming pool rested, well feeded and hydrated. All testing sessions occurred in an indoor 25 m swimming pool, 2 m deep, with a water temperature of 27 °C. For dry-land data collection, 10 min of dry-land warm-up outside of the swimming pool was performed previously to dry-land power testing (with the same methodology associated to regular training sessions), after which, dry-land tests were completed. 5 min after dry-land testing, a standardized in-water warm-up, consisting primarily of 600 m of aerobic swimming of low to moderate intensity was performed previously to in-water testing. After 10 min of seated rest to avoid fatigue influence in testing and at the same time to prevent swimmers from losing the benefits from warm-up, the master swimmers performed the in-water tests.

2.5 Dry-Land Tests

Upper and lower body limbs (UL and LL) power measurements were performed in dry-land environment. For the UL, the swimmers completed a 3 kg MBT test. This protocol has been previously reported [25], each subject sat on a chair with their back positioned against the chair and with bent legs and feet flat on the floor at shoulder level, holding the MB against their chest until they heard an audible cue to begin the throw, at which point they threw the ball as far as possible in front of them. The subjects were instructed to keep their upper back pressed against the bench, staying in contact throughout the full throw using maximal effort, torso and hip rotation were not allowed. The maximum throwing distance was measured with a flexible steel tape [26].

Maximal isometric strength was determined using a digital hand dynamometer handgrip (Camry 90 kg, Guangdong, China), to assess the strength in the dominant hand. This criterion was implemented because it was previously observed a statistically significant difference between the grip and pinch strengths of dominant and nondominant hands in favour of the dominant hand [27]. Three attempts were made with 1 minute resting intervals, to ensure that fatigue or learning effects did not influence the performance. Only the best attempt was used for further analysis. For LL evaluation, swimmers executed countermovement jumps (CMJ) as previously described [26]. A device (Ergojump Digitime 1000; Digitest, Jyvaskyla, Finland) was used to assess the maximum height, obtained during the jump. Participants began from a standing position, performed a crounching action at a 90-degree angle immediately before jumping vertically. Each subject completed 3 repetitions of the exercise were performed, separated by a 2 min time interval to ensure that fatigue or learning effects did not influence the performance. The average maximum height of the 3 trials was measured to assess LL power.

Master swimmers body mass was assessed through bioelectric impedance analysis method (Tanita BC 420S MA, Japan). Height was recorded for each subject with a portable stadiometer (Seca Instruments, Ltd., Hamburg, Germany).

2.6 In-Water Tests

After completing the warm-up, each subject performed a 50 m maximal front crawl swimming test (T_{50}) from a push off start in the wall on the surface level, this procedure was implemented to eliminate the influence of the dive. Master's swimming performance at 15 and 25 m (T_{15}) and (T_{25}) was determined with digital chronometer (Seiko S140, Japan) by two expert researchers. A 10 min period was implemented between each individual swimming bout to avoid water turbulence. During each swimming trial, SR (cycles·min^{-1}) and SL (m·cycle^{-1}) were determined as kinematical indicators. Both were measured with a digital chronometer (Golfinho Sports MC 815, Aveiro, Portugal) from 3 consecutive stroke cycles, between 5–15 m on each 25 m course. Swimming velocity (in m·s^{-1}) was determined based in the ratio between the distance and the time to travel such distance. The product of SL to the swimming velocity (in m·s^{-1}) allowed the assessment of SI considered a valid indicator of swimming efficiency [28].

2.7 Statistical Analysis

The data were treated using descriptive statistics, mean (*M*) standard deviation (*SD*), confidence interval (95%) and their normality was tested by Shapiro-Wilk test. The comparison of the pre- and posttest data was performed through the *t*-test for paired samples. Pearson's linear correlation coefficient was used to test the relationships between the study variables. Significance was accepted at the $p < 0.05$ level. The effect size was calculated through *d*-cohen, being considered trivial (0–0.2), small (0.2–0.6), moderate (0.6–1.2), large (1.2–2), very large (2–4) and extremely large (>4) [29]. Linear regression models between swimming performance and stoke kinematic and power variables were computed. Data analysis was performed using the SPSS v.24.0 program (SPSS Inc., Chicago, IL, USA) and Microsoft Excel.

