Original article

Gender and distance influence performance predictors in young swimmers

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Abstract—Predictors of performance in adult swimmers are constantly changing during youth especially because the training routine begins even before puberty in the modality. Therefore this study aimed to determine the group of parameters that best predict short and middle swimming distance performances of young swimmers of both genders. Thirty-three 10-to 16-years-old male and female competitive swimmers participated in the study. Multiple linear regression (MLR) was used considering mean speed of maximum 100, 200 and 400 m efforts as dependent variables, and five parameters groups as possible predictors (anthropometry, body composition, physiological and biomechanical parameters, chronological age/pubic hair). The main results revealed explanatory powers of almost 100% for both genders and all performances, but with different predictors entered in MLR models of each parameter group or all variables. Thus, there are considerable differences in short and middle swimming distance, and males and females predictors that should be considered in training programs.

Keywords: short distance, middle distance, physiological parameters, biomechanical parameters

Resumo—"Gênero e distância influenciam preditores de desempenho em nadadores jovens." Preditores de desempenho modificam-se constantemente na juventude devido ao início precoce das rotinas de treinamento sistematizado na natação. Sendo assim, o objetivo do estudo foi determinar o grupo de parâmetros que melhor prediz performances de curta e média distância em nadadores jovens de ambos os gêneros. Trinta e três nadadores competitivos de ambos os gêneros (10 a 16 anos) participaram do estudo. Foi utilizada regressão linear múltipla (RLM) considerando as velocidades médias de 100, 200 e 400m como variáveis dependentes, e cinco grupos de parâmetros como possíveis preditores (antropometria, composição corporal, parâmetros fisiológicos e biomecânicos, idade cronológica/ pilosidade pubiana). Os principais resultados revelaram poder de explicação próximo a 100% para ambos os gêneros em todas as performances, entretanto com diferentes preditores nos modelos de RLM. Logo, há consideráveis diferenças que devem ser consideradas em programas de treinamento entre preditores de performances de curta e média distância, para meninos e meninas.

Palavras-chaves: curta distância, média distância, parâmetros fisiológicos, parâmetros biomecânicos

Resumen—"Género y la distancia de influencia predictores del rendimiento en nadadores jóvenes." Predictores de rendimiento en nadadores adultos cambian constantemente en la juventud, especialmente porque la rutina de entrenamiento comienza antes de la pubertad. Por tanto, el objetivo fue determinar el conjunto de parámetros que mejor predice el rendimiento de corta y media distancia de los nadadores de ambos sexos. Participaron 33 nadadores de ambos sexos (edad, 10-16 años). Regresión lineal múltiple fue usada considerando la velocidad promedio de 100, 200 y 400m como variables dependientes, y cinco grupos de parámetros como posibles predictores (antropometría, composición corporal, parámetros fisiológicos y biomecánicos, edad/vello púbico). Los principales resultados revelan explicación cercana al 100% para ambos sexos en todas las distancias, pero con diferentes modelos de predicción para cada grupo de parámetros o con todos los parámetros. Por tanto, existen diferencias considerables entre los predictores de cortas y media distancias en los niños y niñas que deben ser considerados en los programas de entrenamiento.

Palabras claves: corta distancia, media distancia, parámetros fisiológicos, parámetros biomecânicos

Introduction

The competitive participation and systematic training routine of swimmers usually start before puberty (Lätt et al, 2009); therefore, the performance of the young athletes depends not only on training but also on physical growth and development (Baxter-Jones, Eisenmann, & Sherar, 2005). Technical, physiological, and bodily parameters are identified as traditional adult performance predictors and major factors that influence performance improvement in youngsters, thereby highlighting differences between genders, different chronological ages, and maturational status throughout childhood and adolescence (Geladas, Nassis, & Pavlicevic, 2005; Jürimäe et al., 2007; Lätt et al., 2010; Lätt et al, 2009; Saavedra, Escalante, & Rodriguez, 2010; Vitor & Böhme, 2010; Zuniga et al., 2011).

In athletes of any age, body size is directly related to swimming speed. However, the influence of lean and fat mass on the performance of young swimmers remains to be fully clarified (Geladas et al., 2005; Pyne, Anderson, & Hopkins, 2006; Saavedra et al., 2010; Zuniga et al., 2011). It is known that being an aquatic modality, swimming is largely dependent on technical skills and the optimal combination of stroke rate (SR) and length (SL) that results in maximal speed and great swimming economy (Pelayo, Alberty, Sidney, Pordevin, & Dekerle, 2007). However, in young individuals, all anthropometrical changes strongly influence these technical indexes and, consequently, performance itself (Jürimäe et al., 2007; Lätt et al., 2009; Zamparo et al., 2008).

