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**100m and 200m front crawl performance prediction based on anthropometric and physiological measurements**

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**Abstract**

**Background:** The identification of the variables that are able to predict swimming performance is one of the main purposes of the “swimming science” community. **Research question:** The aims of the study were: (i) to compare the anthropometric and physiological profiles of 100m and 200m front crawl swimmers and; (ii) to identify anthropometric and physiological variables that account for the prediction of the swimming performance at the 100m and 200m front crawl events. **Methods:** Twenty-six male swimmers were divided in two groups (12 for 100m group and 14 to 200m group). The swimmers’ personal best performance for the 100m and the 200m front crawl was converted to FINA points. The subjects performed a graded swimming test and an all-out test (100 or 200m maximal swims) in different days, in which physiological measures were evaluated. Forward step-by-step linear regression models were computed to predict swimming performance. The subjects’ performances (season best and all-out test) were taken as dependent variables. The age, physiological and anthropometric measures were selected as independent variables. **Results:** Anthropometric and physiological profiles of 100 and 200m swimmers are different and the mean oxygen uptake during exercise combined with training experience may explain 200m front crawl best season performance with a high precision ( $\approx 2\%$  error). The models computed were able to predict from 44 % (i.e. 200m all-out bout) to 61 % (i.e. 200m season best) swimming performance. Predictive power of the models was less accurate in the 100m event (error > 10%). **Conclusions:** The authors conclude that the extent to which the physiological and anthropometric variables combine to predict performance probable is group-specific. **Keywords:** competitive swimming, front crawl, prediction, performance, energetic, anthropometrics

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## **Introduction**

The identification of the variables that are able to predict swimming performance is one of the main purposes of the “swimming science” community<sup>1</sup>. Swimming performance is related, on a regular basis, to the anthropometric and physiological variables, and several original research and review papers reported such interplay between the swimming performance and the swimmer’s physiological and/or anthropometric profiles<sup>2,3</sup>. Indeed the physiological and the anthropometric evaluations are some of the most assessed domains in the last decades within the “swimming science”<sup>4,5</sup>.

Swimming performance has been related to maximal total energy release and energy cost<sup>6-8</sup>. In addition, the energy cost of swimming has been found to correlate negatively with performance<sup>9,10</sup>. From a physiological point of

view, swimming performance is strongly dependent on aerobic and anaerobic parameters<sup>11</sup>. Several authors have reported that peak oxygen uptake ( $\dot{V}O_2$ ) was the best swimming performance predictor<sup>12</sup>. The lactate threshold has also been considered as a parameter of performance prediction<sup>13</sup>. The velocity associated with the  $4\text{mmol}\cdot\text{L}^{-1}$  lactate threshold<sup>14,15</sup> has been addressed in the recent literature. Some authors have reported the analysis of the accumulated oxygen deficit and the subsequent anaerobic contribution to total energy expenditure for male front crawl swimming performances<sup>16-19</sup>. The peak post-exercise blood lactate, another indicator of anaerobic energy release, has been found to present positive correlations with swimming performance<sup>20</sup>. Thus the physiological profile is one of the most relevant factors in the enhancement of swimming performance.



Many studies show that swimming performance is also influenced by anthropometrics<sup>21</sup>. Elite swimmers are taller, with broad shoulders and narrow hips, compared to the normal population and to sub-elite swimmers<sup>21</sup>. Arm span was also reported as being relevant to swimming performance and certain biomechanical variables<sup>22</sup>. The lean body mass is also related to swimming<sup>23</sup>.

Freestyle swimming events represent most of the races available in swimming competitions. Moreover, the front crawl is the fastest swimming technique and the one used largely in freestyle events. Within these events, the 100m and the 200m distances are the ones for which the highest number of swimmers regularly register in a competition. Hence much attention has been given to these freestyle events and to the front crawl technique. Some studies have described the physiological and/or anthropometric profile of the 100m and of the 200m front crawl specialists<sup>11, 18, 24, 25</sup>. But, to the best of these authors' knowledge, little effort has been made to compare them. The only exception was a similar research project conducted on breaststroke events<sup>26</sup>.