3. Results

T_{25} significantly decreased after 12 weeks of training (18.82 ± 2.92 *vs.* 18.60 ± 2.87 sec, $p = 0.02$), the same was observed in the case of T_{50} (40.36 ± 7.54 *vs.* 38.32 ± 6.41 sec, $p = 0.00$). T_{15} did not change after training. In pretest, T_{15} was not correlated to SR_{15}, but presented an inverse significant correlation with SL_{15} and SI_{15} (respectively, r = –0.80 and r = –0.88, in both cases $p < 0.01$). Considering T_{25} and the same data collection moment, very similar values were observed regarding the same variables relationship (respectively for SL_{25} and SI_{25}, r = –0.79 and r = –0.87, in both cases $p < 0.01$). In T_{50}, as in the case of T_{15} and T_{25}, also no correlations were observed compared to SR, contrary to SL_{50} and SI_{50} (respectively, r = –0.81 and r = –0.90, in both cases $p < 0.01$).

T_{15} was correlated to MBT (r = –0.69, $p < 0.01$), CMJ (r = –0.59, $p < 0.05$) and HG (r = –0.56, $p < 0.05$). In T_{25} and T_{50} no correlations were observed to CMJ, only to MBT (respectively r = –0.70 and r = –0.66, in both cases $p < 0.01$) and HG (respectively r = –0.58 and r = –0.55, in both cases $p < 0.01$). Table 1 shows the results in swimming kinematics and power variables in pretest and posttest.

In posttest, T_{15} was not correlated to SR_{15}, but to SL_{15} and SI_{15} (respectively, r = –0.83 and r = –0.90, in both cases $p < 0.01$). Also no correlations were observed considering SR and T_{25}, but the last was highly correlated to the respective SL and SI (respectively for SL_{25} and SI_{25}, r = –0.80 and r = –0.88, in both cases $p < 0.01$). In T_{50}, also no correlations were observed compared to SR, contrary to SL_{50} and SI_{50} (respectively, r = –0.78 and r = –0.86, in both cases $p < 0.01$). T_{15} was correlated to MBT (r = –0.83, $p < 0.01$), CMJ (r = –0.59, $p < 0.05$) and HG (r = –0.63, $p < 0.05$). T_{25} was also correlated to MBT (r = –0.80, $p < 0.01$), CMJ (r = –0.52, $p < 0.05$) and HG (r = –0.63, $p < 0.05$) and in T_{50} no correlations were observed to CMJ, only to MBT and HG (respectively r = –0.72, $p < 0.01$ and r = –0.58, $p < 0.05$). Effect size of swimming kinematic and power variables comparing the pretest and posttest was

Table 1. Results in swimming kinematics and power variables in pretest and posttest.

Variable	Pretest	Posttest	Effect Size	95% CI	
	(M ± SD)	(M ± SD)	d	L_{Limit}	U_{Limit}
SR_{15} (cycles·min^{-1})	46.63 ± 4.45	46.07 ± 4.47	–0.13	–0.84	0.59
SR_{25} (cycles·min^{-1})	46.17 ± 4.34	45.71 ± 4.21*	–0.11	–0.82	0.61
SR_{50} (cycles·min^{-1})	44.92 ± 4.43	43.85 ± 4.40**	–0.24	–0.96	0.48
SL_{15} (m·cycle^{-1})	1.96 ± 0.36	2.04 ± 0.42	0.19	–0.53	0.91
SL_{25} (m·cycle^{-1})	1.76 ± 0.33	1.81 ± 0.34*	0.24	–0.48	0.96
SL_{50} (m·cycle^{-1})	1.66 ± 0.36	1.76 ± 0.33*	0.27	–0.45	0.99
SI_{15} [meter^2·(cycle·s)$^{-1}$]	3.03 ± 0.98	3.25 ± 1.20	0.19	–0.52	0.91
SI_{25} [meter^2·(cycle·s)$^{-1}$]	2.45 ± 0.76	2.53 ± 0.81*	0.24	–0.48	0.96
SI_{50} [meter^2·(cycle·s)$^{-1}$]	2.19 ± 0.80	2.40 ± 0.75*	0.27	–0.45	0.99
MBT (m)	4.03 ± 0.68	4.21 ± 0.72*	0.26	–0.46	0.98
CMJ (cm)	27.62 ± 4.02	28.50 ± 4.58	–0.15	–0.87	0.57
HG (kg)	39.25 ± 12.68	41.49 ± 13.00*	0.17	–0.54	0.89

