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Effects of a 10-week dry-land strength and conditioning program in physical capacities and start of previously federated and regular swimming practitioners

Efecto de un programa de entrenamiento de fuerza y acondicionamiento en seco sobre las habilidades físicas en practicantes federados en natación

O efeito de um programa de treino de força e condicionamento em seco nas capacidades físicas e partida em praticantes regulares de natação previamente federados

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ABSTRACT

The aim of this study was to evaluate the effects of a 10-week strength and conditioning (S&C) program in physical capacities and start in previously federated and regular swimming practitioners. 16 swimmers (9 male, 17.00±2.16 years of age, 179.14±5.76 cm of height and 69.79±3.11 kg of weight; 7 female, 15.86±2.34 years of age, 163.86±4.98 cm of height and 60.19±3.60 kg of weigh) were equality, but randomly separated in two groups (control group and experimental group, CG and EG, respectively). In the pre-test, swimmers performed three starts in two different models, grab start and track start, the best start was registered. Kinematic parameters of the swimming start and time at 15 m were determined. Flexibility, countermovement jump and 3 kg medicine ball throw were also assessed. In post-test, 10-weeks after a regular 2-sessions week specific dry-land S&C program of 60 min was performed by the EG, all tests were repeated. Flexibility, strength and muscular power gains were significant in EG, contrarily to CG. Swimming start flight phase variables improved more in EG compared to CG, with specificities observed in grab and track start but not a linear consequence with performance in 15-m mark in both groups. A 10-week dry-land S&C program can provide benefits in physical capacities in regular swimming practitioners, fact that may improve the initial phase of the swimming start, prior to the underwater moment, which should deserve attention by the coaches in daily training aiming performance enhancement at 15 m.

Keywords: Training, Strength, Flexibility, Kinematic, Performance.

RESUMEN

El propósito de esto estudio fue evaluar el efecto de un programa de fuerza y acondicionamiento (F&A) en seco de 10 semanas sobre las habilidades físicas y el salto en practicantes habituales de natación previamente federados. 16 nadadores (9 masculino, 17.00±2.16 años de edad, 179.14±5.76 cm de altura y 69.79±3.11 kg de peso and 7 mujer,

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Sociedad Iberoamericana de Psicología del Deporte

15.86±2.34 años de edad, 163.86±4.98 cm de altura y 60.19±3.60 kg de peso) fueron equitativamente, pero al azar divididos en dos grupos (control y experimental, respectivamente, GC e GE). En el pre-test realizaron tres saltos en dos modelos, *grab start* e *track start*, siendo el mejor registrado. Se han determinado parámetros cinemáticos del salto en natación y el tiempo a los 15 m. También se evaluaron la flexibilidad, el salto con contramovimiento y el lanzamiento de una pelota medicinal de 3 kg. En el post-test, 10 semanas después de un programa de F&A en seco con 2 sesiones semanales de 60 min interpretado por GE, las pruebas se repitieron. Las mejoras de flexibilidad, fuerza y potencia muscular fueron significativas en el GE, en contraste con el GC. Las variables de la fase de vuelo en el salto mejoraron más en el GE en comparación con el CG, con especificidades observadas en el *grab start* e *track start*, pero no una consecuencia lineal con el rendimiento a 15 m en ambos grupos. Un programa de F&A seco de 10 semanas puede promover beneficios en las habilidades físicas de nadadores habituales, hecho que puede mejorar la fase inicial del salto en la natación, previa al momento subacuático, que debe merecer la atención de los entrenadores en las sesiones diarias con el objetivo de a una mejora del rendimiento a 15 m.

Palabras clave: Entrenamiento, Fuerza, Flexibilidad, Cinemática, Rendimiento.

RESUMO

O objetivo deste estudo foi avaliar o efeito de um programa de força e condicionamento (F&C) em seco de 10 semanas nas capacidades físicas e salto em praticantes regulares de natação previamente federados. 16 nadadores (9 masculinos, 17.00±2.16 anos de idade, 179.14±5.76 cm de altura e 69.79±3.11 kg de peso; 7 femininos, 15.86±2.34 anos de idade, 163.86±4.98 cm de altura e 60.19±3.60 kg de peso) foram equitativamente, mas de forma aleatória divididos em dois grupos (controlo e experimental, respetivamente, GC e GE). No pré-teste, nadadores realizaram três saltos em dois modelos, *grab start* e *track start*, sendo registado o melhor. Foram determinados parâmetros do salto na natação e o tempo aos 15 m. Flexibilidade, salto em contramovimento e lançamento de bola medicinal de 3 kg foram também avaliados. No pós-teste, 10 semanas após programa de F&C em seco com 2 sessões semanais de 60 min realizado por GE, testes foram repetidos. As melhorias de flexibilidade, força e potência muscular foram significativas no GE, contrariamente ao GC. As variáveis da fase inicial do salto associadas ao voo melhoraram mais no GE comparativamente ao GC, com especificidades observadas no *grab start* e *track start*, mas não uma consequência linear com o desempenho aos 15 m em ambos os grupos. Um programa de F&C em seco de 10 semanas pode promover benefícios nas capacidades físicas de praticantes regulares de natação, facto que pode melhorar a fase inicial do salto na natação, anterior ao momento subaquático, que deve merecer atenção pelos treinadores nas sessões diárias visando uma melhoria de desempenho aos 15 m.

