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Two Different Approaches to Dry-land Training Do Not Improve the Water Performance of Swimmers

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ABSTRACT

International Journal of Exercise Science 16(6): 770-790, 2023. Literature diverges about the performance improvement after dry-land training. Thus, the objective of the present study was to compare the effect of two models of dry-land training. Twenty-nine swimmers were divided into three groups, combined strength and power training (PTG), only strength training (STG), and a control group (CG). Measurements were taken for six weeks, before dry-land exposure (M1), after four weeks of specific training with exposure to dry-land training by two groups (M2), and after two weeks of taper without exposure to dry-land training (M3). Strength in specific exercises, jumping tests, and 50, 100, and 200m freestyle performance were evaluated on M1 and M3, while hematological and strength parameters in tethered swimming were measured in M1, M2, and M3. PTG showed time-effect improvement for 200, 100, and 50m performance ($p<0.014$), CG for 200 and 100m ($p<0.047$), and STG only for 100m (p:0.01). No differences were found in Δ performance between groups. PTG showed improvement in the peak force of tethered swimming on M2 (p:0.019), followed by a decrease on M3 (p:0.003). PTG and STG also showed an increase in creatinine, lactate dehydrogenase (LDH), and creatine kinase (CK) after M2 ($p<0.038$). Finally, it was concluded that both dry-land training sessions could change hematological parameters and improve physical attributes on dry-land and tethered swimming tests without improving performance.

KEY WORDS: Power, strength, tethered swimming, muscular damage

INTRODUCTION

Speed, strength, and muscle power have been indispensable for swimmers in short events (50, 100, and 200 meters) (26, 47, 59). Besides improving water motor tasks (43), power training also provides determinant adaptations for competitive swimming (16, 20, 45). The benefit of improving strength and speed include improved synchronization and motor recruitment (48) and greater metabolic efficiency (1), essential adaptations in swimming performance. In addition, increased muscle strength and power in the upper limbs, main muscle groups involved in swimming propulsion (15), have great representativeness in a swimming training program's final result (32, 59). Considering that improving strength and power may improve competitive swimming performance (17), dry-land training is a strategy many coaches have used to increase these capabilities (18). Despite the physical motor gain on land (3, 26, 56, 59), this training method presents divergent results regarding the transfer of gain to performance in water (25, 26, 56, 57, 59).

Evidence shows that dry-land training is accompanied by improved swimming performance related to increased upper limb power (25, 26, 56) and mechanical swimming parameters like stroke rate, stroke length, and stroke depth (47, 56). On the other hand, there is evidence of the absence of performance improvements in other studies (44, 57, 59). The inclusion of dry-land training in the swimmer's routine must also be carefully monitored. The resisted training it usually accompanied by muscle damage biomarker, inflammatory process, metabolic-neurologic responses, and hormonal alterations (13, 38). Although evidences for muscle damage inherent in swimming training (46), there are no reports regarding dry-land training and whether it would be able to increase the burden of muscle damage in addition to in-water training. Considering that the dry-land training overload can induce the swimmer to non-functional overtraining, monitoring biomarkers such as creatine kinase (CK) and lactate dehydrogenase (LDH) is a good strategy used in sports (8).

Among the studies that reported the inefficiency of dry-land training, it is worth highlighting the inefficiency of assisted training methods (59) and maximum strength (26). The ineffectiveness of these training methods may occur due to the low specificity (57), once the dislocation in swimming is highly dependent on technical factors (e.g., stroke amplitude, members coordination, stroke angle, body balance, head angle during breathing) (15, 39). Specific training is needed considering the importance of speed, strength and power training in the technical gesture of swimming (28, 59). In this way, Newton et al.(37) considers resisted training to be highly relevant for Olympic-level performance and emphasizes the importance of periodization progression and inclusion of strength and power training. In this sense, Muniz-Pardos et al. (35) presented in their systematic review that a quality study is needed to compare different training routines, highlighting the comparison between power and strength involvement on dry-land approaches.

Thus, the present study aimed to determine the effect of two different models of dry-land training, the first mainly focused on power enhancement (PTG) and the second focused on strength enhancement (STG), on the freestyle performance in 50, 100, and 200m. In addition, to explain the possible sources of performance improvement, this study also compared the hematological responses, tethered swimming, specific strength, and jumping tests between the two dry-land models.

Our hypothesis considers that PTG can better transfer the technical gesture in water (32, 37). Because free-weight training involves more muscles (stabilizing muscles)(52), this model may induce more muscle damage markers flux. Thus, PTG is expected to have more significant muscle damage and improved performance.

METHODS

Twenty-nine swimmers were divided randomly into three groups: PTG (n = 11), STG (n = 7), and control group (CG, n = 7). The three groups performed the same periodized training in the water. However, PTG and STG were submitted to a dry-land training program three times a week (Mondays, Wednesdays, and Fridays), carrying out a total of 12 training sessions. Details of group performance and anthropometric data for each group are provided in the complementary material. Before the dry-land training period, PTG and STG held three familiarization sessions with the respective training program's exercises. The familiarization was made through educational exercises and subjectively estimated load at ~ 50% of repetition maximum (RM). Although the evaluations comprised six weeks, the swimmers had four weeks of dry-land intervention. The experimental design was conducted throughout the season, with the first assessments performed after 4-weeks of training (preparatory period – M1), second assessments after 8-weeks (specific period – M2), and the last evaluations after 10-weeks (taper period – M3). Dry-land and in-water evaluations were arranged in different four-day periods. For PTG and STG, the maximum dynamic voluntary contraction (one-rep max) of bench-press (both PTG and STG), squat (only PTG), and clean (only PTG) was established on the first gym session of M1 and last session of M2. Performance evaluation, jump tests, tethered swimming, and blood collection were made on M1 and M3. Blood collection and tethered swimming were also made on M2 (Figure 1).

