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Repeatability and application of tethered swimming tests for recreational swimmers

Repetibilidade e aplicação de testes de nado estacionário para nadadores recreacionais

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Abstract – Tethered swimming tests are applied to evaluate propulsive forces in crawl stroke and may also be used to evaluate force applied by the movement of lower (leg kicking) and upper limbs (arm stroke). Considering the large number of recreational swimmers, this tool may be useful for coaches to evaluate the technique and force production by swimmers. As little attention has been paid to the application of these tests with recreational swimmers, the aims of this study were to verify the repeatability of the tethered swimming test for arm stroke, leg kicking and crawl stroke and to verify the relationship between performance in a 50-m test and in the tethered test with recreational swimmers. In this case, repeatability was defined as the agreement between the results of two successive evaluations. Ten male swimmers performed two 30-s maximal intensity tethered swimming tests with leg kicking, arm stroke and crawl stroke and three 50-m crawl stroke tests. Repeatability was found for mean force of all tests and for impulse evaluated in crawl stroke. Inverse relationship of the time to complete 50 m with the maximum and mean forces and with the impulse in the crawl stroke and an inverse relationship between time to complete 50 m and the mean force in the leg kicking were observed. Therefore, results from full tethered swimming tests applied with recreational swimmers may help swimming coaches.

Key words: Force Strength; Athletic performance; Swimming.

Resumo – *O teste de nado estacionário é empregado para avaliar as forças propulsivas no nado crawl e também pode ser utilizado para avaliar a força aplicada pelos movimentos dos membros superiores (braçada de crawl) e inferiores (pernada de crawl). Considerando o grande número de nadadores recreacionais, esta ferramenta pode ser útil para professores avaliarem a técnica e a produção de força de seus alunos de natação. Como pouco se sabe sobre a aplicação desses testes com nadadores recreacionais, os objetivos deste estudo foram verificar a repetibilidade do teste de nado estacionário para braçada de crawl, pernada de crawl e nado crawl e verificar a associação entre o desempenho no teste de 50 m e nos testes de nado estacionário em nadadores recreacionais. Neste caso, repetibilidade foi definida como a concordância entre resultados de duas avaliações sucessivas. Dez participantes do sexo masculino realizaram dois testes máximos de nado estacionário de 30 s, executados com pernada de crawl, com braçada de crawl e com nado crawl completo e três testes máximos de 50 m crawl. Foi encontrada repetibilidade para a força média de todos os testes e para o impulso avaliado no nado crawl. Também foi observada associação negativa do tempo do teste de 50 m com as forças máxima e média e impulso no nado crawl e uma relação inversa entre o tempo dos 50 m e a força média da pernada de crawl. Portanto, resultados de teste de nado estacionário aplicados em nadadores recreacionais podem ajudar professores de natação.*

Palavras-chave: *Desempenho atlético; Força muscular; Natação.*

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INTRODUCTION

Tethered swimming test is a tool widely used for the evaluation of the propulsive force in swimming[1]. It can be done in a stationary or semi-stationary manner. In the first case, the swimmer performs the swimming technique while attached to a material, such as a rigid steel cable, which does not allow significant forward displacement[2,3]. In the second case, the individual swims attached to a material that allows body displacement[4].

The tethered swimming test has been used by coaches and researchers to evaluate swimmers[3,5,6], since, considering crawl stroke, the test presents some similarities with non-tethered (free) swim for stroke rate and for some physiological responses such as blood lactate concentration, heart rate and subjective perception of effort[6,8,9]. In addition, several studies have identified an association between the outcome of the tethered swimming test and sports performance[3,10] and have verified the test repeatability for competitive swimmers[7,8,11].

The tethered swimming test can be performed with full crawl stroke, but also be used to evaluate the force applied by the lower (leg kicking) and upper limbs (arm stroke)[2,3]. This evaluation by limb and full crawl stroke allows assessing the lack of force or coordination of the combined action of upper and lower limbs, making it an interesting assessment tool. Morouço et al.[3] verified that male swimmers apply greater forces during full crawl stroke, but assuming that the sum of the average forces of leg kicking and arm stroke is 100%, the average force generated in the full crawl stroke was equal to 84.4%. Thus, the authors observed a force deficit of 15.6% in the full crawl stroke, indicating a coordination problem involving the combination of upper and lower limbs.

