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# Agreement, reliability, predictors and classification proposal of a 15´-time trial test to assess critical power in amateur swimmers

# Concordancia, fiabilidad, predictores y propuesta de clasificación de un test contrarreloj de 15´ para evaluar la potencia crítica en nadadores aficionados

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**Abstract**. This study aimed to explore the agreement and reliability of a 15′-time trial test ($T_3$15′) to assess critical power in a large cohort of amateur swimmers. An observational retrospective cohort study total of 2212 amateur swimmers were made evaluating the results of anthropometry, cardiovascular and functional fitness assessments. Also, the participants performed a front crawl swimming 15′all-out test to assess critical power. The Kolmogorov-Smirnov, t-test, regression, percentiles, intraclass correlation coefficient and Cohen's d effect size were developed using a statistical software A $T_3$15′ categorization proposal was made based on sex and age. There were differences by sex in all anthropometric, functional, physiological and $T_3$15′ outcomes. The $T_3$15′ swimming test obtained almost perfect reliability in the distance based on intraclass correlation values and linear correlation coefficients. A bias of $T_3$15′ of 2% was found, which represented a total of 10.65m between tests. $T_3$15′ is a useful test to assess critical power as a baseline fitness reference value for programming swimming exercises in amateurs.
**Keywords:** anaerobic capacity, aerobic capacity, swimming, critical speed, evaluation, assessment.

**Resumen**. Este estudio tuvo como objetivo explorar el acuerdo y la confiabilidad de una prueba contrarreloj de 15' ($T_3$15') para evaluar la potencia crítica en una gran cohorte de nadadores aficionados. Se realizó un estudio de cohorte retrospectivo observacional con un total de 2212 nadadores aficionados que evaluaron los resultados de las evaluaciones antropométricas, cardiovasculares y de condición física funcional. Además, los participantes realizaron un test total de 15' estilo crol para evaluar la potencia crítica. Kolmogorov-Smirnov, prueba t, regresión, percentiles, coeficiente de correlación intraclase y el tamaño del efecto d de Cohen se desarrollaron utilizando un software estadístico. Se realizó una propuesta de categorización del $T_3$15′ en función del sexo y la edad. Hubo diferencias por sexo en todos los resultados antropométricos, funcionales, fisiológicos y $T_3$15. La prueba de natación $T_3$15' obtuvo una confiabilidad casi perfecta en la distancia basada en valores de correlación intraclase y coeficientes de correlación lineal. Se encontró un sesgo de $T_3$15′ del 2%, lo que representó un total de 10.65m entre pruebas. $T_3$15′ es un test útil para evaluar la potencia crítica como valor de referencia de la condición física para la programación de ejercicios de natación en aficionados. Se hizo una propuesta para categorizar $T_3$15' con base en el sexo y la edad.
**Palabras clave:** capacidad anaeróbica, capacidad aeróbica, natación, velocidad crítica, evaluación, valoración.

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## Introduction

Baseline evaluations allow determining the health level of a group and estimating different thresholds concerning their health and physical conditioning (Hernández-Cruz et al., 2022). Commonly, sports and health sciences assessments study physical fitness and quality of life (Tuesca-Molina, 2005). In this sense, the literature indicates that physical fitness assessment is fundamental and extremely useful when programming exercise (O'Donoghue, 2015). Frequent evaluations may allow coaches, athletes and stakeholders to make informed decisions using valid scientific information about the general health status of a target population.

The physical performance of athletes is based on the physiological and anthropometric adaptations developed through training, as these allow having the capacity to meet competition demands (Lätt et al., 2010). A key aspect of evaluation is monitoring the health status of individuals who practice physical activity (Curotto-Winder et al., 2022). This involves systematic data collection to overview fitness evolution concerning health to identify deficiencies in planning or consider the relevance of a training methodology (Hernández-Wimmer et al., 2021; Zacca et al., 2016). Also, MacDougall (2005) s an educational process where one gains deeper knowledge of their body and sport. Interpreting test results allows better understanding the activity's physical and physiological components. Establishing reference values in fitness tests is key to classify performance considering sex, age, and other contextual factors (Tveter et al., 2014).