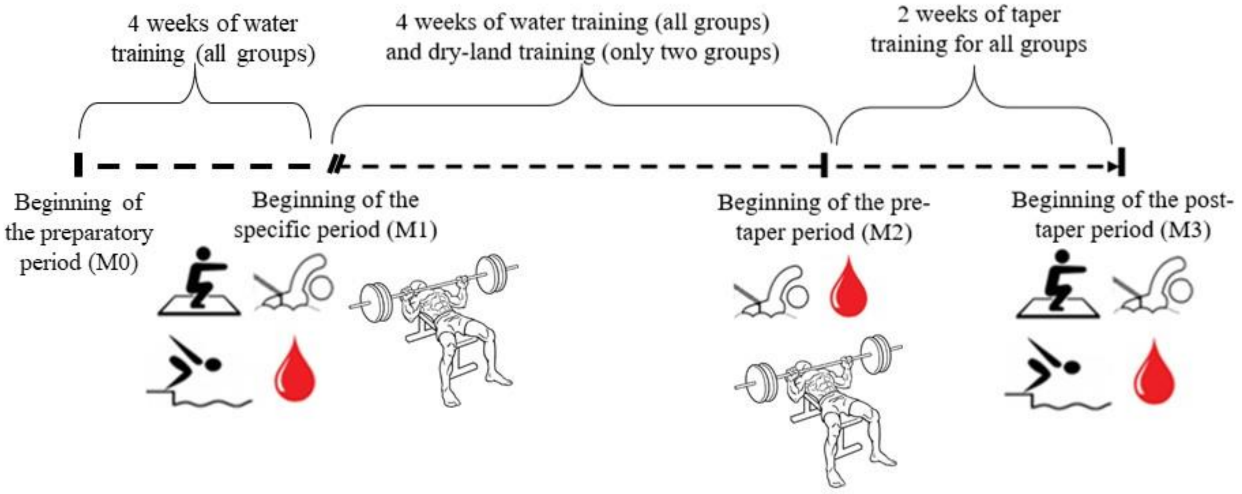

Figure 1. The experimental design was used to investigate the effects of two models of dry-land training in swimmers. 🏊: freestyle performance evaluation at distances of 50, 100, and 200m, 🤸: jump test, 🏊: tethered swimming test, 🩸: blood collection, 🏋: maximum dynamic voluntary contraction on gym, M1: moment 1, M2: moment 2, M3: moment 3.

Participants

Twenty-nine young swimmers (thirteen women and sixteen men) voluntarily participated in the study with 15.6 ± 2.1 years old, 164.7 ± 5.6 cm of body mass and 58.8 ± 4.4 Kg of weight who competed for a minimum of 2 years affiliated with the state federation to which the region belonged. The participants had an average daily training volume of approximately 5000 m, six days·week-1. The performance of the swimmers represents 93.1%, 66,1% and 57.9% of the world record of 50, 100 and 200 m freestyle swimming, respectively. The swimmers were in the fifth month of periodization and had at least one year of experience in training with strength exercises out of the water. Participants were only confirmed in the study after signing (by parents or legal guardian) the informed consent term approved by the University's Ethics Committee responsible for the research (36). Participants who obtained two consecutive absences or three non-consecutive absences were excluded from the sample. Only one participant was not included in the sample. Using G*Power software (Dusseldorf, Germany, 3.1.9.7 version) the 50m performance of the present study was tested and showed a effect size of 0.71 by Cohen's d and a sample power of 0.41.

Protocol

Twenty-nine young swimmers (thirteen women and sixteen men) voluntarily participated in the study with 15.6 ± 2.1 years old, 164.7 ± 5.6 cm of body mass and 58.8 ± 4.4 Kg of weight who competed for a minimum of 2 years affiliated with the state federation to which the region belonged. The participants had an average daily training volume of approximately 5000 m, six days·week-1. The performance of the swimmers represents 93.1%, 66,1% and 57.9% of the world record of 50, 100 and 200 m freestyle swimming, respectively. The swimmers were in the fifth month of periodization and had at least one year of experience in training with strength exercises out of the water. Participants were only confirmed in the study after signing (by parents or legal guardian) the informed consent term approved by the University's Ethics Committee responsible for the research (36). Participants who obtained two consecutive absences or three non-consecutive absences were excluded from the sample. Only one participant was not included in the sample. Using G*Power software (Dusseldorf, Germany, 3.1.9.7 version) the 50m performance of the present study was tested and showed a effect size of 0.71 by Cohen's d and a sample power of 0.41.

Tethered swimming test: The evaluation by tethered swimming test was made using an apparatus proposed by Papoti et al. (40) composed of a data acquisition system (National Instruments), voltage amplifier (MK-TC05 - Brazil), and a dynamometer containing a load cell (LIDER - CS-25, Brazil). For this, an inextensible rope was tied around the waist of the swimmers, analyzing the swim strength during an effort. The system was previously calibrated to the tests with the overlap of three known weights (5, 10, and 15 Kg). Before and after the efforts of each swimmer, the system offset was verified. The test started with an initial performance of ten seconds of easy swimming (subjectively determined by the swimmers), followed by 30s of maximum effort. The start and end of the test were limited by an audible signal (whistle). It was considered to mean force as the mean force during the 30s of effort,

disregarded the first second where the cable was extended; peak force was the highest force value during the thirty seconds of evaluation.
Specific strength evaluation: The strength tests were based on protocol proposed by Brown and Weir (11) where the participants performed a warm-up divided into two stages, initially running on a treadmill (5min at 9 km/h) followed by a specific warm-up on the evaluated exercise composed of ~20 repetitions using a subjectively low load. After the warm-up, a load considered subjectively close to the maximum (stablished by the participant) was set, and five attempts (5 min between each attempt) were made to reach the maximum repetition. If the participant did not reach it, a mathematical adjustment was performed to predict the maximum repetition value (12).