Palavras chave: Treino, Força, Flexibilidade, Cinemática, Desempenho.

INTRODUCTION

Substantial literature on youth sport has linked early sport specialization to negative consequences, such as burnout and dropout (Larson, Young, McHugh, & Rodgers, 2019), having been previously highlighted the relevant interest to continue promoting the practice of physical activity among the youngest (Moral-Campillo, Reigal-Garrido, & Hernández-Mendo, 2020). Swimming is often associated with early specialization, where training in swimming pool is monotonous and the performance influenced by a complex interaction of morphological, metabolic, neuromuscular, and biomechanical factors, with the start performance requiring a combination of reaction time, vertical and horizontal force off the block, and low resistance during underwater gliding (Keiner et al., 2019). More specifically, swim start performance has been identified as a determining factor for success, especially in sprint distance events, as it is the part of the race that the swimmer is travelling at the fastest velocity (Tor, Pease & Ball, 2015). Requires an explosive muscular response, especially of the lower body musculature, with swimmers having to apply large forces rapidly on the start block to increase net impulse and maximize take-off velocity in the desired direction (Rebutini, Pereira, Bohrer, Ugrinowitsch, & Rodacki, 2014).

In short swimming events (e.g. 100 m events), the start and turn account for nearly a third of the final race time (Morais, Marinho, Arellano, & Barbosa, 2018). Swim start is defined as the time from the starting signal to when the swimmer crosses the 15 m mark in a race (West, Owen, Cunningham, Cook, & Kilduff, 2011), with 15 m being the maximum distance that a swimmer can travel underwater before their head is required to break the surface of the water in all strokes except for breaststroke (FINA, 2018). The marginal differences in the outcome of modern swimming sprint races have increased the scientific interest in the start performance, which accounts for 25% of the total race time (Peterson Silveira et al., 2018; Rejman et al., 2017; Veiga & Roig, 2017). Supporting this evidence is the recent Rio 2016 Olympic finals, where the men's 50-m freestyle sprint was won with 21.40 seconds and only a 100th of a second ahead of the silver medal winner.

Start performance is strongly related to overall race time for 50-m, 100-m and 200-m race events (Tor, Pease, Ball, & Hopkins, 2014). It can be subdivided in four phases: the block phase (from start signal to take-off from the starting block), the flight phase (from take-off to water contact), the underwater phase (from water contact to the swimmer's resurfacing, the so-called 'break-out'), and the start of free swimming (from the break-out to the 15-m line), marks the point at which the underwater phase has to be completed). As close margins often exist between medalists in sprint swimming events, being able to identify areas to achieve marginal gains in performance by tenths or even hundredths of a second can make a difference in overall performance (Bishop, Smith, Smith, & Rigby, 2009).

The block phase requires a quick reaction to the starting signal and a large take-off velocity that is primarily horizontal in direction (Garcia-Hermoso et al., 2013). The greater the impulse produced on the start block, the greater the change in the momentum of the swimmer (Thng, Pearson, & Keogh 2019). The subsequent flight phase is an example of projectile motion, whereby the swimmer becomes airborne and finishes when contact the water (Slawson, Conway, Cossor, Chakravorti, & West 2013; Tor et al. 2014). The flight phase is followed by the underwater phase, in which swimmers attempt to maintain a streamlined position with their arms outstretched in front of the head to minimize velocity loss while also performing multiple propulsive undulatory leg kicks (except in breaststroke) until their head resurfaces before the 15-m mark (Formicola & Rainoldi, 2015). The block, flight, and underwater phase account for approximately 11%, 5%, and 84% respectively of the total start time (Slawson, et al., 2013).

Strength and muscular power are significant determinants of success in swimming-related sports (Karpiński et al., 2020). Most studies examined the effects of plyometric jump training (PJT) in male young athletes which is why there is a need to conduct additional research with female young athletes (Sammoud et al., 2019; Ramirez-Campillo et al., 2018, 2020). A number of studies has observed that males are able to produce higher velocities at the same percent of one repetition maximum and have a greater rate of force development and countermovement jump (CMJ) height than females (McMahon, Rej & Comfort, 2017; Torrejon, Balsalobre-Fernandez, Haff, & Garcia-Ramos 2019). Nevertheless, young non-elite swimmers might have relevant functional deficits in tasks involving mobility of the hips, knees and ankles, proper stride mechanics during a stepping motion, and also stabilization of the core and spine in an anterior and posterior plane during a closed-chain upper body movement (Lucas et al., 2021), evidences that should be meticulously monitored by coaches, that should become aware, perceive, and implement certain strategic projects created by national sports federations, fact that is closely related to coaches experience (Costa et al., 2021).