Specifically, in swimming, the critical speed has been assessed by two methods (based on distance or time) to determine the aerobic and anaerobic capacity, this is the case of the study by Iii et al. (2017), in which they used the final time obtained in different distances (100, 200, 400, 800, 1200 and 1500-m front crawl), but these trials cannot precisely predict individual performance. On the other hand, Tsai & Thomas (2017) assessed the validity of a protocol of 3-minutes and evaluated the critical speed in the last 30-seconds. Based on time, another study realized by González-Haro et al. (2005) validated a test to assess the maximum aerobic speed to calculate the training zones based on speed.

While evidence exists assessing aerobic and anaerobic capacity of high-performance athletes, it is limited

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regarding health. Two recognized protocols evaluate aerobic capacity in swimming for health: 12-minute swim test (t-12) (Cooper, 1982), and 30-minute swim test (t-30) (Purcaru, Jari, & Teodorescu, 2022). Both assess maximum aerobic capacity via maximum distance covered in 12 or 30 minutes (front crawl) in a pool of known size, but only t-12 presents defined levels by sex and age (Cooper, 1982).

Currently, another used test is the swimming test of 15-minutes (t-15), but a defined categorization does not exist yet (Trinidad-Morales & Lorenzo-Calvo, 2012). This test is easy to apply, so that the evaluator only needs a stopwatch to control the time and measure the total distance that the athlete covered at the end of the test (Moritani et al., 1981). Developing accurate t-15 categorization would help control and design training and evaluate starting level and evolution. Therefore, this study aimed to: (a) explore agreement and reliability of a 15´-time Testssessing critical power in amateur swimmers; (b) analyze anthropometric, functional and physiological predictors of performance; and (c) propose a classification criterion based on a large cohort.

## Methods

### *Study Design*

This observational retrospective cohort study utilized two protocols. First, each participant underwent anthropometric, functional, and physiological assessments followed by a 15-minute front crawl swimming time trial test (T15´) considered as test. A subsample of initial participants was recruited to perform a second T15´ test seven days after the first considered as retest (see Figure 1).

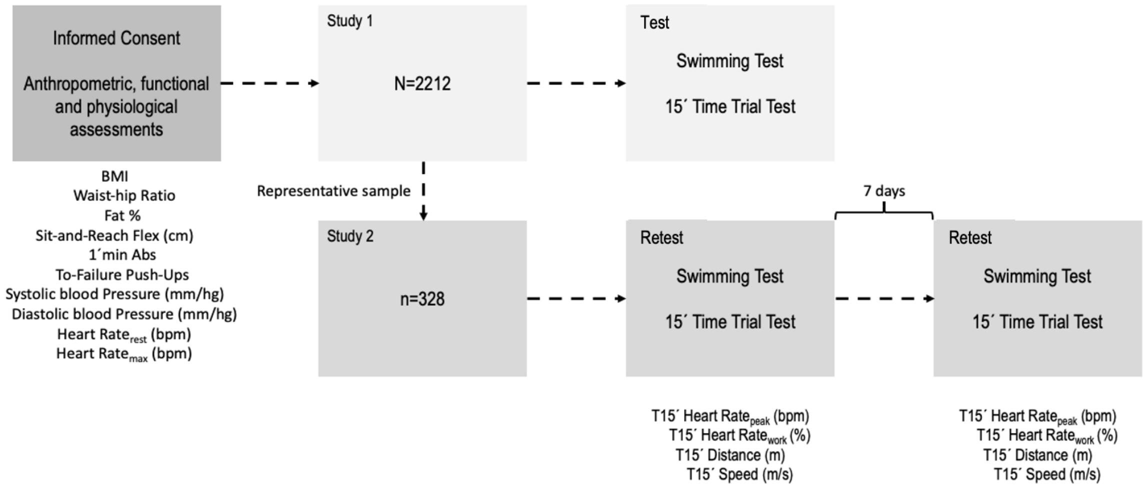


Figure 1. Flowchart of study design. BMI: Body Mass Index, Abs: Abdominals, T15: 15 minutes trial.