Jump evaluation: Three types of jumps were evaluated: Countermovement Jump (CMJ), Squat Jump (SJ), and Countermovement jump with arm-swing (CAS). There were three attempts of each type of jump being considered the highest. Each jump was separated by 30 seconds, and each type of jump was separated by 2 minutes. For this purpose, a pressure-sensitive platform (AXONJUMP, Argentina) was used, connected to a computer with specific software (Axonjump 4.0), being used at the highest height reached between the jumps (31). For all jump tests participants were instructed to keep their feet slightly apart and parallel, keeping the tip of their feet behind a line drawn in the middle of the platform. Initially the participants keep hip and knee joints at 90º and perform the vertical jump without arm swing at the signal to evaluate SJ. To perform the CMJ, the participants remained standing with their knees and hips fully extended and performed a rapid downward preparation movement, followed by a jump. For the CAS, participants performed a swing of the arms as a preparatory movement, with the knees flexed at 90º, and the jump was performed by throwing the arms forward, extending the hips, knees, and ankles.

Blood analysis: After fasting at least eight hours before collection, 20 ml of blood were obtained from the right antecubital vein. The samples were centrifuged for 15 minutes at 300 xg. The plasma and blood cells were stored at -80°C for further analysis. Blood samples were used to analyze plasma activity of CK (MPR3 CK NAC-activated; Boehringer Mannheim)(61), LDH (kinetic UV assay; Kit Advia, Bayer, EUA)(4), hematocrit, mean corpuscular volume (MCV). These samples were also used to determine numbers of neutrophils, lymphocytes, eosinophils, platelets (automated assays)(54), creatinine (Kinect calorimetric assay)(30).

Dry-land training: PTG performed a training adaptation of the program proposed by Newton et al.(37) for four weeks. The training was composed of free-weight exercises focusing on power (plyometric bench-press, barbell squat clean and press, reactive pull-over and barbell jump squat) and strength (bench triceps dips, pull-up). STG performed training on conventional cable and stack training equipment containing only strength exercises (machine biceps preacher, bench-press machine, wide grip lat pulldown, leg-press 45º, triceps cable rope push, machine calf raises).

For both groups, predominantly upper limb exercises were trained, focusing on strengthening the main muscles involved in swimming (triceps brachii, latissimus dorsi, and pectoralis)(32). The main difference between the dry-land training was that STG performed “gym machine" training emphasizing strength and hypertrophy while PTG performed "free-weight" training focused on strength and power. PTG participants were also encouraged to perform the concentric phase of the exercises as fast as possible. For the technical execution of the weight training exercises was proposed the model of Delavier (22) while for the barbell clean and bench-press was proposed the model of Dantas and Coutinho (19). The sessions lasted an average of 50 minutes and were held in the afternoon, before training in the water, three times a week (Mondays, Wednesdays, and Fridays). Table 1 shows the two different types of training program sessions with their corresponding volumes and intensities for the four weeks of training out of the water, with the same recovery interval between sets being used for both groups (minimum one and maximum 5 min).

The load equalization of the dry-land training is unable to application between PTG and STG because they are training models using different equipment, load, number of repetitions and velocity execution. Furthermore, the logistics of the training involving two groups in the same gym did not allow load equalization using other equipment than the included in the present approach. It is worth highlighting that PTG performed the sessions with free-weights and STG with weight machines and cable machines. In addition to strength training being safer on guided equipment (5) this model was adopted since power training appears to be most effective with free-weights and strength training on machines (5, 60).

The training performed in water was monitored into two periods, a specific period (4 weeks), focused on improving endurance and physical development, followed by a taper period, focused on speed development and swimming technical quality (2 weeks). Swimmers trained in water six times a week, and during the dry-land exposure period, PTG and STG performed dry-land training three times a week (at different times). For monitoring training intensities and volumes, the velocity corresponding to the anaerobic threshold (AT) was previously determined with a "lactate minimum" test (21), interval training being adjusted according to Madsen and Lohberg (31). Training stimuli were organized into training zones based on Seiler (53). These training zones were: below AT (Z1), at AT (Z2), and above AT (Z3; velocity training was also incorporated in this zone). The specific period had a volume of 28,500 meters/week (~ 60.1% on Z1, ~ 25.9 on Z2 and ~ 13.9% on Z3). The taper had a volume of 12,800 meters/week (71.1% on Z1, 16.1% on Z2 and 12.8% on Z3) (9, 41).

Statistical analysis

Statistical analyses were performed using the Jamovi software version 1.8 (The Jamovi project; Sydney, Australia). Some data did not show normality and heterogeneity even after correction attempts (e.g., strength testeosinophils, CK, platelets); therefore, non-parametric methods were chosen for all variables. Time effect of performance, power tests, one-rep max, hematological analysis and tethered swimming test were compared by the Friedman test and pos-hoc test (Durbin-Conover). The difference between moments (Δ) was compared between groups using the Kruskal-Wallis test and the respective pos-hoc (Dwass-Steel-Critchlow-Flingner test) for group-effect. The Δ of swim performance was analyzed individually to establish possible correlations using the Spearman correlation matrix. All analyzes had a significance level set at $p < 0.05$.