Swimmers performing a combined intervention consisting of maximal strength and high-intensity interval endurance training twice per week over 11 weeks, in addition to their regular swimming training, improved dry-land strength, tethered swimming force and 400-m freestyle performance compared to a control group that continued regular training within their teams (Aspenes, Kjendlie, Hoff, & Helgerud, 2009). Furthermore, an 8-week intervention period of plyometric training on swimming start performance through explosive power training showed positive effects (Bishop et al., 2009). However, strength training is most frequently prescribed in elite swimming programs compared to former federated swimmers who maintain their regular practice with punctual and non-regular participation in competitive events, despite lower-body strength is strongly correlated to swimming start performance (West et al., 2011). Hence, the aim of this study was to evaluate the effects of a 10-week dry-land strength and conditioning (S&C) program on physical capacities and swimming start in previously federated and regular swimming practitioners.

MATERIALS AND METHODS

Participants

16 swimmers (9 male, 17.00±2.16 years of age, 179.14±5.76 cm of height, 69.79±3.11 kg of weight and 516 FINA point score in 100 m freestyle; 7 female, 15.86±2.34 years of age, 163.86±4.98 cm of height, 60.19±3.60 kg of weigh and 503 FINA point score in 100 m freestyle) were recruited by convenient sampling in a local club competing in second national division in Portugal to take part in the study. During the period in which they were federated, they had experience with calisthenic dry-land S&C training.

Inclusion criteria required that subjects were previously federated in Portuguese Swimming Federation since the cadets age category with regular participation in regional and national competitions and had at least 2 years of regular 3 times a week swimming practice in a late day swimming class specifically integrated by previous federated swimmers, without any kind of dry-land S&C training. Participants were excluded if they had an injury or did not attend 2 of the 3 weekly training swimming sessions in the last 3 months before the beginning of the research.

For two years prior to the research moment (which occurred in between March and May 2019) subjects regularly performed an average 2.5 km of in-water swimming per session and occasionally participated in competitions destinated to non-federated swimmers. The study was conducted in accordance with the Declaration of Helsinki for research involving human participants (Harriss, MacSween, & Atkinson, 2019). All parents and individuals with 18 years of age or older gave their written informed consent and under-age subjects their assent.

Procedures

Participants were equality but randomly separated in two groups (control group and experimental group, respectively CG and EG). During a 10-week period, both groups performed the regular 45-min in-water swimming training but only the EG strictly performed 60-min, 2 sessions a week dry-land S&C training with emphasis in explosive strength and flexibility training (after a period of 2-weeks for dry-land S&C training adaptation). Training was daily supervised by two of the researchers, both graduated in sports sciences, one with level 2 and other with level 1 swimming coach certification in Portugal. No specific technical training aiming swimming start improvement was performed by both groups during the 10-week dry-land S&C training.

In testing days (pre-test and post-test, previously and after dry-land S&C implementation), subjects were instructed to report to the swimming pool well hydrated, fed and to abstain from caffeine, alcohol and strenuous exercise in the 24-h preceding the testing sessions. The same environmental conditions (time of day ± 2-h, water temperature ~28ºC and relative humidity ~50%) and the same warm-up protocol was applied in pre and post-test in swimming pool and dry-land to minimize the effects of circadian rhythms and differences in prior exercise.

In the swimming pool, 800 m moderate intensity warm-up was performed (300 m swim, 50 m pull, 50 m kick, 4 3 50 m at increasing speed, 200 m easy swim), previously adopted in Amaro, Marinho, Marques, Batalha, & Morouço (2017) study. Dry-land warm-up in pre, post-test and in training sessions during the 10-wekk period had approximately 15 min (included as part of the 60 min sessions), composed by aerobic tasks, articular mobility, and dynamic stretching. The data collection was performed by two experienced swimming coaches and researchers.

All dry-land S&C training sessions were performed in a gym before the swimming sessions and the exercises were associated to small investment in materials and easy transportability. In the end of each dry-land training session 10 to 15 min of flexibility exercises were performed by the subjects, time span included in the total session duration. The work:rest ratio was 1:1 in all exercises that involved several repetitions. The dry-land S&C sessions were planed and close monitored by one of the researchers, graduated in sports sciences with 5 years of experience in S&C and level 2 swimming coach certification, who assured the quality of movement and exercise intensity (with emphasis in power). The 10-week dryland-land S&C program was adapted from 8-week, 2 times a week 75 min intervention of Rejman et al. (2017), prolonged to a 10-week period as in Amaro et al. (2017) research. Table 1 depicts the 10-week dry-land S&C program performed by the EG.

Dry-land strength and conditioning evaluations

The swimmers were weighed on a Tanita scale (Inner Scan UM-076), the “Sit and Reach” was used to measure the flexibility of the lower limbs (LL), handgrip strength (HG) was assessed with a digital handheld dynamometer (Camry 90 kg), a measuring tape was used for arm span and flexibility of upper limbs (UL), CMJ was determined using Ergojump System (Byomedic, SCP, Barcelona, Spain), For the UL body power measure the swimmers completed a 3 kg medicine ball throwing test (MBT). Each subject sat on a chair with their back positioned against the chair and held the ball to the front with both hands. They were instructed to throw the medicine ball as far as possible. Torso and hip rotation were not allowed. The maximum throwing distance was measured with a flexible steel tape. Three approved attempts were made with 1-min resting intervals, to ensure that fatigue or learning effects did not influence the performance.