Furthermore, physiological parameters such as anaerobic threshold are widely used in swimming for training guidance. In particular, anaerobic threshold can be directly or indirectly determined by the lactate minimum (LM) protocol or critical speed (CS), respectively (Greco & Denadai, 2005; Ribeiro, Balikian, Malachias, & Baldissera, 2003; Toubekis, Tsami, Smilios, Douda, & Tokmakidis, 2011; Zacca et al., 2010), and greatly influences the performance of adult or young athletes, with an explanatory power of up to 97% (Altimari, Altimari, Gulak, & Chacon-Mikahil, 2007). However, the physiological maturity during puberty and gender-specific maturation process lead to marked changes in this parameter in children and adolescents (Armstrong & Mcmanus, 2011; Greco & Denadai, 2005; Mcmanus & Armstrong, 2011).

To our knowledge, no studies have investigated and compared different variables (chronological age, maturity status, anthropometrical, body composition, physiological and biomechanical parameters) as predictors of short and middle swimming distances in both genders in young swimmers. In addition, comparative data between male and female young swimmers at all puberty stages, according to pubic hair growth, are currently lacking. Therefore, this study aimed to determine the group of parameters that best predict short and middle swimming distance performances of young swimmers of both genders.

Methods

Participants

Thirty-three 10- to 16-year-old young swimmers (17 males and 16 females) of regional and national competing level participated in this study. They were undertaking systematic exercise training for a minimum of two years with an average training volume of 35 km·wk^{-1}. Mean descriptive characteristics for each gender group are shown in Table 1.

Chronological age (CA) was computed from date of birth and date of examination, and sexual maturity was auto-assessed, visually, using the five levels of pubic hair (PH) developed by Tanner (1962), although children and adolescents can more easily identify this sexual characteristic, pubic hair stages were compared with size of breasts stages in girls and size of genitalia in boys because some swimmers may shave the body. In the present study no difference were found between both analyses. Written, informed consent was obtained from subjects and their parents, and ethical approval was granted by the Local Research Ethics Committee (# 121/2010).

Experimental design

Body composition, anthropometrical and sexual maturity parameters were determined in laboratory. Thereafter, following a standard warm-up, in random order and according to the training schedule, participants swam distances of 100 and 400 m at maximum speed, and the Lactate Minimum protocol (LM), using front crawl, in a heated outdoor 50-m pool (25 ± 1°C). For all performances, it was determined the stroke parameters: stroke rate (SR), stroke length (SL) and stroke index (SI).

All tests were performed over 2 weeks with a minimum interval of 48 h between each pool test. Participants were instructed to attend for testing well-rested, well-nourished, and well-hydrated. Participants were also instructed to abstain from caffeine and to refrain from strenuous exercise during this period.

Anthropometry and body composition

Anthropometric measures included body mass (kg), height (cm), and lengths of the right upper (UL) and lower limbs (LL) (cm). All measurements were performed by a single assessor to minimize possible errors. Dual-energy X-ray absorptiometry (DEXA) (DPX-L, LUNAR Corp. Madison, WII, software version 3.6) was used to predict fat mass (g) and lean mass (g), and determine bone mineral content (BMC) (g) and density (BMD) (g·cm^{-2}). The subject and scan positions for whole body analyses were standardized. Subjects were positioned in dorsal decubitus with hand facing down in the center of the scanning area.

Swimming speed corresponding to lactate minimum

The incremental protocol for the determination of LM started after an 8-min recovery period from a maximal performance of 200 m, which was used to elevate the blood lactate level and to determine S200. The incremental phase comprised five progressive performances of 200 m at intensities of about 80%, 84%, 88%, 92%, and 96% of S200, controlled by visual and audible signals, with 1-min intervals for blood sampling out of the pool (Fernandes, Sousa, Machado, & Vilas-Boas, 2011; Ribeiro et al., 2003; Tegtbur, Busse, & Braunmann, 1993).