There are several approaches to predicting swimming performance<sup>3</sup>: (i) comparing different cohort groups; (ii) computing statistical models; (iii) developing neural networks and; (iv) by performing cluster analysis. For this research, cohort groups and statistical models were used. The use of cohort groups aims to compare selected variables among subjects with different characteristics. Statistical models allow the identification of the best predictors of swimming performance for a given condition. Much research on swimming performance is done based on the comparison of groups at different competitive levels<sup>27, 28</sup>. Several manuscripts have also been published on the use of statistics<sup>29, 30</sup>. However, few of them have tried to predict swimming performance based on the anthropometric and the physiological profiles. In addition, those few papers paid very little attention to the anaerobic energy fraction of the total energy expenditure and, therefore, to swimming performance. A single example is the paper by Reis et al.<sup>26</sup> which looked at the breaststroke technique.

The aims of the present study were to: (i) to compare the anthropometric and physiological profiles of 100m and 200m front crawl swimmers and; (ii) to identify anthropometric

and physiological variables that account for the prediction of swimming performance in the 100m and 200m front crawl. It was hypothesised that the factors explaining the performances would be different under the two swimming conditions (i.e. during an all-out bout with a snorkel and the season best performance in the competitive context).

## Methods

### Participants

Twenty-six male swimmers ranging from regional to international level volunteered for the study and after medical approval gave their informed consent to participate in the present study. Twelve swimmers were included in the prediction of the 100m front crawl performance and fourteen in the prediction of the 200m front crawl performance. Swimmers were included in a given event prediction model based on their best performance in each swim race. All the procedures were approved by the Institution Ethics Committee and were in accordance with the Helsinki Declaration.

### Testing

The experimental testing was conducted in the 1<sup>st</sup> month of the 2<sup>nd</sup> macro cycle of the season (after the transition period post-winter competitive season) in a short course swimming pool. During the five days prior to testing, the swimmers were not allowed to be engaged in any high-intensity training sessions. The subjects performed several assessments on separate days, with a 24-hour recovery: (i) a graded and intermittent swimming test plus an anthropometric assessment and; (ii) an all-out swimming test plus a performance assessment. All assessments were conducted in the morning (between 10h00 and 12h00) controlling for the circadian effect and in an environmental temperature of 25-28°C and a humidity of 50-60 %.

### Performance assessment

Swimming best performance (in s and in FINA 2004 points) was assessed by time lists for the 100m or 200m front crawl event of official short course competitions of regional, national or international level at the moment of the data collection ( $\pm 2$  months).

The swimmers' all-out performance (in s and in FINA 2004 points) was collected at the same time as the physiological assessment. Each swimmer did the all-out test with an underwater start. Subjects performed the bout alone to prevent any drafting or pacing effects. FINA



2004 points were selected to present the data as it is the only way to be able to compare performance across different swimming events.

### **Anthropometric assessment**

A stadiometer (SECA, 242, Hamburg, Germany) was used for the evaluation of height (in m). A standard scale weighing machine (SECA, 884, Hamburg, Germany) was used to assess body mass (in kg). Arm span (in m) was measured with a tape from one furthest fingertip to the other, with the swimmer's back and buttocks touching a wall, facing away from the wall, the arms are stretched out and abducted horizontally. A total of four skin folds were taken with a skin fold caliper Slim Guide (Creative Health Products, USA) and the fat mass (in %) was estimated according to the Faulkner<sup>31</sup>.