Considering that the tethered swimming test can be characterized as an easy and accessible method[12], it can also be used with swimmers who do not have, as their main objective, high-level performance[13], such as recreational swimmers who train with low weekly volume and sporadically participate in local competitions. In this way, the analysis of the force applied with leg kicking and arm stroke and in the full crawl stroke could be used to verify, in addition to propulsive force, failures in the general swimming coordination of these swimmers. On the other hand, this evaluation can only be carried out if it presents repeatability, that is, if successive evaluations present concordant results, and if the result of the tethered swimming test presents a relationship with the performance for this population.

Thus, considering the large number of recreational swimmers and that the tethered swimming test may be useful for coaches to evaluate the technique and force production by swimmers, the aims of this study were to verify the repeatability of the tethered swimming test for the upper limbs (arm stroke), lower limbs (leg kicking) and full crawl stroke, and to verify the association between performance over the 50-m test and tethered swimming tests with recreational swimmers. According to previous studies with competitive swimmers[3,7,8,10,11], it has been hypothesized that there is

repeatability for the tests and that there is also an association between the results of the tethered swimming test performed with crawl stroke and crawl stroke performance of recreational swimmers.

METHODOLOGICAL PROCEDURES

Participants

First, sample calculation was performed on WINPEPI software (version 11.62)[14] considering two observations by each participant, an expected value of an intraclass correlation coefficient (ICC) of 0.8[15] with probability of 80% that 80% of the confidence interval of the ICC had lower limit of not less than 0,41[16]. Based on these criteria, the sample calculation indicated minimum of eight participants.

Based on the above and considering the possibility of sample loss throughout the research, the sample was composed of ten recreational swimmers, according to the following inclusion criteria: (a) being male; (b) be at least 18 years of age; (c) swimming under the guidance of a Physical Education professional two to four times a week for at least three months; (d) absence of injury or any other restriction, three months prior to the study, which could affect performance in the tests[6] and (e) have no health problems that could be aggravated by physical exercise.

Of the 10 participants, nine swimmers completed the study (30.3 ± 9.7 years of age, 79.0 ± 13.3 kg of body weight, 1.8 ± 0.1 m of height, 1.8 ± 0 , 1 m of arm span). Participants swam from 5 to 8 km per week. This research was approved by the local ethics committee; in addition, all participants signed the free and informed consent form.

Data collection

The experiment was carried out in a 25-m pool with water at average temperature of 28°C and environmental temperature averaged 33°C. Before evaluations, the sample participated in three familiarization sessions with the tethered swimming test. In these sessions, a 5-m long rigid steel cable was used with one end attached to an adjustable belt around the swimmer's waist and the other end attached to a pool starting block. In each session, after standard 500 m warm-up (200 m crawl stroke, 100 m leg kicking, 100 m arm stoke and 100 m free), three sets of two 30-s tethered swimming tests were performed. In the first test, the swimmer was advised to do the test with increasing intensity, while the second consisted of a maximum test, that is, the swimmer was asked to generate and to maintain the greatest possible force over time.

Each series, in a random order, was performed (1) with arm stroke with the aid of floats (pull buoy and E.V.A. leggings) between and around the legs; (2) leg kicking with float (swimming board) under the hands, while shoulders were flexed with extended elbows and (3) with full crawl stroke. A 5-min active recovery was allowed between tests, while between series, there was 10 min of active recovery. Among the three sessions, there was

an interval of 24 to 48 hours. The maximum 50-m test required no familiarization, since it was a normal activity for swimmers evaluated.

After familiarization, three evaluation sessions were performed. In each session, after standard warm-up, the following tests were performed: (1) maximum 50-m test of crawl stroke starting in the water and (2) two maximum 30-s tethered swimming tests with 20 min of active recovery. The order of tests was randomly selected. In all tests, swimmers were instructed to keep their faces in the water, but they could inspire when they needed. In addition, throughout the tests, verbal encouragement was given to participants.

The maximum 50-m test was initiated with participant inside the pool in order to decrease the effect of the exit against the edge of the pool. To evaluate performance, two experienced timekeepers checked the time with the help of timers (Vollo VL - 510). In each session, the two maximum tethered swimming tests were performed either (1) with arm stroke or (2) with leg kicking or (3) with full crawl stroke, similarly to familiarization. The order was randomly defined for each participant and the tests started and ended with the sound of a whistle. Between each session, there was an interval of 24 to 48 hours, and participants were instructed to avoid vigorous physical exercises 24 hours before evaluation sessions.

For the tethered swimming tests, the end of the steel cable was attached to the swimmer's waist with the aid of an adjustable belt, while the other end was attached to a load cell (capacity of up to 1000 N) fixed to the pool starting block. This load cell was connected to a signal conditioner (Miotool Fisio USB 2 channels, 2000 Hz) and this to a notebook (DELL Inspiron 14), allowing the recording of force data.