For CMJ, each subject started from an erect standing position and the end of the concentric phase corresponded to a full leg extension: 180º. Three jumps were performed, each followed by 2-min of rest. An average of the three jumps was taken to analysis. For HG strength, subjects were asked to hold the dynamometer in dominant hand, putting in latter maximum effort for around 5-sec. This procedure was repeated thrice with 1-min rest in between, to prevent fatigue. The mean of the three readings was referred to as the maximal isometric tension. Arm span was measured with subjects facing away from the wall, with back and buttocks touching the arms were horizontally stretched out to measure from one furthermost finger to the other with a measuring tape. Sit and reach test was performed with subjects sitting on the floor with legs stretched out straight ahead with both soles of the feet placed flat against the box. Afterwards, with the palms facing downwards, and the hands on top of each other or side by side, the subjects reached forward along the measuring line as far as possible, ensuring that the hands remained at the same level and holding that position for at least 3-sec while the distance was recorded. The best of two repetitions was assumed.

Swimming pool evaluations

Each swimmer performed three sets for each of the two swimming start variants (grab and track start - a total of six per evaluation session), which were filmed for further analysis. For this purpose, we used Kinovea (video analysis software dedicated to sports movements and physical exercise - version 0.8.15), analyzing speeds, angles and distances. To acquire the measurements of the kinematic variables, a video system consisting of a digital camera (Leica camera of a Huawei Mate 9) was used, placed 7 m from the diagonal formed between the anterior distal vertex of the second starting block and the inner edge side of the pool (the latter position was at a distance perpendicular to the side edge of 3 m and another 3 m perpendicular to the starting line). This camera was positioned out of the water, parallel to the movement, on a tripod, approximately 1.20 m from the ground, with the function of capturing the images required to the study, in its various phases preceding the underwater path (block phase and take off, flight or aerial phase, entry into the water and slide or underwater route). The second camera (GoPro Hero 5 Black Edition), was placed at 5 m from the starting line, submerged approximately 0.5 m from the surface. It was attached to an aluminum rod that was fixed in the desired location, with the purpose of observing the phase after entering the water and the corresponding underwater path.

Table 1. Dry-land strength and conditioning 10-week training routine performed by the experimental group.

The videos were transferred to the computer, for editing and cutting we used Avidemux v2.7 (64-bit version). The conversion to MP4 file was carried out by Handbrake program. The analyzed variables were:

Week	Workout 1 Exercises	Series	Reps	Weight	Workout 2 Exercises
	Power Skipping	2	-	10 m	Power skipping
	Squat Jump	2	10	-	Jumping alternating step-ups
1st	Push-ups	2	10	-/10 kg	Jumping jacks
	Chest Passes (ball)	2	10	3 kg	Chest passes
and	Power Skipping	2	-	10 m	Power skipping
	Knee-tuck jumps	2	10	-	Alternating jumping high knee
3rd	Over-head throw (ball)	2	10	3 kg	Over-head throw (ball)
	Lifting the weights over head	2	10	10 kg	Lifting the weights over head
	Alternate sprint bounding	3	-	30 m	Double speed hops
	Power Skipping	3	-	10 m	Power skipping
	Squat Jump	3	10	-	Jumping alternating step-ups
2nd	Push-ups	3	10	-/10 kg	Jumping jacks
	Chest Passes (ball)	3	10	3 kg	Chest passes
and	Power Skipping	3	-	10 m	Power skipping
	Knee-tuck jumps	3	10	-	Alternating jumping high knee
4th	Over-head throw (ball)	3	10	3 kg	Over-head throw (ball)
	Lifting the weights over head	3	10	10 kg	Lifting the weights over head
	Alternate sprint bounding	3	-	30 m	Double speed hops
	Power Skipping	4	-	10 m	Power skipping
	Squat Jump	4	10	-	Jumping alternating step-ups
5th	Push-ups	3	10	-/10 kg	Jumping jacks
	Chest Passes (ball)	3	10	3 kg	Chest passes
and	Power Skipping	4	-	10 m	Power skipping
	Knee-tuck jumps	4	10	-	Alternating jumping high knee
7 th	Over-head throw (ball)	3	10	3 kg	Over-head throw (ball)
	Lifting the weights over head	3	10	10 kg	Lifting the weights over head
	Alternate sprint bounding	4	-	30 m	Double speed hops
	Power Skipping	5	-	10 m	Power skipping
	Squat Jump	5	10	-	Jumping alternating step-ups
6th	Push-ups	3	10	-/10 kg	Jumping jacks
	Chest Passes (ball)	3	10	3 kg	Chest passes
and	Power Skipping	5	-	10 m	Power skipping
	Knee-tuck jumps	5	10	-	Alternating jumping high knee
8th	Over-head throw (ball)	3	10	3 kg	Over-head throw (ball)
	Lifting the weights over head	3	10	10 kg	Lifting the weights over head
	Alternate sprint bounding	5	-	30 m	Double speed hops
	Power Skipping	6	-	10 m	Power skipping
7th	Squat Jump	6	10	-	Jumping alternating step-ups
	Push-ups	3	10	-/10 kg	Jumping jacks
9th	Chest Passes (ball)	3	10	3 kg	Chest passes
	Power Skipping	6	-	10 m	Power skipping
and	Knee-tuck jumps	6	10	-	Alternating jumping high knee
	Over-head throw (ball)	3	10	3 kg	Over-head throw (ball)
10th	Lifting the weights over head	3	10	10 kg	Lifting the weights over head
	Alternate sprint bounding	5	-	30 m	Double speed hops