### *Participants*

Study 1 included 2211 amateur swimmers (age: 33.2±10.3 years, body mass: 71.6±14.8 kg, height: 1.6±0.1 m) from a university swimming club. The sample comprised 922 males (age: 32.2±9.3 years, body mass: 79.3±13.8 kg, height: 1.7±0.1 m) and 1289 females (age: 34±10.9 years, body mass: 66.1±12.9 kg, height: 1.6±0.1 m). Study 2 included 328 participants (age: 32.1±9.96 years, body mass: 73.3±13.8 kg, height 1.7±0.1 m) from the total sample. To participate in the present study, swimmers met the following inclusion criteria: (a) adults, (b) realize 2-3 session per week with an average distance between 3000-5000 meters, (c) had over 2 years of swimming experience, and (d) had no injuries or musculoskeletal problems that would impair normal performance. Study 2 sample size was calculated based on the following equation:

Where N= 2212, e= margin of error set at 5%, p set at 95% and z value selected was 1.96 (Charan & Biswas 2013).

All swimmers were notified of the procedures and details of the study protocol. Besides, all potential risks and rights during their participation were informed and agreed upon by both parties. All procedures were performed following biomedical guidelines based on the Helsinki Declaration (2013) and the protocol was reviewed and accepted following national regulations and Institutional Review Board guidelines.

$$n = \frac{\frac{z^2 \cdot p(1-p)}{e^2}}{1 + \frac{z^2 \cdot p(1-p)}{e^2 N}}$$

### *Instruments and procedures*

The baseline measurements of body mass (kg), height (cm), waist-hip ratio and body fat percentage were performed following the International Society for the Advancement of Kinanthropometry guidelines (Stewart et al., 2011). It was performed in a controlled laboratory at 23 °C ± 0.9°C. Body mass (kg) was assessed using an HD-313 Tanita (Tanita Corporation, Tokyo, Japan) (precision= 0.1 kg) and height with a rod stadiometer (Seca 213, Hamburg, Germany). Body mass index was calculated based on height and body mass outcomes. The waist-hip ratio was assessed using a tape measure. Fat percentage was measured using digital bioimpedance (Inbody 370, Seoul, Korea) (precision= 2%).

The functional test sit-and-reach (cm), 1′ abdominals (n) and to-failure push-ups (n) were selected. The Sit-and-reach test (Hartman & Looney, 2003; Wells & Dillon, 1952) was selected to assess mobility and was performed using a special wooden box and the best of two consecutive repetitions was selected. For the 1′ abdominals was chosen to determine muscle resistance, participants were asked to perform a half sit-up following previous evidence (Diener, Golding, & Diener, 1995). Finally, the upper limb′s strength was measured using to-failure push-ups following previous guidelines (Merrigan et al., 2020).

Systolic and diastolic blood pressure (mm/Hg) and heart rate were measured using a cardiac monitor (Polar Model FT7; Kempele, Finland). Heart rate was assessed in two different moments: (a) at rest (Heart $Rate_{rest}$) and (b) peak heart rate during the test ($T_3$15′Heart $Rate_{peak}$). In addition, maximum heart rate (Heart $Rate_{max}$) was theoretically estimated using age and the percentage of work heart rate ($T_3$15′ Heart $Rate_{work}$) through Karvonen formulae (Karvonen, Kentala, & Mustala, 1957).