Data analysis

For force analysis in the Matlab software (R2009b), the force recorded in the first cycle was discarded due to the inertial effect of cable extension at the beginning of the assessment[5,12]. After, the force signal was smoothed with a fourth-order Butterworth digital filter with cutoff frequency according to residual analysis[17]. As the steel cable had an angle with the water surface, the force values were corrected based on a trigonometric relation, thus obtaining the horizontal component of the force. This was used to determine the maximum force (the highest force value recorded in the test) and the average force (arithmetic mean of force values recorded in the test). In addition to these variables, in the tethered swimming test with full crawl stroke, the mean impulse was determined as the area under the force-time curve[10]. Of the three 50-m tests, only the one that presented the shortest time was analyzed, being determined by the average of the two times obtained by timekeepers.

Statistical analysis

To describe the results, mean and standard deviation were determined. In order to evaluate repeatability, Cronbach's alpha and ICC were checked

considering the results of the two series of tethered swimming tests with arm stroke and leg kicking. Based on Field[15], repeatability would be found with Cronbach's alpha greater than 0.70 and ICC equal to or greater than 0.80. In addition, the measurement accuracy was evaluated using the standard error according to Denegar and Ball[18].

The association between 50-m test time and the mean of variables obtained in the two tethered swimming tests (leg kicking, arm stroke and full crawl) was verified with the Pearson correlation coefficient after confirming data normality with the Shapiro- Wilk test. Confidence intervals for correlation coefficients were also determined. A 5% significance level was used for all tests, and confidence intervals were reported as effect size[19]. All statistical procedures were performed in SPSS software (version 22.0 for Windows), with the exception of the Pearson correlation coefficient confidence interval, which was obtained in WinPepi software[14].

RESULTS

As can be seen in Table 1, repeatability (Cronbach's alpha > 0.7 and ICC ≥ 0.8) was found for the mean force of all tests and for impulse evaluated in the full crawl stroke. Table 2 shows the results of the association between the mean kinetic variables and the time in the 50-m crawl test. The mean 50-m test time was 33.04 ± 3.85 seconds.

Table 1. Mean ± standard deviation, repeatability and accuracy of measurements

	Variable	Test 1	Test 2	ICC	Cronbach's alpha	Standard error
Leg kicking	Maximum force (N)	93.6 ± 27.1	101.2 ± 30.5	0.73. p = 0.008 CI: 0.18 to 0.93	0.84	14,7
	Mean force (N)	35.4 ± 10.1	35.3 ± 10.0	0.87. p = 0.001 CI: 0.52 to 0.97	0.93	3,6
Arm stroke	Maximum force (N)	254.1 ± 108.9	265.7 ± 87.4	0.77. p = 0.005 CI: 0.26 to 0.94	0.87	46,5
	Mean force (N)	71.1 ± 20.2	72.5 ± 20.4	0.97. p < 0.001 CI: 0.89 to 0.99	0.99	3,2
Full crawl stroke	Maximum force (N)	319.2 ± 92.0	298.7 ± 72.6	0.75. p = 0.006 CI: 0.22 to 0.94	0.86	40,8
	Mean force (N)	91.6 ± 24.0	89.3 ± 22.8	0.98. p < 0.001 CI: 0.89 to 0.99	0.99	3,5
	Impulse (N·s)	2747.5 ± 720.0	2678.4 ± 683.5	0.98. p < 0.001 CI: 0.90 to 0.99	0.99	105,6

ICC is the intraclass correlation coefficient and CI is the 95% confidence interval.

Table 2. Relationship between performance in the 50-m crawl test and the variables obtained in tethered swimming tests (n = 9).

	Leg kicking	Arm stroke	Full crawl stroke
Maximum force	r = -0.59. p = 0.095 CI: -0.90 to 0.12	r = -0.40. p = 0.281 CI: -0.84 to 0.36	r = -0.85. p = 0.004 CI: -0.97 to -0.43
Mean force	r = -0.75. p = 0.020 CI: -0.94 to -0.17	r = -0.48. p = 0.193 CI: -0.87 to 0.27	r = -0.76. p = 0.018 CI: -0.95 to -0.19
Impulse			r = -0.76. p = 0.018 CI: -0.95 to -0.19

r is the Pearson's correlation coefficient and CI is the 95% confidence interval.