1) Flight time - the time between the last contact of the

feet with the starting block and the first finger contact with water (in seconds); 2) Entry distance - the distance from the swimming pool wall under the starting block to the first contact of the swimmer's fingers with the water (in meters); 3) Dive angle - an angle between the horizontal line and the line which connects the body centre of mass (CM) with the referential spot on the hand, at the moment of the first contact of the fingers with the water (in degrees); 4) Velocity - velocity of CM from the last contact of feet with the starting block, until first contact with the water's surface (meters per second); 5) Breaking surface distance - The distance at which the swimmer's head breaks the surface of the water for the first time (in meters); 6) Time breaking distance - Time at which the swimmer's head breaks the surface of the water for the first time (in seconds) and; 7) Time at 15 m – Performance time at 15 m (in seconds).

Statistical Analysis

The sample size required was computed beforehand (GPower, v.3.1.9, University of Kiel, 62 Germany). The data are expressed as the mean ± standard deviation (SD). Normality and homogeneity of data were confirmed with Shapiro-Wilk and Levene tests. Differences between tests were examined using t-test. Linear regression models between variables were computed with trendline equation and determination coefficient (R^2). Pearson's linear correlation coefficient and statistical significance was accepted at $p < 0.05$. All statistical analysis were performed with the Statistical Package for the Social Sciences (version 25.0; SPSS, Chicago, IL, USA).

RESULTS

Regarding post-test and in the EG, CMJ was correlated to HG (r=0.76, p<0.05), HG to 3 kg MBT (r=0.76, p<0.05), and UL flexibility (r=0.79, p<0.05). In CG, CMJ was highly correlated to HG (r=0.88, p<0.01) and MBT (r=0.93, p<0.01). HG was also correlated to MBT (r=0.88, p<0.01). Table 2 presents the swimming characterization and physical capacities in pre and post-test.

In EG, improvement in UL and LL flexibility were observed (p<0.05 and p<0.01, respectively), the same was observed with respect to strength and muscular power variables, CMJ and 3kg MBT (p<0.01) and HG (p<0.05). In CG, only UL flexibility and HG improved after 10-week in-water swimming training, both without significant differences. CMJ and MBT mean values slightly decreased, without significant differences (p>0.05), contrarily to LL flexibility (p<0.05). Table 3 shows the swimming grab start model variables determined in pre and post-test both in CG and EG.

In swimming grab start, and considering EG, the differences between pre-test and post-test were observed mainly in the first phase of the swimming start (flight time, entry distance, dive angle and velocity). Noteworthy that although the breaking surface distance significantly improved, also the time breaking distance was higher. In the CG, the dive angle was different (higher, contrarily to EG, p<0.05), also the velocity improved (p<0.05) and breaking surface distance highly increased (p<0.01), such as observed for time breaking distance (p<0.05). Time at 15 m slightly improved in EG, but not in CG. Table 4 depicts the swimming track start model variables determined in pre and post-test both in CG and EG.

In swimming track start, the entry distance highly improved in EG (p<0.01), contrarily to CG. The dive angle was different in both groups (p<0.05), but lower in EG and higher in CG. Velocity also significantly increased in CG (p<0.05) and EG (p<0.01). Breaking surface distance improved in both groups (EG p<0.01 and CG p<0.05), but also time breaking distance was higher in CG (p<0.05) and EG (p<0.01). The time at 15 m improved in CG (p<0.05), but not in EG.

Comparing physical capacities to swimming start variables in post-test, CMJ was correlated to entry distance in grab start (r=0.81, p<0.05) and track start (r=0.80, p<0.05) and velocity in grab start (r=0.77, p<0.05) and track start (r=0.76, p<0.05). Linear regression between CMJ and entry distance in displayed in figure 1.

Table 2. Swimmers' characterization and physical capacities in pre and post-test.