For swimming evaluation, the $T_3$15′ test was used. This test is a time trial to assess swimming aerobic performance through critical power (Moritani et al., 1981), understood as the maximum effort swimmers can maintain during a long period. This $T_3$15′ was performed following a 10-min warm up in a 25-m swimming pool. The participants were asked to make a 15′all-out time trial of front crawl. The variables of $T_3$15′ speed (m/s) and $T_3$15′ distance (m) were registered.

### *Statistical Analysis*

The Kolmogorov-Smirnov test was used to confirm data normality, verifying the feasibility to use parametric inference statistics. For study 1, to compare the $T_3$15′ test by sex an independent measures t-test were performed in all anthropometric, functional and physiological variables. To explore the level prediction of these variables of $T_3$15′ test outcome, a stepwise regression ($R^2$) was selected. A categorization proposal was performed using the total distance of the $T_3$15′. It was divided into five categories using 20th, 40th, 60th, 80th percentiles for general, men and women populations. All categories were divided by age. This aspect is consistent with validated systems used in other endurance-based fitness tests like the 12-minute swim test (Cooper, 1982), as well as provides a reasonable goal for improving from untrained to trained aerobic fitness (Dekerle et al., 2002) and allow coaches to better target intensity and volume according to an individual's baseline fitness category (Fernandes, 2011).

For study 2, over-time test consistency was assessed via reliability using intraclass correlation coefficient (ICC) with respective 95% IC and it was confirmed via the linear correlation between measurements. ICC was interpreted following previously proposed ranks as: 0 poor, 0.01-0.02 trivial, 0.21-0.4 regular, 0.41-0.6 moderate, 0.61-0.8 substantial and 0.81-1 almost perfect (Kramer & Feinstein, 1981). Linear correlation was qualified as follow: 0.1-2 poor, 3-5 fair, 6-7 moderate, 8-9 very strong, 1 perfect (Kramer & Feinstein, 1981). Bias and agreement between measurements were assessed using the Bland Altman Plotting method with respective 95% IC; it was complemented by mean differences analysis between measurements using repeated measures t-tests. Moreover, the magnitude of the significance was assessed using Cohen's d effect size (Cohen, 1988), qualitatively rated as follows: $< 0.2$ trivial, 0.2-0.6 small, 0.6-1.2 moderate, 1.2-2 large, and 2.0-4.0 very large (Hopkins et al., 2009). All tests were performed following previous guidelines for agreement and reliability testing (Kottner & Streiner, 2011; Zaki et al., 2012). Statistical differences were considered if $p<0.05$. Statistical analyses were developed using a special software (v.24, Statistic Package Social Sciences, Chicago, IL).

## Results

### *Study 1*

Table 1 presents the differences by sex in all anthropometric, functional, physiological and $T_3$15′ outcomes. There were trivial to large significant differences in all variables.

Table 1.
Anthropometric, functional, physiological and $T_3$15′ test results of amateur swimmers.