RESULTS

It was confirmed that the performance improvements for the PTG group were evidenced by time effect in all distances (p: 0.001, 0.001 and 0.014 on the 200, 100, and 50m freestyle performance, respectively) while STG only showed improvement for a distance of 100m (p: 0.010) and CG for 200 and 100m (p: 0.047 and 0.016 respectively). PTG improved the squat jump and CMJ (p: 0.004 and 0.014, respectively). PTG showed improvement on one-rep max of clean, bench-press and squat (p: 0.017, 0.019 and 0.003, respectively). STG also showed improvement on bench-press (p: 0.007).

On tethered swimming test, PTG showed improvement of peak force on M2 (p: 0.019) followed by a decrease at baseline on M3 (p: 0.003). (Table 3)
STG and CG showed a decrease (M1>M3) in the percentile of hematocrit (p: 0.001 and 0.003, respectively). PTG, STG and CG showed decrease of MCV on M2 (p: 0.001, 0.001 and 0.006 respectively) with recovery at baseline on M3 for STG and CG (p: 0.008 and 0.031 respectively) and increase (M3>M1) for PTG (p: 0.039). PTG, STG and CG showed increase (M1<M3) of platelets (p: 0.002, 0.001 and 0.001 respectively). PTG and STG showed increased creatinine on M2 (p: 0.003 and 0.004 respectively) and M3, compared to M1 (p: 0.001 and 0.001 respectively). PTG and STG showed an increase of LDH on M2 (p: 0.005 and 0.014 respectively), followed by stabilization on M3 (p: 0.005 and 0.024 respectively). PTG and STG showed an increase of CK on M2 (p: 0.003 and 0.038 respectively) followed by a decrease to baseline (p: 0.009 and 0.008 respectively). (Table 4)

It was found that PTG was higher Δ% of SJ than CG between M1 and M3 (p: 0.001). STG showed a higher Δ% of CAS than CG between M1 and M3 (p: 0.026). PTG showed a lower Δ% of CK than CG between M2 and M3 (Table 5).

Correlations were found for PTG between 200m and 100m performance (p: 0.85); 100m and 50m performance (p: 0.71); 200m and mean force on tethered swim (p: -0.62) and; 50m performance and eosinophils (p: 0.64). Correlations were found for STG between 200m and 100m performance (p: 0.95) and; 200m performance and peak force on tethered swim test (p: 0.64) (Table 6).

Table 1. Exercise, musculature focus, objective of exercise and details of the periodization performed by free-weight training group.

Exercise	Musculature	Objective	Details	Training arrangement according to the three separate days of the week to carry out the dry-land approach											
				Week 1			Week 2			Week 3			Week 4		
Barbell squat clean and press	Upper and Lower	Power	Set x Reps	2x6	2x6	2x4	2x6	2x4	1x2	2x4	2x4	2x2	2x4	2x4	2x2
			Load	70%	70%	80%	70%	80%	90%	80%	80%	90%	80%	80%	90%
Pull-up	Upper	Strength	Set x Reps	4x6	4x6	4x6	2x6	2x4	2x4	2x6	2x4	2x4	2x6	2x4	2x4
			Load	90%	90%	90%	90%	95%	95%	90%	95%	95%	90%	95%	95%
Plyometric bench-press	Upper	Power	Set x Reps	2x8	2x8	2x8	2x8	2x8	2x6	2x8	2x6	2x6	2x6	2x6	4x6
			Load	30%	40%	40%	40%	40%	50%	50%	50%	60%	60%	60%	60%
Bench triceps dip	Upper	Strength	Set x Reps	4x8	4x8	4x8	4x8	4x8	4x8	4x8	4x8	4x8	4x8	4x8	4x8
			Load	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%
Reactive pull-over	Upper	Power	Set x Reps	4x8	4x8	4x8	2x8	2x6	2x6	2x8	2x8	2x6	2x8	2x6	2x6
			Load	80%	80%	80%	80%	85%	85%	80%	80%	85%	80%	85%	85%
Barbell squat jump	Lower	Power	Set x Reps	2x8	2x8	2x8	2x8	2x8	2x6	2x8	2x8	2x6	4x6	4x6	4x6
			Load	30%	30%	30%	40%	40%	50%	50%	50%	60%	60%	60%	60%
Machine biceps preacher	Upper	Strength	Set x Reps	3x10	3x10	3x10	3x8	3x8	3x8	2x8	2x8	2x6	2x8	2x8	2x6
			Load	80%	80%	80%	85%	85%	85%	85%	85%	90%	85%	85%	90%
Wide grip cable pulldown	Upper	Strength	Set x Reps	3x10	3x10	3x10	3x8	3x8	3x8	2x8	2x8	2x6	2x8	2x6	2x6
			Load	80%	80%	80%	85%	85%	85%	85%	85%	90%	85%	90%	90%
Machine bench-press	Upper	Strength	Set x Reps	3x10	3x10	3x10	3x8	3x8	3x8	2x8	2x6	2x6	2x8	2x6	2x6
			Load	80%	80%	80%	85%	85%	85%	85%	90%	90%	85%	90%	90%
Triceps cable rope push	Upper	Strength	Set x Reps	3x10	3x10	3x10	3x8	3x8	3x8	2x8	2x6	2x6	2x8	2x8	2x6
			Load	80%	80%	80%	85%	85%	85%	85%	85%	85%	85%	85%	90%
Leg-press 45°	Lower	Strength	Set x Reps	3x10	3x10	3x10	3x8	3x8	3x8	2x8	2x8	2x6	2x8	2x6	2x6
			Load	80%	80%	80%	85%	85%	85%	85%	85%	90%	85%	90%	90%
Machine calf raises	Lower	Strength	Set x Reps	3x10	3x10	3x10	3x8	3x8	3x8	2x8	2x8	2x6	2x8	2x6	2x6
			Load	80%	80%	80%	85%	85%	85%	85%	85%	90%	85%	90%	90%

Table 2. Performance, jump tests and one-rep max tests in median ± interquartile range and respective difference between before (Moment 1) and after six weeks of training (Moment 3).