M ± SD, mean ± standard deviation; SR, stroke rate; SL, stroke length; SI, stroke index; MBT, 3 kg medicine ball throwing; CMJ, countermovement jump; HG, handgrip strength. * significantly different $p < 0.05$; ** significantly different $p < 0.01$; U_{Limit}, upper limit, L_{Limit}, lower limit.

mostly trivial (0–0.2), namely associated to kinematic variables associated 15 m swimming distance, CMJ and HG, but in some cases small (0.2–0.6), more specifically MBT, and kinematic variables associated to 25 and 50 swimming distances. Fig. 1 provides the possibility to schematically observe the effect size of kinematic and dry-land power variables between pretest and posttest.

Considering the relationship between dry-land power variables, in pretest MBT was highly correlated to HG (r = 0.83, $p < 0.01$) and in posttest MBT was also correlated to CMJ (r = 0.57, $p < 0.05$) and highly correlated to HG (r = 0.86, $p < 0.01$).

In pretest and posttest, SR at 15, 25 and 50 m was not correlated to any dry-land power variables. Contrarily, in pretest SL_{15}, SL_{25} and SL_{50} were correlated to MBT (respectively, r = 0.54, r = 0.58 and r = 0.65, in all cases $p < 0.05$). The same was observed regarding the correlations between SI_{15} and MBT (r = 0.61, $p < 0.05$), also correlations between both SI_{25} and SI_{50} and dry-land power variable MBT were observed (respectively, r = 0.65 and r = 0.69, in both cases $p < 0.05$).

In postttest, correlations were also observed between SL_{15}, SL_{50} and MBT (respectively, r = 0.63 and r = 0.54, in both cases $p < 0.05$), SL25 and MBT (r = 0.65, $p < 0.01$). The same was observed considering SI_{15}, SI_{25} and SI_{50} relationship to MBT (respectively, r = 0.67, r = 0.73 and r = 0.65, in all cases $p < 0.05$). SI_{15} in posttest was correlated to CMJ (r = 0.56, $p < 0.05$), the same was observed regarding SI_{50} and CMJ but in pretest (r = 0.57, $p < 0.05$). HG was only correlated to SI_{25} in posttest and SI_{50} in pretest (in both cases, r = 0.55, $p < 0.05$). Fig. 2 depicts the linear regression of kinematic variable SI and the correspondent front crawl swimming performance time in 15, 25 and 50 m, and 50 m front crawl swimming performance time linear relationship to power variables. All information in related to posttest.

It was observed that the r^2 value, distribution of points and regression line showed a greater relationship between swimming performance in the 50 m and kinematic variable SI (panel C), compared to dry-land power variables (panels D, E and F). The r^2 values considering the relationship between swimming performance time in the different distances and the correspondent SL were lower compared to SI, namely 0.69 (15 m), 0.63 (25 m) and 0.60 (50 m). Regarding SR, in all swimming distances the r^2 values were below 0.00.

4. Discussion

The aim of this study was to investigate the effects of 12 weeks in-water training in stroke kinematics, dry-land power, and swimming sprints performance in healthy and physically active male master swimmers (training experience of 11 ± 4 years, and average swimming training volume ~2.5 km/day, 3 times a week), and the relationships between these variables in this sports population. The main findings were, 12 weeks of in-water training in master swimmers: (1) Enhance swimming performance occurred in 25 m ($p < 0.05$) and fundamentally in 50 m ($p < 0.01$); (2) Do not promote changes in SR, SL and SI in swimming performance at 15 m, contrarily to 25 and 50 m, where SL and SI significantly increased; (3) Leads to improvement in upper limb power variables (MBT and HG), but not lower limb (CMJ) and; (4) Revealed that enhancements in T_{15}, T_{25} and T_{50} are mostly related to kinematic proficiency improvement.