	Control Group (n= 8)		Experimental Group (n= 8)	
	Pre-test	Post-test	Pre-test	Post-test
Height (m)	1.67 ± 0.07	1.67 ± 0.07	1.71 ± 0.10	1.72 ± 0.11
Body mass (kg)	65.62 ± 5.54	65.48 ± 4.80	63.06 ± 5.78	64.05 ± 6.82
UL Flexibility (cm)	5.37 ± 2.45	5.56 ± 3.40	10.81 ± 4.09	14.42 ± 6.24**
LL Flexibility (cm)	0.19 ± 12.60	0.08 ± 9.60*	11.06 ± 12.15	11.56 ± 10.82*
Arm span (m)	1.65 ± 0.11	1.68 ± 0.06	1.73 ± 0.11	1.74 ± 0.11
CMJ (cm)	28.78 ± 9.64	28.71 ± 8.40	33.70 ± 11.65	37.22 ± 11.27**
MBT 3kg (m)	3.81 ± 1.31	3.76 ± 1.05	4.43 ± 1.18	4.63 ± 0.97**
HG (kg)	30.52 ± 10.17	30.91 ± 9.78	40.06 ± 11.65	41.90 ± 12.03*

Statistical differences between groups. * ($p<0.05$) ** ($p<0.01$). UL: Upper limbs; LL: Lower limbs, CMJ: *Countermovement jump; MBT: Medicine ball throwing; HG: Handgrip strength.*

Table 3. Grab start variables determined in both control and experimental groups in pre and post-test.

Grab start	Control Group (n= 8)		Experimental Group (n= 8)	
	Pre-test	Post-test	Pre-test	Post-test
Flight time (s)	0.21 ± 0.10	0.20 ± 0.10	0.35 ± 0.07	0.32 ± 0.07*
Entry distance (m)	2.43 ± 0.29	2.48 ± 0.31	2.86 ± 0.29	3.01 ± 0.35**
Dive angle (º)	45.63 ± 7.16	48.08 ± 5.96*	41.42 ± 5.64	35.88 ± 6.78**
Velocity (m/s)	3.71 ± 0.64	3.88 ± 0.51*	4.41 ± 0.35	4.87 ± 0.39**
Breaking surface distance (m)	8.73 ± 2.31	10.47 ± 0.79**	10.58 ± 1.02	10.76 ± 1.95*
Time breaking distance (s)	4.80 ± 1.12	5.57 ± 1.31*	5.38 ± 0.85	5.65 ± 1.68*
Time at 15 m (s)	10.09 ± 1.67	10.39 ± 1.33	8.57 ± 0.90	8.34 ± 0.71

Statistical differences between groups. * ($p<0.05$) ** ($p<0.01$).

Table 4. Track start variables determined in both control and experimental groups in pre and post-test.

Track start	Control Group (n= 8)		Experimental Group (n= 8)	
	Pre-test	Post-test	Pre-test	Post-test
Flight time (s)	0.23 ± 0.09	0.19 ± 0.09*	0.31 ± 0.07	0.30 ± 0.07
Entry distance (m)	2.37 ± 0.30	2.35 ± 0.32	2.79 ± 0.35	3.02 ± 0.35**
Dive angle (º)	44.75 ± 5.30	46.38 ± 4.87*	40.63 ± 7.41	38.96 ± 7.43*
Velocity (m/s)	3.60 ± 0.44	3.71 ± 0.50*	4.40 ± 0.33	4.94 ± 0.36**
Breaking surface distance (m)	8.90 ± 2.04	9.19 ± 1.67*	10.63 ± 1.81	11.06 ± 1.60**
Time breaking distance (s)	5.27 ± 1.31	5.58 ± 1.13*	5.83 ± 1.26	6.23 ± 1.74**
Time at 15 m (s)	10.50 ± 2.09	10.26 ± 1.67*	8.99 ± 1.00	9.13 ± 1.53

Statistical differences between groups. * ($p<0.05$) ** ($p<0.01$).

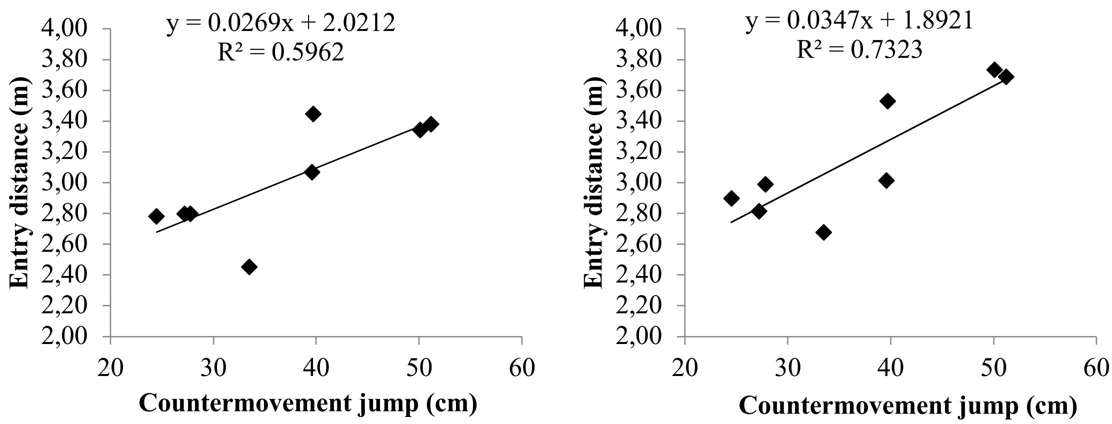

Figure 1. Linear regression of countermovement jumps on entry distance in swimming start in grab start model (left) and track start model (right) in experimental group and post-test.