Group	Parameters	Moment 1		Moment 3		Δ%
	Performance (s)					
	200m	148.4	± 17.3	139.5	± 18.7	-6.37#
	100m	64.8	± 10.1	62.3	± 11.8	-4.03#
	50m	29.3	± 4.9	27.6	± 6.4	-6.16*
	Power test (cm)					
	Squat jump	35	± 6.6	36.3	± 8.2	3.58#
PTG	CMJ	37.4	± 9.4	39.6	± 9.4	5.56*
	CAS	230	± 49	223	± 56	-3.14
	One-Rep max (Kg)					
	Clean	46	± 27	52	± 24	11.54*
	Bench-press	60	± 29	62	± 26	3.23*
	Squat	70	± 63	80	± 50	12.50#
	Performance (s)					
	200m	155.2	± 30.5	150.9	± 29.6	-2.83
	100m	72.3	± 16.6	68.5	± 15.5	-5.62*
	50m	33.0	± 7.5	32.0	± 7.4	-3.10
	Power test (cm)					
	Squat jump	27.2	± 8.7	24.6	± 8	-10.57
STG	CMJ	29.1	± 6.6	28.2	± 8.6	-3.19
	CAS	179	± 26	187	± 45	4.28
	One-Rep max (Kg)					
	Clean	n.a.		n.a.		
	Bench-press	38	± 21	40	± 25	5.00#
	Squat	n.a.		n.a.		
	Performance (s)					
	200m	154.5	± 15.7	152.6	± 18.0	-1.27*
	100m	72.7	± 6.6	70.2	± 4.3	-3.66*
	50m	32.6	± 2.4	32.3	± 2.8	-0.96
	Power test (cm)					
	Squat jump	29.2	± 8.5	28.2	± 8.9	-3.55
CG	CMJ	31.4	± 9.3	32.1	± 8.7	2.18
	CAS	180	± 57	167	± 53	-7.78
	One-Rep max (Kg)					
	Clean		n.a.		n.a.	
	Bench-press		n.a.		n.a.	
	Squat		n.a.		n.a.	

PTG - Combined strength and power training group; STG - Strength training group; CG - Control group; CMJ – Countermovement jump; SWA – countermovement jump with arm swing; n.a. – Not applicable; * p<0.05; # p<0.00

Table 3. Difference between moments of tethered swimming test in median ± interquartile change before training (Moment 1), after 4 weeks of specific training and dry-land intervention (Moment 2) and 2 weeks of taper weeks training (Moment 3).

Group	Parameters (N)	Moment 1		Moment 2		Moment 3		Δ% Between moments		
		Median	IQC	Median	IQC	Median	IQC	M1 x M3	M1 x M2	M2 x M3
PTG	Mean force	88,2	± 43,6	92,4	± 37,3	93,4	± 36,9	5,6	4,5	1,1
	Peak Force	149,4	± 85,3	194,2	± 66,4	168,6	± 78,3	11,4	23,1$^{\#}$	-15,2$^{\#}$
STG	Mean force	64,3	± 27,8	63,6	± 24,2	59,4	± 33,1	-8,2	-1,1	-7,1
	Peak Force	125,2	± 73,3	164,3	± 81,2	128,8	± 79,7	2,8	23,8	-27,6
CG	Mean force	61,7	± 10,2	56,6	± 12,8	60,5	± 9,7	-2,0	-9,0	6,4
	Peak Force	157,6	± 69,9	147,6	± 41,2	135,6	± 44,8	-16,2	-6,8	-8,8

IQC – Interquartile change; PTG - Combined strength and power training group; STG - Strength training group; CG - Control group; * $p<0.05$; $^{\#}$ $p<0.01$.

Table 4. Difference between moments of hematological parameters in median ± interquartile change before training (Moment 1), after 4 weeks of water training and dry-land intervention (Moment 2) and 2 weeks of taper weeks training (Moment 3).