### **Graded and intermittent test**

The graded and intermittent test included several swim bouts at a constant velocity<sup>16</sup>. The distance of the two first bouts was 350m and 400m respectively from the third bout onwards. Distances were selected based on the time needed to accomplish a physiological steady state. At low sub-maximal bouts the distance of 350m was the one required to be accomplished as the swimming speed is slower. With increasing intensity, swim speed increases. Therefore to maintain more or less the time needed for the steady state, it was necessary to increase the distance to 400m. Initial velocity was established according to the swimmers' individual performance in a 400m front crawl event. The increments on subsequent bouts were 10% of the 400m best performance velocity per each stage until exhaustion. During this test the swimming velocity of the subjects was kept constant by an electronic pacer placed at the bottom of the swimming pool (TAR. 1.1, GBK-electronics, Aveiro, Portugal). The subjects were instructed to follow the pacer's light signal, and they had had previous experience using such a device. No warm-up was performed before the start of the test and passive recovery between successive bouts was individualised. The subjects started each bout when their oxygen uptake presented two consecutive values within  $2\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$  from that recorded before the start of the first bout (average oxygen uptake during 2<sup>nd</sup> minute prior to the start of the first bout of the graded test). The test was started with the subjects in the pool, pushing off the wall with their feet. After every 25m an open turn technique was performed (i.e. a body rotation to the side wall, without diving

and subsequent feet push-off from the wall). The swimmers were advised to reduce gliding during the start and turnings. The test ended with the subject's voluntary exhaustion or until they could no longer swim at the predetermined pace.

Throughout the test, expired gases were collected breath-by-breath and analysed with a gas analyser (K4b<sup>2</sup>, Cosmed, Rome, Italy) connected to a valve (AquaTrainer, Cosmed, Rome, Italy). Before each test, calibration procedures were performed as suggested by the manufacturer. The oxygen uptake was averaged thereafter at 20s intervals. Immediately after the conclusion of each bout, capillary blood samples were collected from the finger to determine the blood lactate concentration with a hand-portable lactate analyser (Accusport, Boehringer, Mannheim, Germany). This device was previously reported as having a satisfactory accuracy, reliability and validity<sup>32</sup>. In addition, prior to each test, a calibration of the hand-portable lactate analyser was performed with several YSI 1530 Standard Lactate Solutions (i.e. 2-, 4-, 8- and  $16\text{mmol}\cdot\text{L}^{-1}$ ).

### **The all-out test**

The all-out test was performed in one of the two events: (i) the 100m front crawl ( $n=12$ ) or; (ii) the 200m front crawl ( $n=14$ ). Subjects were assigned to each distance according to their best competitive performance and were asked to swim as if they were in a timed competitive race. Subjects were allowed to perform their regular basic competition warm-up drills. The test was not started until the subject's oxygen uptake returned to resting values (the same individual value recorded before the start of the graded test). Each subject performed the test individually. The start of the test and each turn-over were performed as described in the graded test.

Throughout the test, oxygen uptake was also measured with the same gas analyser (K4b<sup>2</sup>, Cosmed, Rome, Italy) connected the valve (AquaTrainer, Cosmed, Rome, Italy) and thereafter averaged again in 20s intervals. The calibration procedures were also performed before each test. In addition, capillary blood sample collections were made every 2min post-race until blood lactate concentrations levelled off.

### **Calculations**

The graded test was performed to obtain  $\text{VO}_2$ /velocity relationship points that enabled the calculation of a valid regression. Peak  $\text{VO}_2$





(in  $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ) was the highest 20s average oxygen uptake ( $\text{VO}_2\text{mean}$ , in  $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ) value observed in each subject either in the graded or in the all-out test. Swimming velocity associated with peak  $\text{VO}_2$  ( $V_{\text{peakVO}_2}$ , in  $\text{m}\cdot\text{s}^{-1}$ ) was estimated from the inclusion of the peak  $\text{VO}_2$  of each subject in the individual  $\text{VO}_2$ /velocity regression equation. The  $\text{VO}_2$ /velocity regression was developed for each subject using the steady-state  $\text{VO}_2$  values during the last minute of each exercise bout in the graded test. An individual resting  $\text{VO}_2$  measurement ( $\text{VO}_2$  at null velocity) was also included in the regressions. Oxygen uptake measurements from incomplete bouts were excluded from the regression model. In addition, bouts that failed to comply with the  $\text{VO}_2$  steady-state attainment (given by a difference below  $2\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$  between two consecutive min) were not included in the regression models. The energy cost of swimming ( $C_s$ , in  $\text{ml}\cdot\text{kg}^{-1}\cdot\text{m}^{-1}$ ) was determined from the slope of the  $\text{VO}_2$ /velocity regression line.