Earlobe capillary blood samples (25 μL) was collected into a glass tube at the end of each stage of the incremental test and at the third, fifth, and seventh minute after lactatemia induction, during passive recovery, to ensure that there was sufficient increase of lactate concentration. From these samples, blood lactate concentration was subsequently determined by electro enzymatic methods using an automated analyzer (YSI 2300 STAT, Ohio, USA). The speed corresponding to LM was determined for each participant from the blood lactate concentrations (mmol·L-1) and the swimming speed (m·s^{-1}) data obtained from the incremental swimming test. The data were fitted by a second-order polynomial regression curve and the speed corresponding to LM was considered the swimming speed at the minimum point of this curve (Pardono et al., 2008). The higher lactate concentration obtained after lactatemia induction was considered the peak lactate (La$_{peak}$).

Stroke parameters

Stroke parameters were determined during the execution of maximal performances (100, 200, and 400 m); the efforts started in the pool with a pushed off from the side of the pool at an audible beep. The total stroke cycles (SC) were counted and the time (T) taken to complete each distance was recorded using a manual chronometer, thereafter, the mean speed (S) of the 100-m (S100), 200-m (S200), and 400-m (S400) were calculated in m·s^{-1}. The stroke parameters were calculated as follows (Caputo, De Lucas, Greco, & Denadai, 2000; Pelayo et al., 2007):

$$SR = SC / T \text{ (cycles·s}^{-1}\text{)}$$

$$SL = S / SR \text{ (m·ciclo}^{-1}\text{)}$$

$$SI = SL / S$$

Critical speed

CS was determined for 4 distance combinations (CS1 = 100, 200 e 400 m, CS2 = 100 e 200 m, CS3 = 100 e 400 m, e CS4 = 200 e 400 m), using the slope of the linear regression between the swimming distances and time of covering each performance (Toubekis et al., 2011; Wakayoshi et al., 1992).

Statistical analysis

Data are presented as mean ± standard deviation (SD) and were analyzed using the Statistical Package for the Social Sciences 15.0 software (SPSS Inc., USA). The Shapiro-Wilk test was used to check the normality of the data distribution. The mixed analysis of variance (ANOVA) for repeated measures was used to compare the speed and stroke parameters between the 3 distances, LM values and 4 CS combinations, and both genders. Bonferroni adjustment was used for multiple-comparisons analysis. The independent-sample *t* test was used to compare the other variables between the genders. Multiple linear regression (MLR) analysis was used in each group of parameters (anthropometry, body composition, biomechanical, physiological and age/maturation) for both genders, with S100, S200, and S400 as dependent variables; the backward method was used with probability of F as criteria to include ($p<0.05$) or exclude ($p>0.10$) variables in the prediction models. In addition, another MLR analysis for each gender and performance using all the variables entered in each parameter group model was performed to determine the parameters that best explain these performances. Predictive equations for S100, S200, and S400 were generated for each gender using all the parameters entered in the model. The relationships between variables were examined using standard error of estimate (SEE) and statistical significance was set at $p<0.05$.

Results

The mean ± SD descriptive values for anthropometry, body composition, age/ maturation, biomechanical, physiological, and performance parameters are presented in Table 1. The mixed ANOVA for repeated measures indicated significant differences between distances ($p<0.001$) for speed, SR and SI, also significant differences between genders for speed ($p=0.003$), SR ($p=0.014$) and SI ($p=0.035$). The physiological variables (LM, CS1, CS2, CS3, CS4) showed an effect for gender ($p=0.003$), but not for the method of analysis ($p=0.390$). A *post hoc* analysis revealed that in long swimming distances, the SR, speed, and SI values were low for both genders ($p<0.01$). Moreover, the male swimmers presented higher values for speed, physiological parameters, and SI than did the female swimmers ($p<0.01$).

Tables 2 and 3 show the MLR parameters for each group of parameters. Among all the variables entered in the model, the biomechanical variables per se best explain S100 (99.7%) for males, and S100 (98.3%) and S200 (98.3%) for females, whereas the physiological variables best explain S200 (99.2%) and S400 (99.7%) for males, and S400 (99.2%) for females.

Considering all variables for males, the explanatory power for S100 was 99.9%, 99.7% for S200 and 99.9% for S400; the generated predictive equations for this gender are shown below:

Table 1. Mean ± Standard Deviation (SD) of independent variable groups: anthropometrical, body composition, biomechanical, physiological and age/maturation; and speeds as dependent variables for male and female swimmers.