Group	Parameters	Moment 1		Moment 2		Moment 3		Δ% Between moments		
								M1 x M3	M1 x M2	M2 x M3
PTG	Hematocrit. %	43.8	± 4	42.6	± 3.05	42	± 5	-4,3	-2,8	-1,4
	MCV. fL	88.9	± 3.905	84.99	± 3.56	87	± 5.31	-2,2*	-4,6$^{\#}$	2,3$^{\#}$
	Platelets. x10^3/mm^3	256	± 34	265	± 38	287	± 22.5	10,8$^{\#}$	3,4*	7,7
	Neutrophils. /mm^3	3549	± 901	3360	± 1548.5	3876	± 1451	8,4	-5,6	13,3
	Eosinophils. /mm^3	171	± 148.75	106	± 291	256	± 155.5	33,2	-61,3	58,6
	Lymphocytes. /mm^3	2652	± 681.75	3132	± 585.5	2788	± 1122	4,9	15,3	-12,3
	Creatinine. mg/dL	0.8	± 0.21	0.92	± 0.345	1.05	± 0.21	23,8$^{\#}$	13,0$^{\#}$	12,4
	LDH. U/L	328	± 30.5	370	± 62.7	373.4	± 75.15	12,2$^{\#}$	11,4$^{\#}$	0,9
	CK. U/L	188	± 209	456	± 486.5	289	± 254.5	34,9	58,8$^{\#}$	-57,8$^{\#}$
STG	Hematocrit. %	43.9	± 2.6	43.1	± 2.45	41.2	± 3.15	-6,6$^{\#}$	-1,9	-4,6$^{\#}$
	MCV. fL	86.5	± 2.62	85.2	± 2.555	86.6	± 2.64	0,1	-1,5$^{\#}$	1,6$^{\#}$
	Platelets. x10^3/mm^3	241	± 51.5	294	± 69.5	291	± 94	17,2$^{\#}$	18,0$^{\#}$	-1,0
	Neutrophils. /mm^3	3135	± 589.5	3710	± 1293.5	3816	± 699	17,8	15,5	2,8
	Eosinophils. /mm^3	195	± 124.5	222	± 84	198	± 67.5	1,5	12,2	-12,1
	Lymphocytes. /mm^3	2268	± 941.5	2475	± 1003	2484	± 806.5	8,7	8,4	0,4
	Creatinine. mg/dL	0.71	± 0.175	0.79	± 0.145	0.96	± 0.2	26,0$^{\#}$	10,1$^{\#}$	17,7
	LDH. U/L	316	± 58.5	375.2	± 51.4	340.2	± 66.45	7,1*	15,8*	-10,3
	CK. U/L	144	± 112	195	± 160.5	182	± 126	20,9	26,2*	-7,1$^{\#}$
CG	Hematocrit. %	42.4	± 1.7	41.6	± 2	39.4	± 1.35	-7,6$^{\#}$	-1,9	-5,6*
	MCV. fL	86.93	± 2.89	84.15	± 1.955	86.7	± 2.65	-0,3	-3,3$^{\#}$	2,9$^{\#}$
	Platelets. x10^3/mm^3	273	± 76.5	322	± 146	324	± 65.5	15,7$^{\#}$	15,2$^{\#}$	0,6
	Neutrophils. /mm^3	2496	± 1268.5	2537	± 1872	3290	± 1450.5	24,1	1,6	22,9
	Eosinophils. /mm^3	156	± 223	177	± 303	190	± 244.5	17,9	11,9	6,8
	Lymphocytes. /mm^3	2058	± 410	2360	± 1017.5	2176	± 353.5	5,4	12,8	-8,5
	Creatinine. mg/dL	0.65	v0.23	0.67	± 0.075	0.77	± 0.125	15,6	3,0	13,0
	LDH. U/L	375	± 84	393.1	± 52.1	424.7	± 75.55	11,7	4,6	7,4
	CK. U/L	149	± 65	197	± 93.5	176	± 92.5	15,3	24,4	-11,9

IQC – Interquartile change; PTG - Combined strength and power training group; STG - Strength training group; CG - Control group; MCV - Mean Corpuscular Volume; LDH - Lactate Dehydrogenase; CK - Creatine Kinase; * $p<0.05$; $^{\#}$ $p<0.01$.

Table 5. Group-effect between different moments. Data was showed by mean of the percentile difference.

Parameters	**Δ% (M1 - M3)**			**Δ% (M1 - M2)**			**Δ% (M2 - M3)**		
	PTG	STG	CG	PTG	STG	CG	PTG	STG	CG
Performance									
200m (s)	-4,6	-2,1	-4,9						
100m (s)	-6,9	-3,0	-6,6						
50m (s)	-5,1	-2,7	-4,0						
Power tests									
SJ (cm)	5,2	0,1	-3,4*						
CMJ (cm)	6,4	-2,0	0,6						
CAS (cm)	0,2	2,5	-5,6#						
One-Rep max									
Clean (Kg)				8,3					
Bench-press (Kg)				5,5	7,1				
Squat (Kg)				18,7					
Tethered swimming									
Mean force (N)	0,6	0,0	3,3	3,6	-1,9	-0,9	-3,1	8,3	4,0
Peak Force (N)	2,9	0,2	-6,5	15,5	14,2	-1,7	-16,1	-6,8	-3,9
Blood Analysis									
Hematocrit, %	-4,1	-5,4	-6,6	-2,6	0,3	-1,3	-1,6	-5,8	-5,4
MCV, fL	-1,7	-0,7	-0,1	-3,0	-2,5	-2,6	1,3	1,8	2,4
Platelets x 10^3, /mm^3	13,9	14,6	15,7	11,0	14,0	21,8	1,4	-0,1	-9,1
Neutrophils, /mm^3	3,4	17,0	6,6	-15,9	17,6	6,5	9,4	-5,4	-2,9
Eosinophils, /mm^3	23,8	7,8	-184,5	-24,9	20,8	-132,2	11,4	-26,0	-49,3
Lymphocytes, /mm^3	-3,8	4,3	2,8	8,6	-3,0	18,0	-14,9	0,7	-23,7
Creatinine, mg/dL	24,0	17,2	6,3	17,0	9,8	1,0	8,3	7,0	4,7
LDH, U/L	11,6	5,3	4,4	11,5	11,0	-0,8	-0,6	-7,2	4,5
CK, U/L	-6,4	-1,3	-6,7	36,3	25,5	-0,3	-66,3	-55,7	-12,9*

PTG - Combined strength and power training group; STG - Strength training group; CG - Control group; CMJ – Countermovement jump; CAS – countermovement jump with arm swing; LDH - Lactate Dehydrogenase; CK - Creatine Kinase; * different from PTG; # different from STG;

Table 6. Pearson correlation of the difference between performance and all measured parameters of pre (M1) and post-taper moment (M3). For one-rep max test, the difference of clean, bench-press, and squat was fixed between M1 and M2.