The accumulated oxygen deficit (AOD, in  $\text{ml}\cdot\text{kg}^{-1}$ ) was calculated as the difference between accumulated oxygen demand and accumulated oxygen uptake during the all-out test. This estimation was not corrected for body oxygen stores. The accumulated oxygen deficit was calculated by linear extrapolation of the energy cost previously assessed. The accumulated oxygen uptake was the integration of oxygen uptake during the all-out test over the time. The aerobic energy fraction (in %) was obtained, dividing the accumulated oxygen uptake by the accumulated oxygen demand.

Accumulation of blood lactate (in  $\text{mmol}\cdot\text{L}^{-1}$ ) in the graded test was traced by linear interpolation to determine the swimming velocity corresponding to the  $4\text{mmol}\cdot\text{L}^{-1}$  threshold. Swimming velocities associated with the  $2\text{mmol}\cdot\text{L}^{-1}$  ( $V_2$ , in  $\text{m}\cdot\text{s}^{-1}$ ) and the  $4\text{mmol}\cdot\text{L}^{-1}$  ( $V_4$ , in  $\text{m}\cdot\text{s}^{-1}$ ) thresholds were determined by linear interpolation of the points relating blood lactate and swimming velocity during the graded test. The  $\text{VO}_2$  elicited at the  $2\text{mmol}\cdot\text{L}^{-1}$  ( $\text{VO}_2@V_2$ , in %) and the  $4\text{mmol}\cdot\text{L}^{-1}$  ( $\text{VO}_2@V_4$ , in %) thresholds were calculated by the inclusion of  $V_2$  and  $V_4$  in the individual  $\text{VO}_2$ /velocity regression equation and expressed as a fraction of peak  $\text{VO}_2$ .

## Statistics

The normality and homocedasticity assumptions were checked respectively with the Shapiro-Wilk and the Levene tests. Descriptive statistics (mean and one standard deviation) from all variables were calculated.

The Mann-Whitney U test was computed to compare significant differences in all variables selected (age, performance, anthropometrics and physiology) according to the swimmer's group variable (100m versus 200m performances). Z values presented are based on positive ranks. The level of statistical significance was set at  $P \leq 0.05$ . The effect size was computed with Cohen's *d* for all variables. It was considered a: (i) small effect size if  $0 \leq |d| \leq 0.2$ ; (ii) medium effect size if  $0.2 < |d| \leq 0.5$  and; (iii) large effect size if  $|d| > 0.5$

Forward step-by-step linear regression models were computed to predict swimming performance (for both the 100m and 200m groups). The subjects' performances (season best and all-out test) were taken as endogenous (i.e. dependent) variables. The age, physiological and anthropometric measures were selected as exogenous (i.e. independent) variables. The variables were entered into the equation if  $F \geq 4.0$  and removed if  $F \leq 3.96$ . The level of statistical significance was set at  $P \leq 0.05$ .

## Results

Table 1 presents the descriptive statistics and comparison of performance, age, anthropometric and physiological variables between the 100m and the 200m groups. There were no significant differences between both events, neither for the swimming best performance nor for the swimming all-out performance based on FINA points. There were significant differences between groups in the arm span and estimated body fat. In both cases mean values were higher in the 200m swimmers. The sample size was considered as having a large effect on data based on the Cohen's *d* values. The  $V_4$ ,  $\text{VO}_2@V_4$ ,  $V_2$ ,  $\text{VO}_2@V_2$ , Blood lactate, peak  $\text{VO}_2$ ,  $V_{\text{peakVO}_2}$ ,  $C_s$ ,  $\text{VO}_2\text{mean}$  were also significantly different but the sample size once again had a large effect.