Variable group	Variable	Male (n=17)	Female (n=16)
Anthropometrical	Body mass (kg)	53.947 ± 13.616	48.707 ± 8.662
	Stature (cm)	161.120 ± 11.806	154.930 ± 8.986
	UL (cm)	74.500 ± 6.768	71.567 ± 5.421
	LL (cm)	85.488 ± 4.904	85.000 ± 6.495
Body composition	Lean mass (g)	41413.120 ± 11225.240*	34383.670 ± 6058.702
	Fat mass (g)	9468.588 ± 5004.469	10861.200 ± 3439.935
	BMC (g)	2127.247 ± 579.699	1931.153 ± 385.622
	BMD (g·cm^{-2})	1.052 ± 0.104	1.042 ± 0.076
Biomechanical	SR100 (cycles·s^{-1})	0.675 ± 0.052*	0.589 ± 0.054
	SR200 (cycles·s^{-1})	0.582 ± 0.060[a]	0.540 ± 0.068[a]
	SR400 (cycles·s^{-1})	0.541 ± 0.050[ab]	0.508 ± 0.063[ab]
	SL100 (m·ciclo^{-1})	2.048 ± 0.294	2.041 ± 0.265
	SL200 (m·ciclo^{-1})	2.180 ±0.419[a]	2.024 ± 0.348
	SL400 (m·ciclo^{-1})	2.201 ± 0.434[a]	2.023 ± 0.373
	SI100	2.879 ± 0.800	2.445 ± 0.502
	SI200	2.793 ± 0.874*	2.197 ± 0.520[a]
	SI400	2.661 ± 0.877[ab]*	2.071 ± 0.546[ab]
Physiological	LM (m·s^{-1})	1.106 ± 0.129*	0.982 ± 0.077
	La$_{peak}$ (mM)	6.639 ± 1.962*	4.960 ± 1.873
	CS1 (m·s^{-1})	1.121 ± 0,187*	0.958 ± 0.107
	CS2 (m·s^{-1})	1.165 ± 0.158[c]*	0.989 ± 0.079
	CS3 (m·s^{-1})	1.125 ± 0.184*	0.961 ± 0.104
	CS4 (m·s^{-1})	1.108 ± 0.200*	0.950 ± 0.118
Age/maturation	CA (y)	13.559 ± 2.346	13.179 ± 2.255
	PH	3.59 ± 1.004	3.600 ± 1.056
Speeds	S100 (m·s^{-1})	1.381 ± 0.215*	1.195 ± 0.109
	S200 (m·s^{-1})	1.255 ± 0.178[a]*	1.075 ± 0.092[a]
	S400 (m·s^{-1})	1.180 ± 0.190[ab]*	1.010 ± 0.105[ab]

Note. S = speed; UL = upper limbs; LL = lower limbs; BMC = bone mineral content; BMD = bone mineral density; SR = stroke rate; SL = stroke length; SI = stroke index; LM = lactate minimum; CS = critical speed; CA = Chronological age. *$p<0.05$ compared to female group; [a]$p<0.05$ compared to 100 m; [b]$p<0.05$ compared to 200 m; [c]$p<0.05$ compared to LM.

Table 2. Multiple linear regressions to determine the group of parameters (i.e., anthropometrical, body composition, biomechanical, physiological, age/maturation, all variables) that best predict 100, 200 and 400 m performances in boys.

Group	Variables	Speed	Variables entered in model	R^2	Adjusted R^2	SEE
Male	Anthropometrical	S100	Stature, UL, LL	0.772	0.719	0.114
		S200	Stature, UL, LL	0.804	0.759	0.088
		S400	Body mass, UL	0.763	0.729	0.099
	Body composition	S100	Lean mass	0.784	0.770	0.103
		S200	Lean mass, BMC	0.853	0.832	0.073
		S400	Lean mass	0.743	0.726	0.099
	Biomechanical	S100	SR100, SI100	0.997	0.997	0.012
		S200	SL200, SI200	0.985	0.982	0.024
		S400	SR400, SI400	0.988	0.986	0.023
	Physiological	S100	LM, CS2, CS3, CS4	0.951	0.935	0.055
		S200	LM, CS2, CS3, CS4	0.992	0.990	0.018
		S400	LM, CS2, CS4	0.997	0.997	0.011
	Age/maturation	S100	CA	0.762	0.747	0.108
		S200	CA	0.801	0.788	0.082
		S400	CA	0.740	0.723	0.100
	All variables	S100	LL,UL, Lean mass, SI100, SR100	0.999	0.999	0.007
		S200	LL, BMC, SL200, SI200, CS4	0.997	0.996	0.011
		S400	Body mass, lean mass, CS2, CS4, CA	0.999	0.998	0.008

Note. S = speed; UL = upper limbs; LL = lower limbs; BMC = bone mineral content; SR = stroke rate; SL = stroke length; SI = stroke index; LM = lactate minimum; CS = critical speed; CA = chronological age.