Parameters	**PTG**			**STG**			**CG**		
	200m (s)	100m (s)	50m (s)	200m (s)	100m (s)	50m (s)	200m (s)	100m (s)	50m (s)
Performance (time)									
200m (s)	1.00			1.00			1.00		
100m (s)	0.85#	1.00		0.95#	1.00		0.64	1.00	
50m (s)	0.35	0.71*	1.00	0.52	0.52	1.00	0.11	0.11	1.00
Jump tests									
Squat jump (cm)	0.06	-0.13	-0.17	0.42	0.39	0.02	-0.20	0.14	-0.47
CMJ (cm)	0.23	0.21	0.00	0.19	0.16	0.01	-0.68	-0.61	-0.29
CAS (cm)	-0.31	-0.54	-0.46	0.37	0.35	0.25	-0.11	-0.67	-0.07
One-Rep max test									
Clean (Kg)	-0.34	-0.29	-0.14	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Bench-press (Kg)	-0.32	-0.21	0.30	0.22	0.26	-0.22	n.a.	n.a.	n.a.
Squat (Kg)	-0.17	-0.16	-0.17	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Tethered swimming test									
Mean force (N)	-0.62*	-0.59	-0.25	0.19	0.19	-0.06	0.58	0.25	0.45
Peak Force (N)	-0.16	-0.38	-0.17	0.64*	0.59	0.02	0.64	0.14	0.25
Hematological analysis									
Hematocrit, %	0.02	0.12	0.10	0.29	0.28	-0.10	0.07	0.32	-0.50
MCV, fL	-0.04	0.04	-0.26	-0.36	-0.33	0.21	-0.50	0.07	-0.07
Platelets, /mm^3	-0.10	0.07	0.28	-0.35	-0.22	-0.27	-0.36	0.07	-0.39
Neutrophils, /mm^3	-0.39	-0.10	0.16	-0.51	-0.42	-0.28	0.46	0.25	0.29
Eosinophils, /mm^3	0.28	0.41	0.64*	-0.14	-0.15	0.01	0.50	0.18	-0.39
Lymphocytes, /mm^3	-0.15	-0.10	0.29	-0.22	-0.29	0.05	-0.07	0.36	-0.43
Creatinine, mg/dL	-0.04	-0.17	-0.51	-0.14	-0.24	0.14	-0.71	-0.50	-0.36
LDH, U/L	0.15	0.28	0.12	-0.10	-0.09	0.53	0.11	-0.54	-0.50
CK, U/L	0.21	0.07	-0.35	-0.36	-0.39	0.12	0.32	0.05	0.47

PTG - Combined strength and power training group; STG - Strength training group; CG - Control group; CMJ – Countermovement jump; CAS – countermovement jump with arm swing; MCV - Mean Corpuscular Volume; LDH - Lactate Dehydrogenase; CK - Creatine Kinase; n.a. – Not applicable; * $p < 0.05$; # $p < 0.01$

DISCUSSION

The present study was aimed to determine the effect of two models of dry-land, PTG and STG, on performance at different distances, strength parameters in tethered swimming, jumping tests, and hematological parameters. The hypothesis was rejected that free-weight training would improve performance with a higher flow of stress biomarkers. Despite differences regarding the response of biomarkers such as CK, the Δ performance was statistically similar between dry-land and control groups.

Similar to the findings of Tanaka et al.(57), who did not observe improvements in 29.9 m and 365.8 m performance after a period of dry-land intervention, the present study found no differences between CG, PTG and STG. The composition of the Tanaka et al.(57) series and training objectives were similar to STG. Despite the time-effect, which PTG showed improvement for all distances (50, 100, and 200m) and STG showed only for 100m, all groups showed similar Δ performance, even being intermediate distances those studied for Tanaka et al., (57).

In addition to presenting two different dry-land training models, this study also included a training plan that included a training period followed by a taper period. The literature is still limited in presenting studies investigating the effect of dry-land training using taper effects. Although dry-land training improves upper and lower limb power and strength (51, 57), Schumann et al.(51), in a relevant study, found no evidence of improved performance after dry-land training associated with a taper period. Even using young swimmers, the differences in the methods between our study and Schumann et al.(51) include the taper duration (2 weeks x 5 days respectively), training approach (exercises, load and training emphasis), water training according to the distance that the swimmers competed (in the present study, there was no differentiation) and absence of control group. By not using a control group without exposure to dry-land training, Schumann et al.(51) study cannot conclude that dry-land training can limit the development of performance in the water.

It is also worth noting that the performance improvement in 50m performance of PTG (6.3%) was more significant than that found in the same distance after free-weights strength training of Strass (56)(2.1%). The improvement found in this study (Table 2) was also greater than two training models presented by Girold et al.(26), focused on strength training with free-weights (2.8%) and in resistance training with elastic bands (2.3%).

The lack of specificity is one of the most cited fundamentals to invalidate dry-land training. In this scenario, Aspenes et al.(3) presented a slight improvement only for the 400m freestyle performance after resistance and strength training using a cable cross-over apparatus that simulates strokes. This result demonstrates that the training specificity in the motor gesture is as important as in the neuromuscular junction (32). Performance improvement occurs among several factors for shorter distances, including increasing power (28). In that case, it is necessary

that, in addition to transference by motor gesture, training also emphasizes speed execution and exercise load.
Despite Loturco et al. (29) showing no correlation between 200m freestyle performance and physical parameters outside and inside the water (29), the present study indicated that the PTG and STG Δ performance on 200m correlates with the Δ mean and peak force on tethered swimming respectively (Table 6). As presented by PTG on the mean force, a negative correlation between tethered swimming parameters and performance was expected, translating that the reduction in swimming time is associated with the increase in the tethered swimming parameter. STG showed that the time reduction (performance improvement) was correlated with a decrease in peak force. This result may be explained because STG did not improve the 200m performance since the peak force on tethered swim test was the best correlate variable of 200m performance (49).