Table 1: Comparison of performance, age, anthropometric and physiological variables between 100m (n=12) and 200m (n=14) groups

	100m group (mean ± 1 SD)	200m group (mean ± 1 SD)	Z value	P value	Cohen's d
Swim best performance (s)	56.44 ± 3.72	131.76 ± 41.27	-4.32	< 0.01	2.57
Swim all-out performance (s)	68.08 ± 5.98	140.53 ± 22.44	-4.33	< 0.01	4.41
Swim best performance (FINA)	587.5 ± 117.70	559.46 ± 197.40	-0.34	NS	0.17
Swim all-out performance (FINA)	341.50 ± 88.14	356.31 ± 111.52	-0.41	NS	0.15
Age (years)	18.6 ± 2.8	17.1 ± 2.3	-1.30	NS	0.58
Training experience (years)	12.3 ± 1.9	8.9 ± 3.2	-2.67	< 0.01	1.29
Body mass (kg)	67.8 ± 15.2	70.3 ± 6.6	-0.10	NS	0.21
Height (m)	1.77 ± 0.05	1.79 ± 0.06	-0.31	NS	0.36
Arm span (m)	1.84 ± 0.06	1.89 ± 0.05	-2.22	0.03	0.91
Estimated body fat (%)	10.7 ± 1.0	10.1 ± 0.6	-2.21	0.03	0.72
V <sub>4</sub> (m.s <sup>-1</sup> )	1.10 ± 0.07	1.20 ± 0.07	-3.14	< 0.01	1.43
VO <sub>2</sub> @V <sub>4</sub> (%)	69.59 ± 4.12	81.00 ± 6.95	-3.84	< 0.01	2.00
V <sub>2</sub> (m.s <sup>-1</sup> )	0.97 ± 0.09	1.07 ± 0.09	-2.86	< 0.01	1.11
VO <sub>2</sub> @V <sub>2</sub> (%)	62.61 ± 4.80	69.57 ± 8.46	-1.93	0.05	1.01
Blood lactate (mmol.L <sup>-1</sup> )	12.59 ± 2.44	10.19 ± 2.65	-2.19	0.03	0.94
Peak VO <sub>2</sub> (ml.kg <sup>-1</sup> .min <sup>-1</sup> )	57.26 ± 8.61	64.28 ± 5.54	-2.16	0.03	0.97
VpeakVO <sub>2</sub> (m.s <sup>-1</sup> )	1.49 ± 0.12	1.67 ± 0.22	-2.55	0.01	1.01
C <sub>S</sub> (ml.kg <sup>-1</sup> .m <sup>-1</sup> )	0.60 ± 0.05	0.70 ± 0.06	-4.10	< 0.01	1.81
Aerobic energy fraction (%)	69.3 ± 10.0	87.9 ± 7.7	-3.60	< 0.01	2.08
AOD (ml.kg <sup>-1</sup> )	20.40 ± 7.50	17.42 ± 13.01	-1.54	NS	0.14
VO <sub>2</sub> mean (ml.kg <sup>-1</sup> .min <sup>-1</sup> )	37.54 ± 4.70	50.21 ± 10.29	-3.60	< 0.01	1.58

V<sub>4</sub> = swimming velocity corresponding to the 4 mmol.L<sup>-1</sup> threshold; VO<sub>2</sub>@V<sub>4</sub> = VO<sub>2</sub> elicited at V<sub>4</sub>; V<sub>2</sub> = swimming velocity corresponding to the 2 mmol.L<sup>-1</sup> threshold; VO<sub>2</sub>@V<sub>2</sub> = VO<sub>2</sub> elicited at V<sub>2</sub>; VpeakVO<sub>2</sub> = velocity associated to the peak VO<sub>2</sub>; C<sub>S</sub> = energy cost of swimming; AOD = accumulated oxygen deficit; VO<sub>2</sub>mean = mean VO<sub>2</sub> during the all-out bout; NS = not significant

Table 2 presents the multiple regressions that were established predicting swimming performance based on several variables. The

models computed were able to predict from 44% (i.e. 200m all-out bout) to 61% (i.e. 200m season best) swimming performance.