| Variables | Total | Men | Women | *t* (*p* value) | *d, rating* |
|---|---|---|---|---|---|
| Anthropometric | 26.1 ± 4.7 | 26.5 ± 4.1 | 26 ± 5 | 2.52 (<0.01) | 0.05, *trivial* |
| Body Mass Index (kg/m2) | 84.8 ± 12.2 | 89.2 ± 11.8 | 81.7 ± 11.6 | 14.9 (<0.01) | 0.3, *small* |
| Waist-hip Ratio (cm) | 30.1 ± 9.2 | 24.7 ± 7.3 | 34 ± 8.5 | -8.62 (<0.01) | *0.18, trivial* |
| Fat percentage (%) | | | | | |
| Functional | 32.1 ± 8.7 | 31.2 ± 9.1 | 32.7 ± 8.3 | -3.62 (<0.01) | 0.08, *trivial* |
| Sit-and-Reach (cm) | 43.7 ± 19 | 49.1 ± 19.7 | 38.6 ± 16.3 | 11.66 (<0.01) | 0.24, *small* |
| 1′ Abdominals (n) | 19.6 ± 11 | 22.6 ± 11.1 | 17.3 ± 10.3 | 10.58 (<0.01) | 0.22, *small* |
| To-Failure Push-Ups (n) | | | | | |
| Physiological | 115.1 ± 21.9 | 118.9 ± 3 | 112.4 ± 10.8 | 7.03 (<0.01) | 0.15, *trivial* |
| Systolic blood Pressure (mm/Hg) | 71.1 ± 9.2 | 72.6 ± 9.3 | 70.1 ± 8.9 | 6.51 (<0.01) | 0.14, *trivial* |
| Diastolic blood Pressure (mm/Hg) | 72.2 ± 16.3 | 70.6 ± 21.5 | 73.4 ± 11 | -4.01 (<0.01) | 0.08, *trivial* |
| Heart Raterest (bpm) | 183.1 ± 8 | 183.8 ± 7.2 | 182.5 ± 8.5 | 3.77 (<0.01) | 0.08, *trivial* |
| Heart Ratemax (bpm) | 156.9 ± 33.8 | 160.1 ± 45.3 | 154.5 ± 20.8 | 3.57 (<0.01) | 0.08, *trivial* |
| Heart Ratepeak (bpm) | 76.7 ± 31.4 | 79.7 ± 43.8 | 64.6 ± 16.3 | | 0.08, *trivial* |
| Heart Ratework (%) | | | | 3.45 (<0.01) | |

| | | | | | |
|---|---|---|---|---|---|
| T315′ Test | | | | | |
| Distance (m) | 477.5 ± 165.2 | 502.5 ± 176.3 | 457.5 ± 153.4 | 5.85 (<0.01) | 0.12, *trivial* |
| Speed (m/s) | 0.53 ± 0.2 | 0.6 ± 0.2 | 0.5 ± 0.2 | 5.85 (<0.01) | 0.12, *trivial* |

Note. P-value represent differences between sexes in the variables studied.

Based on stepwise lineal regressions results, anthropometric variable of fat percentage predicted the T$_3$15′ distance by 7% ($R^2$=0.07, F= 14.15, p<0.01). Besides, functional variables result of Sit-and-Reach, 1′ abdominals, to-failure push-ups together predicted T$_3$15′ distance by 12.3% ($R^2$=0.12, F= 59.19, p<0.01). Finally, the variables of Heart Raterest, diastolic blood pressure, and Heart Ratemax predicted T$_3$15′ distance by 2.1% ($R^2$=0.02, F= 14.06, p<0.01). Based on the abovementioned results, the categorization proposal was made based on sex and age as two main variables that could affect the T$_3$15′ swimming test results. The proposal is presented in table 2.

Table 2.
Category proposal for men and women amateur swimmers according to T$_3$15′ distance.

| | Low (m) | Fair (m) | Average (m) | Good (m) | High (m) |
|---|---|---|---|---|---|
| General | <325 | 326-425 | 426-525 | 526-625 | >625 |
| Men (years) | <325 | 326-450 | 451-550 | 551-650 | >650 |
| >18 | <400 | 401-550 | 551-650 | 651-700 | >700 |
| 19-25 | <300 | 301-370 | 371-500 | 501-650 | >650 |
| 26-35 | <325 | 326-450 | 451-550 | 551-650 | >650 |
| 36-45 | <350 | 351-500 | 501-550 | 551-650 | >650 |
| 46-55 | <350 | 351-525 | 526-600 | 601-625 | >625 |
| 56-65 | <290 | 291-370 | 371-545 | 546-700 | >700 |
| Women (years) | 300 | 301-400 | 401-500 | 501-600 | >601 |
| >18 | <300 | 301-450 | 451-550 | 551-650 | >650 |
| 19-25 | <300 | 301-400 | 401-550 | 551-650 | >650 |
| 26-35 | <325 | 326-425 | 426-500 | 501-600 | >600 |
| 36-45 | <375 | 376-450 | 451-525 | 526-625 | >625 |
| 46-55 | <300 | 301-350 | 351-400 | 401-470 | >470 |
| 56-65 | <225 | 226-282 | 283-400 | 401-425 | >425 |