This divergence with the study of Loturco et al.(29) may be due to the organization of the periodization that also accompanied the respective load adjustments, ensuring the improvement of motor skills. Although there was an increase (M2) followed by a return to baseline (M3) for peak force on the tethered swim of PTG, there were no differences for mean force in this study (Table 2).

Due to the literary divergence (34), despite the efficiency involving dry-land training, the present study showed that strength and power dry-land training were indifferent to improving freestyle swimming performance on 50, 100, and 200m distances. It is important to note that only water training (CG) improved 200 and 100m, PTG improved all distances, while STG could only improve performance at 100m. Despite the different results presented by the groups regarding the time-effect, the Δ performance was similar between the groups (Table 5).

Both dry-land training models used in the present article provided strength gains in and outside the water (Table 2 and 2). It is also worth mentioning that only the group that trained power and strength (PTG) improved the performance in jump tests (Table 2). However, the Δ power in both groups was similar, being greater only than CG (Table 5). This evidence confirms that dry-land training provides motor improvements out of the water. However, the improvement of attributes such as power in jumping or maximum strength in upper and lower limbs (Table 2) was not transferred to swimming performance, considering that the Δ performance was similar between the three groups (Table 5). A performance test at the M2 would be appropriate to investigate the relationships between water performance and dry-land gains. However, this analysis was not possible due to the organization of periodization proposed by the head coach and the beginning of the taper period.

In addition to the dry-land and performance parameters, it was also found that training, with or without dry-land monitoring, changes hematological parameters (Table 4). Using as a basis, the study of Cadegiani et al. (13) investigated several hematological parameters and their relationship with training level and overtraining syndrome, "safe level" was found for hematocrit (normal level: 38 - 50%), MCV (normal level: 80 - 96 fL), platelets (normal level: 150

- 450 x 10^3 mm^3), neutrophils (normal level: 1500 - 6000 mm^3), lymphocytes (800 - 4000 mm^3) and creatinine (0.7 - 1.3 mg / dL). It should be noted that the only parameter that was outside the range stipulated by Cadegiani et al. (13) was the eosinophils.

Eosinophils regulate the local immune response, usually associated with inflammatory processes and allergies (24). When observing the data, one swimmer was found on PTG who presented eosinophil values above the secure margin in all three moments and another swimmer from the CG who presented only the M1. For the first subject, who had a typical eosinophil response, this behavior may be pool chlorine allergy or allergic rhinitis (24). For example, the second swimmer may have had a recent episode of an intense allergic or inflammatory process like flu or acute bronchitis (14). The correlation of PTG found between 50m performance and eosinophils suggest that improvement may accompany this hematological parameter reduction. Although this parameter responds with the intensification of training, its association with performance is unclear (27), more studies are needed to interpret its relationship with training.

There is evidence of relationships between hematocrits and training level, with athletes having a lower percentage of hematocrits than untrained people (2, 29). Thus, it is suggested that, for the present study, the fitness level acquired by all groups has favored the reduction in hematocrit (Table 4). The reduction in MCV (M2) followed by recovery (M3) may represent an inflammatory response expected from training because it is within safe levels (29). In other conditions, the abrupt reduction of the MCV without recovery could present a risk of sports anemia, a common situation in overtraining (6). In the present study, the average levels of CK and LDH, important biomarkers of muscle damage and overtraining (10), were always within the safe and expected limit (29, 55).

The LDH and CK variation occurred only by the groups exposed to dry-land training during the three moments of analysis (increase in M2 and stabilization in M3) are expected since the muscular metabolic responses, altered according to the training model (e.g., load and intensity), may alter in this parameter (10). Thus, training outside the water seems to have an additional metabolic effect signaled by the change in muscle damage biomarkers (Table 4). In addition to the time-effect, a difference in the Δ CK was found between moments 2 and 3, showing that PTG had a more significant reduction than CG (Table 6).

As well as the increase in the inflammatory process signaled by eosinophils, both PTG and STG indicate an increase in CK (Table 4). These situations can be explained by the "extra" effects of resisted training, whether from strength, hypertrophy or potency stimuli (50, 58). The addition of dry-land training results in a greater inflammatory process (expected after physical exercise), a situation signaled by different muscle damage biomarkers, indicating tissue repair (42).

In addition to the substantial force increase of exercises presented by both groups that had exposure to dry-land training, another parameter that indicates the benefits from this approach was the increase in creatinine. Creatinine is widely recognized for its importance in hydroelectrolytic balance and renal function (33). However, when evaluated in elite and recreational athletes, this parameter also correlates with body mass (7). A study by Milic et

al.(33) showed that this also happens in swimming, suggesting that exposure to dry-land training of the present study may promote mass body gain, increasing creatinine. It should be noted that the increase in creatinine evidenced for PTG and STG on time-effect did not promote a significant change than when compared to the group-effect.
As expected, after the training period, all groups in the present study also increased platelets (Table 2). El-Sayed (23) presented in their literature review that the platelet count is important in diagnosing cardiovascular diseases and the severity index for extreme exercises that can lead to overtraining. On the other hand, within normal levels, as shown in the present study, the increase in platelets should be an indicator of improvement in cardiorespiratory capacity (23).

Among the limitations of this study, both dry-land training models are similar. Although both models use similar muscle portions, the training load was not equalized (previously justified by different training proposals). The training structure was chosen due to the ease of attributing power-free-weight exercises and strength (high load) on gym machines. Thus, further studies will be needed to verify its applicability in elite performance swimming since several coaches use this training strategy.

Finally, the present study concludes that dry-land training can promote motor tasks improvement on dry-land and water but not on water performance improvement. Furthermore, dry-land training showed increased muscle damage biomarkers, whether in a model similar to PTG or STG. However, it did not exceed safe levels and did not correlate with performance.

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