Table 2: Multiple regressions with significance for FINA scores (season best and all-out bout) as dependent variables in the 100m (n=12) and 200m (n=14) groups

Group	Equation	R	R <sub>a</sub> <sup>2</sup>	SE	RE
100m	SB FINA= (927.60·V <sub>2</sub> – 59,02·body fat) + 310.36	0.77	0.49	78.66	13.7%
100 m	ALL FINA= (3.16·body mass) + 114.01	0.78	0.60	40.81	11.4%
200m	SB FINA= (-3.77·TE – 0.985·VO <sub>2</sub> mean) + 223,71	0.78	0.61	15.31	2.4%
200m	SB FINA= (47.66·Age) – 184.68	0.80	0.61	85.61	13.6%
200m	ALL FINA= (20.89·TE) + 191.19	0.66	0.44	79.35	20.1%

SB FINA = season best FINA score; ALL FINA = all-out bout FINA score; TE = training experience; VO<sub>2</sub>mean = mean VO<sub>2</sub> during the all-out bout; R<sub>a</sub><sup>2</sup> = adjusted R<sup>2</sup>; SE = standard error of the regression; RE = relative error

## Discussion

The aims of the present study were to: (i) to compare the anthropometric and physiological profiles of 100m and 200m front crawl swimmers and; (ii) to identify anthropometric and physiological variables that account for the prediction of swimming performance in the

100m and 200m front crawl events. Some smooth but significant differences in the anthropometric and physiological profiles of 100m and 200m specialists were found, added to the fact that both age and given anthropometric and physiological variables were able to predict swimming performance.



Despite the previous body of evidence addressing the contribution of physiological measures to predict swimming performance<sup>9, 12, 27</sup>, the use of swimming valves in physiological testing is recent. Swimming valves attached to gas analysers have been used to assess the physiological response during swimming. However, the valve itself imposes some technical and mechanical constraints during swimming which may lower the precision of such estimates to predict true swimming performance<sup>30</sup>. Therefore these authors hypothesised that the factors explaining performances would be different under the two swimming conditions (i.e. during an all-out bout attached to the snorkel and the season best performance in the competitive context).

Comparing the performance, anthropometric and physiological profiles, there were some smooth but significant differences between the 100m and the 200m swimmers. The arm span and estimated body fat were significantly higher in the longer event swimmers. Arm span is directly related to biomechanical variables such as stroke length<sup>22</sup> and the latter one to efficiency<sup>34</sup> and performance<sup>25, 28</sup>. Fat mass is related to the buoyancy effect, with a more streamlined position in the water, decreasing body torque and drag force<sup>35</sup>. The  $V_4$ ,  $VO_2@V_4$ ,  $V_2$ ,  $VO_2@V_2$ , blood lactate, peak  $VO_2$ ,  $V_{peak}VO_2$ ,  $C_S$ ,  $VO_{2mean}$  were also significantly different between the two groups of swimmers. For example, blood lactate was higher in the shorter event and peak  $VO_2$ ,  $V_{peak}VO_2$ , aerobic energy fraction were higher in the longer one. This seems to be in accordance to previous literature reporting that shortest events are quite dependent from anaerobic pathways and with increasing distance the partial contribution of the aerobic pathways have a trend to be higher<sup>18, 19, 24</sup>.

The best season performance was more accurately predicted by training experience and mean  $VO_2$  during the all-out bout for the 200m event (imprecision  $\approx 2\%$ ), while in the 100m event it was best predicted by estimated body fat and swimming velocity corresponding to the  $2\text{mmol}\cdot\text{L}^{-1}$  threshold (imprecision  $\approx 14\%$ ). When the subject's performance was assessed in the all-out bout, the prediction models were less robust, with body mass as the single predictor for 100m event (imprecision  $\approx 11\%$ ) and training experience as the single predictor for 200m event (imprecision  $\approx 20\%$ ). The correlation coefficient that these authors have

found between performance under the two conditions of exercise was moderate ( $r=0.44$ ;  $P<0.05$ ). This might indicate that the extent into which swimmers adapt to the swimming valve may vary considerably.