S100 = - 0.008 * [(-9.20 * Lean mass) + (1.014 * SR100) + (0.281 * SI100) + (0.002 * LL) - (0.003 * UL)]

S200 = 1.143 * [(-0.002 * LL) - (2.70 * BMC) - (0.421 * SL200) + (0.363 * SI200) + (0.227 * CS4)]

S400 = 0.065 * [(-0,001 * Body mass) + (3.21 * Lean mass) + (0.289 * CS2) + (0.692 * CS4) - (0.004 * CA)]

For females, the explanatory power was 98.2% for S100,

Table 3. Multiple linear regressions to determine the group of parameters (i.e., anthropometrical, body composition, biomechanical, physiological, age/maturation, all variables) that best predict 100, 200 and 400 m performances in girls.

Group	Variables	Speed	Variables entered in model	R^2	Adjusted R^2	SEE
Female	Anthropometrical	S100	Stature, UL	0.408	0.317	0.916
		S200	Stature, UL	0.406	0.315	0.075
		S400	Stature, UL	0.525	0.452	0.078
	Body composition	S100	Lean mass, Fat mass	0.524	0.445	0.081
		S200	Lean mass, Fat mass	0.439	0.345	0.074
		S400	Lean mass, Fat mass	0.357	0.250	0.091
	Biomechanical	S100	SR100, SL100	0.983	0.981	0.015
		S200	SL200, SI200	0.983	0.980	0.013
		S400	SL400; SI400	0.980	0.977	0.016
	Physiological	S100	LM, CS3	0.816	0.788	0.051
		S200	LM, CS3, CS4	0.950	0.938	0.022
		S400	LM, CS3	0.992	0.991	0.010
	Age/maturation	S100	-	0	0	0.111
		S200	-	0	0	0.090
		S400	-	0	0	0.105
	All variables	S100	SR100, SL100	0.982	0.978	0.016
		S200	SL200, SI200, LM	0.988	0.985	0.011
		S400	Lean mass, SL400, LM, CS3	0.998	0.997	0.006

Note. S = speed; UL = upper limbs; LL = lower limbs; BMC = bone mineral content; SR = stroke rate; SL = stroke length; SI = stroke index; LM = lactate minimum; CS = critical speed.

98.8% for S200 and 99.8% for S400 by the variables presented in the predictive equations below:

$$S100 = -1.122 * [(1.973 * SR100) + (0.566 * SL100)]$$

$$S200 = 0.886 * [(-0.495 * SL200) + (0.460 * SI200) + (0.183 * LM)]$$

$$S400 = -0.29 * [(6.43 * Lean\ mass) + (0.023 * SL400) + (0.165 * LM) + (0.839 * CS3)]$$

Discussion

The objective of the present study was to determine the group of parameters that best predict short and middle swimming distance performances of young swimmers of both genders. The main results revealed that when all the variables were considered in the prediction models, the male swimmers always had more variables included than the female swimmers did. Furthermore, the biomechanical variables *per se* best predicted S100 for both genders and S200 for females, whereas the physiological variables best predicted S400 for both genders and S200 for males.

Differences between genders were expected for some variables, primarily because most of the subjects were already in puberty (Armstrong & Mcmanus, 2011; Mcmanus & Armstrong, 2011). Other studies also demonstrated better performance and higher physiological and biomechanical parameter values in males than in females but higher fat mass in females than in males (Geladas et al., 2005; Greco & Denadai, 2005; Saavedra et al., 2010; Zuniga et al., 2011); however the differences in performance predictors between genders are not totally clear.

The present study demonstrated that when considering only biomechanical variables as predictors of S200, both genders had the same variables entered in the model; otherwise, the variables in each MLR analysis were not the

same, with a tendency for the males to have a higher number of parameters in each model than the females. Considering only "all variables" MLR models (Table 2 and 3), it was noted that even with the explanatory power being close to 100% for both genders in all the performances, the males required more variables to be included in each model, using all the independent groups for S100, S200, and S400 predictions, whereas the females required only 3 groups of parameters (body composition, physiology and biomechanical).