With respect to swimming start variables in EG during post-test, flight time was highly correlated to entry distance in grab start (r=0.91, p<0.01) and track start (r=0.90, p<0.01) and to velocity (in both swimming start models, r=0.92, p<0.01). Also entry distance was highly correlated to velocity in grab start (r=0.96, p<0.01) and track start (r=0.95, p<0.01). Time at 15 m was correlated to time breaking distance only in grab start (r=0.79, p<0.05).

DISCUSSION

This study sought to evaluate the effects of a 10-week dry-land S&C program on physical capacities and swimming start in previously federated and regular swimming practitioners. To the best of our knowledge this is the first study which comprehensively analyzes the effect of a specific 10-week dry-land S&C training program on physical capacities and swimming start in previously federated and regular swimming practitioners since most of the studies regarding this scientific topic involved young or elite swimmers. The main results to be derived from this study are the following: i) 10-week dry-land S&C training program improve physical capacities, with greater consequence on strength and muscular power variables compared to flexibility; ii) 10-week dry-land S&C training program improve the first phase of the swimming start variables, previously to the entry in the water by the swimmer and; iii) The time at 15 m is not directly related to the benefits of 10-week dry-land S&C training program.

Jump performance is a key performance determinant in swimming, previously shown to be a valid talent-identification markers that have the potential to discriminate between elite and non-elite athletes (Mitchell, Rattray, Saunders, & Pyne, 2018). Also other studies demonstrated that considerable development of maximal strength abilities is possible, even when trained concurrently to large volumes of aerobic exercise (Berryman et al., 2018; Ronnestad, Hansen, & Raastad, 2011). Ballistic/plyometric training may improve the transfer of maximal strength to power production and rate of force development (Suchomel, Nimphius, Bellon, & Stone, 2018), thereby significantly improving swim start performance metrics including time to 5 m, take-off velocity and impulse (Bishop et al., 2009; Rebutini et al., 2014; Rejman et al., 2017).

Asadi, Arazi, Young, & Saez de Villarreal (2016) explained that the improvement in vertical jump performance after PJT may be attributed to increased fiber length. However, PJT is also likely to improve coordinative aspects during jumping. This is most likely caused by neuromuscular adaptations that enhance power production (Sammoud et al., 2021). Previously, Potdevin, Alberty, Chevutschi, Pelayo, and Sidney (2011) also revealed significant improvements in CMJ and squat jump height after 6-weeks of PJT in adolescent male and female swimmers aged 13 and 15 years. Likewise, de Villarreal, Suarez-Arrones, Requena, Haff, and Ramos Veliz (2015) showed a significant improvement in CMJ height after 6-weeks of PJT in adolescent male water-polo players.

More recently, Sammoud et al. (2019) observed small and moderate improvements in CMJ height and standing long jump performance, respectively, in prepubertal male swimmers following PJT combined with regular swimming training. As noted, lately there has been an increasing interest in strength training in swimming, more specifically, in-water and dry-land S&C training, although, as far as our understanding goes, the literature remains unclear about this topic. Our results revealed that after 10-week of regular in-water training UL flexibility improved in both CG and EG groups, although only in EG the increase was significant. With respect to LL flexibility, a decreased was observed in CG contrarily to the significant improvement in EG. These evidences highlight the relevance of dry-land S&C training implementation to flexibility improvement and also that UL and LL flexibility is associated to different mechanics in swimmers and relationship to in-water training.

Several correlations were observed between the strength and muscular power variables evaluated in this study (CMJ, HG and MBT), fact that underlines the importance of considering these physical capacities and specific dry-land S&C programs. Nonetheless, it is worth mentioning that improvements in strength and muscular power variables were only observed in EG, which is in line with Amaro et al. (2017) study, wherein 6 weeks of complementary dry-land S&C training led to improvements in dry-land strength variables, which were beneficial for aquatic performance only after a 4-week adaptation period. The correlations observed between strength and muscular power variables in our study also highlight the importance of dry-land S&C training aiming strength and muscular power improvement, fact also previously observed in Espada et al. (2015) study, where correlations were observed in 30-39 years group master swimmers between HG and MBT.

The swim start is a separate skill compared to the free swim portion of a race, as swimmers initiate the movement on the starting block above the water for all strokes, except those competing in the backstroke event (Formicola & Rainoldi, 2015; Welcher, Hinrichs, & George, 2008). During the start movement, the arm pull reaches almost 100% body mass to bring the swimmer into an optimal position for force production as quickly as possible (Takeda, Sakai, Takagi, Okuno, & Tsubakimoto, 2017). Sprinting swimmers are prone to take less time on the block, mainly due to their strength, power and quick reaction to stimulus (Marinho, Barbosa, Neiva, Silva, & Morais, 2020). This will lead to a faster water entry, and consequently to less time reaching the 15-m mark (Tonnessen, Haugen, & Shalfawi, 2013).