Note. T$_3$15′: 15 minutes time trial test

***Study 2***

Test vs Retest comparison showed differences (*p*<0.01) but with low practical significance as there were 3.6 bpm, 1.2% and 0.01 m/s of differences between trials in Heart Ratepeak, Heart Rate work, and speed, respectively (see figure 2).

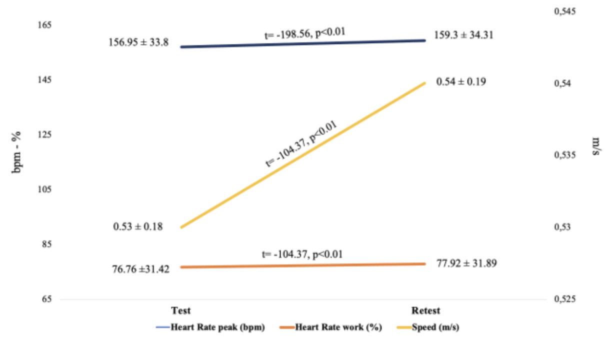


Figure 2. Test vs Retest comparison in Heart Rate$_{peak}$, Heart Rate$_{work}$, and speed. Mean ± standard deviation, bpm: beat per minute. Main axis: Heart Rate$_{peak}$ and Heart Rate$_{work}$; Secondary axis: Speed.

The results evidenced that T$_3$15′ swimming test had obtained an almost perfect reliability in the distance based on intraclass correlation values and linear correlation coefficients (see Table 3).

Table 3.
Distance agreement and reliability of T$_3$15′ swimming test.

| Variable | n | ICC rating | 95% CI | r (p value) | Bias (%) | 95% IC | t (p value) | Cohen d (rating) |
|---|---|---|---|---|---|---|---|---|
| T$_3$15′ Distance (m) | 328 | 0.98 substantial | 0.97; 1 | 0.99 (<0.01) | -10.65 (2%) | -31.47; 10.22 | -34.29 (<0.01) | 1.88, large |

Note. T$_3$15′: 15 minutes time trial test, ICC: intraclass correlation coefficient, CI: confidence interval; r: Pearson correlation; t: t-test value; Cohen's d: Effect size by Cohen's d.

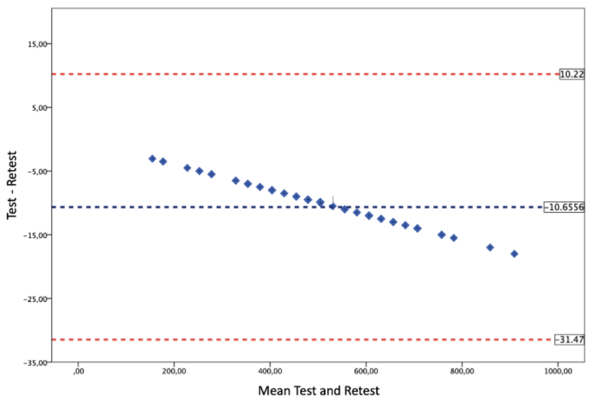


Figure 3. Bland Altman plotting of Test vs Retest.
Left axis: difference between test vs retest, 95% CI (red) and mean differences (blue); bottom axis: total distance of T$_3$15'

Additionally, after agreement tests, a bias of 2% was found, which represented a total of 10.65m (Test: 532.78 ± 155.39m and Retest: 543.44 ± 158.47m) between tests. Also, large differences were found between trials but with a relatively low practical significance considering absolute bias. Indeed, proportional bias was found (see figure 3).