Previous studies reported that peak  $VO_2$  was the best performance predictor at competitive swimming<sup>12</sup>. In the present study, peak  $VO_2$  was not able to predict the best performance of the season. Though this present study did confirm that subjects with the best performance level do attain higher peak  $VO_2$  compared with less proficient swimmers<sup>27</sup>. The  $V_{peak}VO_2$  has also been investigated in front crawl swimming<sup>14, 15</sup>. This may also represent a possible limitation to swimming performance, since it reflects the subject's swimming economy when obtaining maximal  $O_2$  utilisation by the exercising muscles. The mean values of  $V_{peak}VO_2$  that these authors have observed in the 100m group are within those reported by Fernandes et al.<sup>14, 15</sup>, although the subjects' peak  $VO_2$  in the present study was considerably lower than that in Fernandes et al.<sup>14, 15</sup> studies. Differences in the exercise protocol that these authors have used, as well as in the equation that was used to calculate  $V_{peak}VO_2$ , may help to explain the mismatch with the referred studies<sup>14, 15, 27</sup>. This idea is reinforced by the observation in the 200m group in the present study. Indeed, despite the higher  $V_{peak}VO_2$  of this present study's subjects compared to that in the aforementioned studies, these authors subjects' peak  $VO_2$  was still below those of the other studies mentioned. Also, when this study's results are compared with those by Fernandes et al.<sup>10</sup> a higher  $V_{peak}VO_2$  in this study's subjects was accompanied by lower peak  $VO_2$  mean values, when compared to the values found by Fernandes et al.<sup>10</sup>. Although the literature has reported that  $C_S$  can differentiate subjects with different performance levels<sup>9, 27</sup> or correlate negatively with performance<sup>9</sup>, this study's results do not support such data, since  $C_S$  was not included in any of the final regression models found.

The swimming velocity associated with  $V_4$  in the present study was lower than that reported previously by Fernandes et al.<sup>14, 15</sup>, when assessing the individual anaerobic threshold. The apparently higher aerobic ability of the swimmers in Fernandes et al.<sup>14, 15</sup> studies may help to explain the differences. Indeed, the peak  $VO_2$  of the subjects in the present study was considerably lower than those in the referenced studies. Neither  $V_4$  nor the  $V_4/VO_2$



was included in the models that predicted 100m or 200m performance in the present study. Curiously, the swimming velocity associated with the  $V_2$  was combined with body fat to predict the 100m best season performance with a 13.7% imprecision value.

None of the anaerobic ability indicators that these authors have assessed were included in the performance prediction models that were established. The AOD mean values that these authors have observed are close to those reported when using a similar method<sup>16</sup>. Also, these authors' mean values for peak post-exercise blood lactate were also lower than those reported in the literature for trained swimmers performing the same distances, especially in the 200m distance<sup>36</sup>. The literature presents positive correlations between peak blood lactate and performance<sup>20</sup>, but this present study's results do not support such data.

In the present study, the physiological measure that appeared most often in the final prediction models was the mean  $VO_2$  during the all-out bouts. This measure was not found previously in the literature during front crawl swimming. The aerobic energy fraction calculated in the present study for the 100m and 200m events was  $\approx 69\%$  and  $\approx 88\%$ , respectively. These values are higher when compared with previous studies that applied the same method for the same events<sup>17-19</sup>.

## Conclusions

The results of the present study point out that the anthropometric and physiological profiles of 100m and 200m swimmers are different. In addition to this, the mean  $VO_2$  during exercise, combined with training experience, may explain the 200m front crawl best season performance with high precision. In this event,  $VO_2$  mean was negatively associated with SB FINA. This means that the ability to generate a large amount of energy from aerobic sources could be a counter factor in the 200m event. However, since no anaerobic variable was included in the models, this present study's data cannot support such a conclusion. Since results that were observed in the 100m group were vastly different, these authors conclude that the extent to which physiological and anthropometric variables combine to predict performance probability is highly group-specific.

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