Few studies comparing performance prediction between genders primarily used anthropometric and body composition variables, indicating a negative influence of fat mass for young female sprint swimmers (Zuniga et al., 2011) and a positive influence of body size for both genders in short-distance swimming performance (Geladas et al., 2005). The same results were obtained in the present study, except that in addition to the negative influence of fat mass, for females, lean mass was also identified as a positive and important performance predictor; and for the males, bone components, probably representing the growth process, were also entered in the models.

Saavedra et al. (2010) developed a method of multivariate analysis to predict the performance of young swimmers based on multidimensional assessments. Among other non-specific tests as questionnaires and ground fitness tests, CA and a 30-minute test results were introduced into the models of both genders, and technique was entered in the male model. Despite presenting physiological and biomechanical representations in the prediction models, the objective of Saavedra et al. (2010) study was not to compare between the genders since CA was significantly different between males (13.6 ±0.6 years) and females (11.5 ± 0.6 years), possibly representing maturational and chronological differences.

In the literature, more data have been presented for male-

only studies. Lätt et al. (2010) evaluated biomechanical, anthropometrical, and physiological parameters as predictors of S100 in male adolescent swimmers (15.2 ± 1.9 years) and found that SR and SI were optimal for predicting performance (93.6%). These variables were also entered in our model, along with lengths of the LL and UL, and lean mass, with 99.9% of explanatory power. These differences possibly occurred in the chronological age function because the subjects in the present study comprised children and adolescents at several maturity stages, thus increasing the influence of natural body size and composition modifications.

Similarly, Vitor and Böhme (2010) also found SI to be an S100 predictor, along with CS and anaerobic power, in a MLR model (R^2=0.90; SEE=0.03) for male pubescent swimmers aged 12 to 14 years. Similarly to the present study, maturity and age probably influenced the results because of the anaerobic system maturation period (Armstrong & Mcmanus, 2011).

For all swimming distances performances, particularly for the middle and long distance swimming performances, aerobic capacity has a great influence, with an explanatory power of up to 95% for S100 and up to 99% for S200 and S400 in the present study. This was also demonstrated by Vitor and Böhme (2010) using only CS (R^2=0.34 for S100), highlighting this method as an easy and non-invasive manner of aerobic capacity evaluation (Greco & Denadai, 2005; Toubekis et al., 2011).

Previous studies with age-specific subjects and the data from the present study of children and adolescents provided evidence that in an aquatic environment the technique is important (Jürimäe et al., 2007; Lätt et al., 2010; Pelayo et al., 2007; Saavedra et al., 2010; Vitor & Böhme, 2010), and emphasized that experience (years) is a factor influencing its improvement as well, especially in youngsters, with an increase in body size (Grimston & Hay, 1986; Lätt et al., 2009). In addition, taller swimmers have the advantages of greater SL and consequently lower SR at any distance, thus improving their biomechanical pattern (represented by SI) (Jürimäe et al., 2007; Pelayo, Sidney, Kherif, Chollet, & Tourny, 1996; Wakayoshi, D'Acquisto, Cappaert, & Troup, 1995; Zamparo et al., 2008).

Furthermore, a larger lean mass volume could also positively influence biomechanical values by enhancing the force applied in each stroke and the capacity to maintain good SI under exhaustion conditions (Alberty, Sidney, Huot-Marchand, Hespel, & Pelayo, 2005; Pelayo et al., 1996; Wakayoshi et al., 1995). Therefore, although anthropometrical and body composition parameters could not predict performance as well as physiological and biomechanical parameters, they are closely related and influence each other, as evident in each "all variables" MLR model, in which the anthropometrical and body composition parameters were entered in all the male models, and in the S400 female model.

Conclusion

Coaches must be aware of genders specific needs and different distance specialties of young swimmers, given that for short and middle distance events, males and females presented different performance predictors. The biomechanical variables per se best explain S100 (99.7%) for the males, and S100 (98.3%) and S200 (98.3%) for the females, whereas the physiological variables best explain S200 (99.2%) and S400 (99.7%) for the males, and S400 (99.2%) for the females. A prediction power of almost 100% was noted when considering all the variables in the MLR models; however, due to the greater complexity observed in males, they required a larger number of variables entered into the models than the females did.

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