Most aerobic gains occur in the early months of the beginning of the season, due to an increase in training volume in young and elite swimmers [30] and this improve-

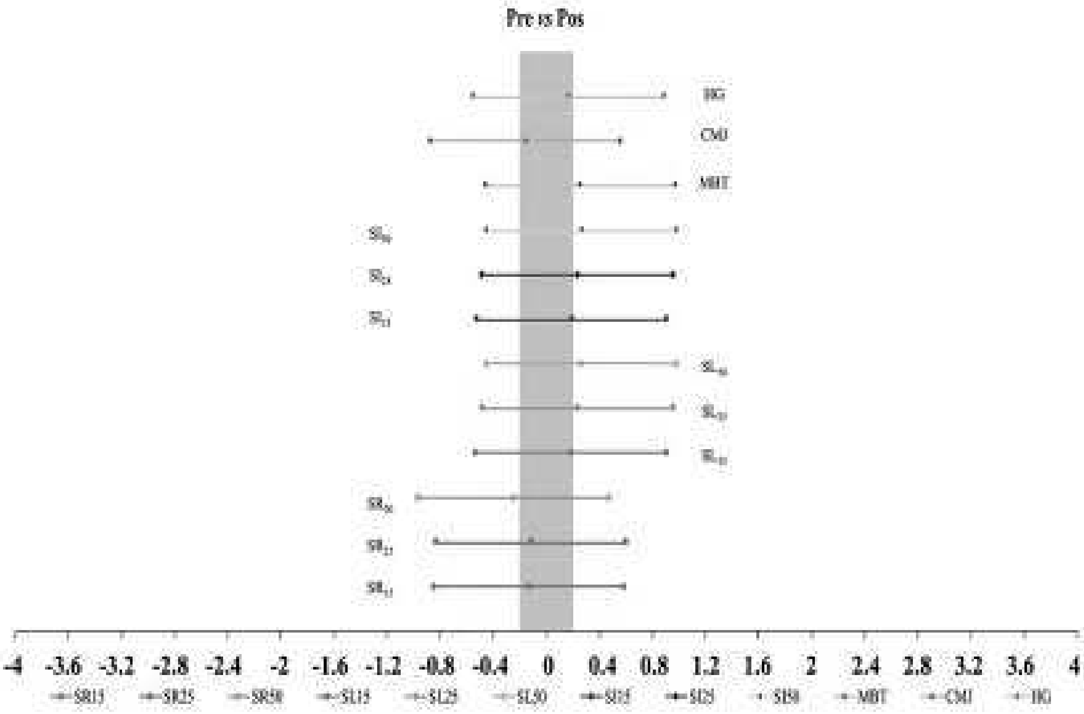

Fig. 1. Swimming kinematic and dry-land power variables effect size between pretest and posttest. SR, stroke rate; SL, stroke length; SI, stroke index; MBT, 3 kg medicine ball throwing; CMJ, countermovement jump; HG, handgrip. 15, 25 and 50 represent swimming distance.