## Discussion

The aims of this study were a. to explore the agreement and reliability of a 15′-time trial test to assess critical power in amateur swimmers, b. to analyze which anthropometric, functional, and physiological predictors of this test performance and c. to propose a test outcome classification criterion based on a large cohort of amateur swimmers.

Several tests can be applied to assess swimmers' physical abilities and critical speed (Mitchell et al., 2018; Pelarigo et al., 2018; Fernandes, 2011; Takahashi et al., 2009). Some tests measure the time it takes to cover a certain distance (e.g. 100, 200, 400, 800, 1000-m front crawl), and very few tests measure the swam distance based on the time it takes to cover it. One of the few tests with this type of protocol consisted of covering the most possible distance in 30 and 60 minutes (Olbrecht et al., 1985). In this study, athletic swimmers were evaluated and significant correlations were found in lactic acid concentrations in blood (Olbrecht et al., 1985). However, swimming continuously for 30 minutes can be too demanding for people with little aerobic resistance, so it would not be an ideal test for amateurs who are just starting in the sport.

Regarding the first objective, the 15' test used to evaluate critical power in amateur swimmers allows participants to swim at their own pace and ability level. Our results found the 15' test to have high reliability and minimal bias for assessing critical power, aligning with previous studies using a 3-minute test protocol. Specifically, we found a 2% bias and high intraclass correlation coefficient of 0.98 for distance covered in the 15' test. These results are comparable to the 2% bias and 0.5% coefficient of variation reported when using a 3-minute swimming test to determine critical speed (Tsai & Thomas, 2017; Mitchell et al., 2018). The strong reliability and low bias support the 15' swimming test as a valid option to evaluate critical power in amateur swimmers (Table 3 y Figure 2).

In the same way, no significant differences were reported between test-retest with one week difference in a 400 m test or a test-retest-retest (González-Haro et al., 2005), revealing similar performance between the two measures. No differences were found in critical speed in well-trained swimmers in a 30-minute freestyle test between 200m and 400 m (Dekerle et al., 2002). Concerning heart rate, this study shows minimal differences in HRmax (3.6 bpm), HR work (1.2%), and speed (0.01 m/s) between both trials. The maximum heart rates during the $T_3 15'$ test (Men= 183.8 ± 7.2 bpm, Women= 182.5 ± 8.5 bpm, General= 183.1 ± 8 bpm) are similar to those reported in different studies to estimate the critical speed through tests of various distances, this implies that this test demands a similar physical effort, so the coaches can decide which test best suits their possibilities and thus use it with confidence (Dekerle et al., 2002; Toubekis & Tokmakidis, 2013; Mitchell et al., 2018). The intensity of the $T_3 15'$ test, as measured by percentage of maximum heart rate, was lower compared to previous research using a progressive swim test protocol. In our study, participants reached an average of 76.7% of maximum heart rate during the $T_3 15'$ trial. In contrast, da Costa et al. (2012) reported non-expert swimmers aged 18-30 years achieved 88-89% of maximum heart rate during a progressive swimming test. The lower relative intensity in our 15' trial may be attributed to the test format allowing participants to pace themselves and achieve a physiological steady state, whereas progressive tests drive swimmers to maximal exertion. We also found minimal heart rate differences of 1.2% between the first and second $T_3 15'$ trials, compared to a 4.6 bpm difference reported for progressive test-retest (da Costa et al., 2012). Overall, our results indicate the $T_3 15'$ test elicits high yet sustainable intensity for amateur swimmers. The heart rate response aligns with critical power testing goals and supports the test's reliability.