Especially at shorter race distances, the quality of the dive start considerably contributes to the overall race result (van Dijk, Beek, & van Soest, 2020). In swimming start, after the aerial phase, swimmers have to manage the transition from air to water (Maglischo, 2003), with the glide beginning when the head enters the water and ending when the head breaks out (Counsilman et al., 1988). Also Guimaraes and Hay (1985) and later Hay (1988) concluded that glide time is more important to the start phase than either block time or flight time and more recently de Jesus et al. (2011) showed the importance of the compromise between underwater velocity and backstroke start performance.

The correlations we observed in the present study between CMJ and flight phase variables in both grab and track start underline the importance of strength and muscular power before the swimmer entry in the water. Along this evidence, our results highlight the importance of dry-land S&C for strength and muscular power improvement, and consequently, enhancement of swimmer's performance in the first seconds of a swimming race, before entry into de water. Also Rejman et al. (2017) verified 3.77 to 4.48 $m.s^{-1}$ improvement in flight average velocity (defined as the velocity of CM from the last contact of feet with the starting block, until first contact with the water's surface) after 6-week of dry-land S&C training in swimmers. It is also pertinent to mention that after the 6 weeks of dry-land S&C program in Amaro et al. (2017) study swimmers did not improve swimming performance. However, the 4-week adaptation period allowed GR2, group with participation in dry-land S&C training, to significantly improve swimming performance.

Furthermore, Benjanuvatra, Edmunds, and Blanksby (2007) reported a nearly perfect relationship between the take-off velocity of CMJ with time to 5 m, whereas Garcia-Ramos et al. (2016) reported a moderate to large relationship between the take-off velocity in the CMJ with time to 10 m and 5 m. Also a significant correlation between entry angle and start performance has been previously found by Ruschel, Araujo, Pereira, and Roesler (2007), who stressed that flight distance is one of the variables that determine starting performance. Nevertheless, in the study of Breed and Young (2003), dry-land resistance training did not affect the distance of the flight phase during the starting jump, which may be related to its specificity. The authors indicated that the dive starting requires changes in body position during flight and the need to find an optimal take-off angle for maximum performance, confirming that take-off velocity is the main determinant of a projectile's range and adding that the arms have a large role in providing horizontal momentum of the body in the rear-weighted track start, particularly during the early part of the movement.

In fact, Aspenes et al. (2009) stated that technical swimming post-resistance training will help the likelihood of the transfer of resistance training to swimming performance. Our results also point to differences in swimming start variables not only between CG and EG, but also when considering the different start techniques (grab and track start). Thus, the swim-start is not just limited to the block and aerial phases but continues until the swimmer re-surfaces and commences swim stroking up to the 15-m mark, fact corroborated by Houel et al. (2013) when analyzing the underwater phase and indicating that swimmers should ideally start dolphin kicks after approximately 6-m of glide and need to be efficient, with a high rate of kicking. Later, Tor et al. (2014) also indicated that the average velocity during the underwater phase is highly dependent on the take-off velocity acquired in the block phase, the horizontal distance obtained in the flight phase, as well as the degree of streamlining and effectiveness of the undulatory leg kicks during the underwater phase.

Our results suggest that a 10-week dry-land S&C training program in regular swimming practitioners improve the first phase of the swimming start, namely the entry distance and velocity in both grab and track start, all variables associated to the phase before the entry in water by the swimmer and underwater phase. We clearly observed that underwater phase influences the performance at 15 m in swimming and is not closely related to the improvement of strength and muscular power variables. In our perspective, motor organization during the underwater phase should be optimized and training optimization is also very relevant, reason why high-level performance swimmers' practice in-water around 10-times a week with a single training session volume normally above 5 km, with come tasks emphasizing technical details. A dry-land S&C training program may also contribute to enhance swimmer's enjoyment since it promotes interactive training moments between individuals outside in-water training environmental, and to that extent motivate swimmers, which could influence behaviors when considering physical exercise (Martín-Moya, Jesús Ruiz-Montero, Rivera García, & Leeson, 2020) and the benignant objective to avoid the dropout of sport.

This study had some limitations. The results are related to male and female swimmers, not for a specific gender. The maturation status of the subjects was not determined. The study took place at a specific stage of the sporting season and should be carefully analyzed in its application in other moments of training for swimmers during a season. Future studies should consider other age groups, with different expertise levels, and consider different methodologies with the aim of evaluation improvement and better address training prescription. The kinematic underwater dynamic performed by the swimmers should be considered in training and evaluation.

PRACTICAL APPLICATIONS

A specific 10-week dry-land S&C training program may enhance physical capacities, more specifically in terms of strength and muscular power compared to flexibility, fact that may improve the initial phase of the swimming start phase prior to the underwater moment, which should deserve detailed attention by the coaches in daily training aiming performance enhancement at 15 m. Future studies should pursue to deepen the detailed knowledge about underwater parameters such as time of first kick (s), distance of first kick (m) and time at max depth (s) and relationship with dry-land S&C training aiming the improvement of swimming start performance. An adaptation period after dry-land S&C training to promote in-water adaptations should be considered and evaluated.

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CONFLICTS OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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