DISCUSSION

To use tethered swimming test as an assessment tool with recreational swimmers, it is necessary to evaluate its repeatability and to verify if any result of the full swim test is related to performance, which would justify its use. Considering the technical improvement[3] for recreational swimmers, it is also interesting to evaluate the force applied in the water, separately, by lower limbs and upper limbs and in the full crawl stroke. Thus, the present study investigated the repeatability and the relationship between results of the tethered swimming test (leg kicking and arm stroke and full crawl stroke) with recreational swimmers' performance.

Although Cronbach's alpha values indicated repeatability for all investigated variables (> 0.7), the ICC found for maximum force of all tests was not satisfactory (Table 1). Thus, repeatability was found for the average force of all tests and for impulse evaluated in crawl stroke, whereas the result showed that the analysis of the maximum force in the tests should be seen with care. Furthermore, the accuracy of measures assessed by standard error[18] was also better for mean forces than for maximum forces (Table 1). These findings partially corroborate the previously established hypothesis, since the maximum force, in addition to the other kinetic variables reached by competitive swimmers in the crawl stroke presents repeatability[11]. On the other hand, it is important to note that, to the best of the authors' knowledge, the present study was the first to investigate the repeatability of tethered swimming tests for leg kicking and arm stroke in crawl swimming.

Negative association of the 50-m test time with maximum and mean forces and impulse in the crawl stroke was reported (Table 2), indicating that the 30-s tethered swimming test correlates with performance in the 50-m test for recreational swimmers as well as for competitive swimmers[5,6,12], which is in accordance with the previously established hypothesis. Furthermore, although these competitive swimmers performed the 50-m test with higher swimming speed, the maximum and mean forces were relatively similar to values found by the present study (Table 1). The maximum and mean forces in the arm stroke and leg kicking tests (Table 1) were also similar to values reported by Morouço et al.[3].

An inverse relationship of the mean leg kicking force in the crawl swimming with time in the 50 meters was also observed. This result is in agreement with that reported by Morouço et al.[3], who observed positive association between swimming speed and maximum force in the tethered swimming test. Thus, recreational swimmers seem to achieve higher swimming speed from the force applied by the movement of legs. This result indicates that in terms of performance, recreational swimmers stand out due to the force they can achieve with the movement of legs, not by the action of arms.

As the mean force values of all tests presented repeatability, it is possible to perform the analysis suggested by Morouço et al.[3] to diagnose force deficit or a coordination problem involving the combination of upper

and lower limbs motion in the crawl swimming with recreational swimmers. Considering that the sum of the mean forces of the leg and arm represents 100%, the mean force in the full crawl stroke represents 84.4%, indicating a force deficit of 15.6%, which is exactly the same as reported by Morouço et al.[3] for competitive swimmers. Thus, recreational and competitive swimmers may present similar force deficit, and an adjustment in the coordination of the combined actions of upper and lower limbs could lead to an increase of the force applied in the full crawl stroke, improving performance[3]. Perhaps, this deficit is natural and does not change with the training level, since recreational and competitive swimmers have the same result. In this case, the observed force deficit could be the result of a similar mechanism that explains the bilateral force deficit already reported in other studies[20,21]. That is, contralateral limbs together generate less force than the sum of forces developed by the right and left limbs alone due to a neural inhibition that occurs in the first situation[21].

In order to verify these hypotheses, further studies should evaluate the effect of training on the force deficit in swimming, and also evaluate muscular activation with electromyography when performing only leg kicking / arm stroke and full crawl stroke. In addition, the present study evaluated only male swimmers, so further studies could perform the same analysis with recreational female swimmers, as women may present different results[3]. Another suggestion involves assessing forces in swimmers of different ages to verify how forces and force deficits vary across different age groups.

CONCLUSIONS

The average force applied by recreational swimmers can be evaluated using tethered swimming tests with leg kicking, arm stroke and full crawl stroke, since it has repeatability; however, maximum force must be analyzed with caution. Another variable that can be investigated is the impulse in the crawl stroke, which also presented repeatability. Moreover, a negative association of time of the 50-m crawl test with maximum and mean forces and impulse in the crawl swimming was found. The 50-m time also showed an inverse relationship with mean force of leg kicking, indicating that the lower limbs may significantly contribute to the performance of recreational swimmers. As the result of the mean forces presented repeatability, it is also possible to analyze coordination problems of the combined action of upper and lower limbs with tethered swimming tests. Based on this methodology, a force deficit of 15.6% was observed with recreational swimmers. Therefore, tethered swimming tests can be used with recreational swimmers to analyze performance and coordination between upper and lower limbs.

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