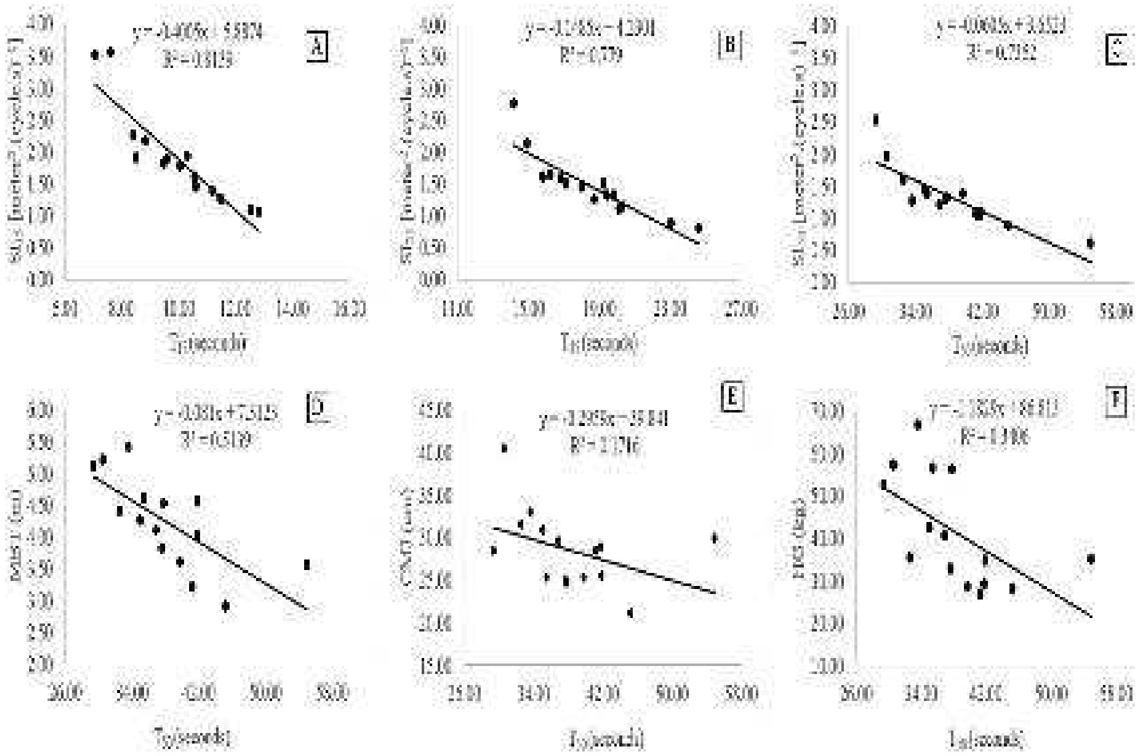

Fig. 2. Linear regression of stroke kinematics, dry-land power, and swimming sprints performance. Stroke index and the correspondent front crawl swimming performance time in 15, 25 and 50 m (panels A, B and C); 50 m front crawl swimming performance time linear relationship to power variables 3 kg medicine ball throwing (panel D), countermovement jump (panel E) and handgrip strength (panel F). All information in related to posttest.

ment has been associated to training-induced adaptations which increase the muscle's ability to aerobically produce energy, reducing the rate of muscle glycogen use and lactate production [31]. The relationship between intensity and training volume is still debated considering in-water swimming practice, despite this, swimming training programs are commonly characterized by high-volume sessions (~4–10 km/day) mainly performed at low intensities [32,33], being at the same time considered that the accuracy in identifying exercise intensities domains is of relevant interest in swimming [34]. This topic is nowadays very pertinent and our findings highlight that 12 weeks of predominantly aerobic training in master swimmers enhance performance time improvement in the 15, 25 and 50 m front crawl, although with greater evidence in the longer distance (50 m), which is included in the competitive swimming events and is one of the most participated by master swimmers. This study also underlines that the time span of the training program and its aerobic characterization did not promote significant changes in al the studied kinematic variables at 15 m, contrary to what was observed in 25 and 50 m since both SL and SI significantly increased, what is an improvement indicator of efficiency, which is relevant in swimming and depends on the technical skill of the swimmers [35].

Recently, it was showed that master swimmers improved their front crawl sprint performance (in 25 m) after four weeks of a typical training mesocycle, including aerobic conditioning and also anaerobic training series and technical development exercises, particularly by increasing the speeds and lowering the speed decrease along the maximal bout [36]. The observations in our study corroborate with the assumptions of these authors, that swimming training enhance kinematic proficiency in swimming. Furthermore, this study showed that the improvement in T_{25} and T_{50} is fundamentally related to kinematic improvement, namely SL and SI. What is interesting to note is that SR does not seem to improve by swimming training in master swimmers and does not influence the performance in T_{15}, T_{25} and T_{50} before and after 12 weeks in-water training in master swimmers, contrary to both SL and SI. Nonetheless, SL and SI relationship to swimming performance time decreased has swimming distance increased, which highlights the influence of aerobic participation in master's swimming, and the importance of a carefully designed training program for this age since energy production systems are the major factors in determining swimming performance [37].

Muscle power is crucial to increase swimming velocity [38] and declines earlier and more sharply than muscle strength [39], fundamentally due to an age-related slowing of contraction speed [39,40]. In the current study, 12 weeks in-water training in master swimmers resulted in significant improvements in UL power variables (MBT and HG), despite the changes in CMJ, associated to LL, were not significant. This evidence leads us to the consider that the influence of swimming training in UL and LL is different, an indication that in master swimmers should be carefully considered since they are in life stages typically associated with sarcopenia. On this basis we suggest that strength and power dry-land programs should be considered in master swimming training and in conjunction with water training evaluated in order to find the best master swimming training strategies. In this regard and of note that an important association exists between severe muscle loss and the increased risk of physical disability [41] cognitive decline [42], metabolic disorders [43] and mortality [44]. Nevertheless, masters swimming teams previously reported relatively low rates of dry-land usage (26%) [16].