Regarding the second objective, the results of the regression analysis indicated that the percentage of body fat percentage predicts 7% of the distance in the $T_3 15'$ test. The results in the Sit-and-Reach, 1′sit-ups, and push-ups predicted 12.3%, while the Heart $Rate_{rest}$, diastolic blood pressure, and Heart $Rate_{max}$ predicted only 2.1%. Based on the information above, this indicates that greater flexibility and abdominal muscular endurance have a favorable influence on swimming capacity. Enhanced flexibility allows a greater range of motion which can increase stroke length and efficiency through the water (Geladas et al., 2005). Likewise, increased abdominal strength enables the core stability and powerful kicks needed to propel the body forward during swimming (Barbosa et al., 2010). Together, increased flexibility and muscular endurance likely improve swimming technique and stamina which then enables individuals to achieve greater distances during the 15' timed swim trial (Zacca et al., 2016). Our findings align with prior research highlighting the importance of these physical capacities for optimal swimming performance (Cañas-Jamett et al., 2020). In master swimmers (between 40 and 80 years), it was reported that the best predictors for short-distance (50, 100 and 200-m) performance were age, height, and grip strength, while in medium (400-m) and long-distance (800-m), only age and height were predictors (Zampagni et al., 2008). The importance of strength at the lever of the upper limbs (Pérez-Olea et al., 2018) and of the power at the level of the lower limbs with swimming speed has also been evidenced (West et al., 2011).

The study by Lätt et al. (2010), found that biomechanical parameters better predicted 100m performance compared to anthropometric and physiological factors in young swimmers. They reported arm span, bone mineral density, bone mass, height, and lactate as strongest correlates. Our study similarly found anthropometric and physiological variables to be weaker predictors, with body fat percentage explaining only 7% of $T_3 15'$ distance. However, we did not assess biomechanical factors. Comparing our results to Lätt et al. suggests biomechanics may better predict test performance than anthropometrics or physiology. Future studies should examine biomechanical predictors of the T315′ test.

Likewise, an investigation led by Wakayoshi et al. (1992), reported strong positive correlations between critical speed and anaerobic threshold oxygen, lactate accumulation onset speed, and 400m average speed in male swimmers ages 18-21 years. Our study did not assess anaerobic threshold, lactate, or 400m times. However, the average speed in our T315′ test was lower than 400m speeds reported in other studies (Laffite et al., 2004; Zacca et al., 2016). Those studies also found speed decreases after the first 100m in a 400m test. This aligns with the concept that critical speed represents the maximum sustainable pace before lactate accumulation (Takahashi et al., 2009). Our lower $T_3 15'$ speeds likely reflect the amateur status of our cohort. Comparisons to Wakayoshi et al. and others indicate potential relationships between T315´ performance, lactate markers, and 400m speeds that should be examined in future amateur swimmer research.

Although this study provides a novel insight about the $T_3$15´ test in recreation athletes and classify test results in five levels to allow comparisons and performance enhancement, different limitation should be included. The sample comprised amateur swimmers from a single university club, thus the results may not generalize to other populations. The regression analysis explained only 12.3% of variance in swimming distance; many other factors likely influence performance. Additionally, while we proposed $T_3$15' categorization criteria, direct validation of the standards requires further investigation. The test-retest design included only a one-week interval, so reliability over longer durations is unknown. Finally, the study was unable to directly compare the 15' protocol to other critical power tests like the 3-minute or 30-minute trials. Future research should examine the $T_3$15' test in elite swimmers, youth athletes, and master populations. Direct comparisons to other critical power protocols would also help further validate the 15' test. Overall, while promising, continued research is needed to address these limitations and firmly establish the $T_3$15' test as an assessment of swimming aerobic fitness.

## Conclusions

The $T_3$15 test is a linear test with simple applicability that can be accessible to the adult population that practices recreational or amateur swimming. The results indicate adequate concordance and reliability, for which its relevance is statistically supported. Likewise, a classification is offered, with this information, swimming coaches or instructors can assess the swimming capacity of each person considering both their sex and their age. The test, in turn, allows to carry out a process of control and monitoring of users who attend swimming centers. Planning training programs can be made easier by taking $T_3$15 test results as a basis.

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