Muscle fiber hypertrophy of the triceps brachii was associated to an 8-week swimming training program [45], where swimmers were engaged in repeating swimming sets of 50, 100, and 200 m and sporadically longer distances (400 and 800 m), with total daily swimming volume close to 2000 m. These findings are very interesting because they are related to a modern tendency in sports, and specifically in swimming, of more intensity training tasks in short prophylactic time intervals, training methodological principals associated quotidian trendy in-water workouts, named high intensity interval training (HIIT) and ultra-short race-pace training (USRPT), and also other forms of cross training namely for aerobic training stimuli throughout running, cycling or rowing, that would enhance the change of training environment with particular cognitive advantages, with the specific in-water training time in the pool being reduced and related to higher intensity and lower volume. Our findings suggest that is of interest to evaluate the training methodological principles in master swimmers and the relationship to kinematic and power variables.

Some limitations should be considered in this study. Subjects were primarily competing at regional or national level, consequently, they are not directly comparable to other swimmers of different age or performance level. Our results should be considered in the specific context of the master swimmers sport level, therefore, it is not possible to directly extend our conclusions to female, younger or even elite master swimmers. Although we assumed as inclusion criterion that master swimmers were not engaged in dry-land strength or power training outside the master swimming club program and provided instruction to participants not to be involved in other regular sports activities during the intervention period, verification only occurred through verbal questioning in the regular training sessions in order not to influence the results. We suggest that in the future a specific interview or filling in a questionnaire about the daily routines of the study participants could be considered. Future studies should elucidate how dry-land power training contributes to enhance swimming performance or kinematic and power variables improvement, and the relationship between these. We suggest that physiological and metabolic variables should be considered in future studies, to be executed with different age-group master swimmers, different genders and intervention time span. It would also be interesting to evaluate different swimming distances and to consider the use of a control group to evaluate the possible influence of in-water and dry-land training strategies in master swimmers.

5. Conclusions

To sum up, 12 weeks of in-water training in healthy and physically active male master swimmers with training experience of 11 $\pm$ 4 years and average swimming training volume ~2.5 km/day, 3 times a week, significantly enhance performance time in 25 and 50 m front crawl swimming. SL and SI are also improved and are the variables that most influence swimming performance time in 15, 25 and 50 m front crawl swimming when compared to SR and dry-land power variables. This intervention swimming training program, characterized with aerobic training tasks and no dry-land training, applied in male master swimmers, results in UL power variables (MBT and HG) improvement, contrary to LL (CMJ).

Swimming performance time relationship with kinematic variables SL and SI decreases with the increase of the swimming distance covered, which means that it is of relevant interest to study intervention strategies in the training of master swimming athletes since aerobic participation is important namely in the 50 and even in the 25 m front crawl. Centering the training process not only in in-water tasks in master swimmers seem to be of relevant interest since age influences stroke kinematic and power variables. Considering this, training of master swimmers should be aiming to preserve and improve the technical skills in association with strength and power variables, through stimulating and attractive training tasks that can be performed dry-land or in-water, with methodological assumptions more focused on increasing the intensity and decreasing the in-water volume of tasks.

Abbreviations

T_{15}, swimming performance time at 15 m; T_{25}, swimming performance time at 25 m; T_{50}, swimming performance time at 50 m; SR, stroke rate; SL, stroke length; SI, stroke index; MBT, 3 kg medicine ball throwing; CMJ, countermovement jump; HG, handgrip; UL, upper limb; LL, lower limb; HIIT, high intensity interval training; US-RPT, ultra-short race-pace training.

Author Contributions

MCE and AP conceptualized the study; MCE, FJS, CCF and AP devised the methodology; FJS, CCF performed the formal analysis; MCE and AP conducted the investigation; MCE, AC, HL, JFR and DMPF wrote and prepared the original draft; FJS and AP reviewed and edited the manuscript; MCE, CCF and FJS analyzed the results using the software; and AC, HL, JFR, DMPF and AP provided supervision. All authors have read and agreed to the published version of the manuscript.

Ethics Approval and Consent to Participate

The study was approved by Ethics Committee of the Polytechnic Institute of Leiria (CE/IPLEIRIA/22/2021) and conducted in accordance with the Helsinki Declaration. All participants provided written informed consent.

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Conflict of interest

The authors declare no conflict of interest.

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