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ORIGINAL ARTICLE

What variables determine sprint performance in young athletes?

Quelles variables déterminent la performance en sprint chez les jeunes athlètes ?

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KEYWORDS
Running;
Track and field;
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Summary
Objectives. — To identify sprint performance determinants in young athletes in the field in both sexes.
Equipment and methods. — Two hundred and fourteen track and field athletes, ages between 13 and 15 years old, were divided into validation group (VG) ($n = 163$) and cross-validation group (CVG) ($n = 51$). The participants were submitted to biological maturity evaluation, anthropometry, vertical jump, 60-m sprint, and running anaerobic sprint test (RAST).
Results. — The multiple regression analysis selected the variables leg length, vertical jump, RAST total time (RASTtt) and fatigue index for both groups, determined 95.5% and 76.9% of sprint performance on boys and girls, respectively. To confirm our results, we performed a cross-validation on the linear regression, which showed that the measured and predicted sprint performances in CVG were not significantly different ($P > 0.05$). In addition, the study demonstrated that biological maturity is associated with all variables of the model ($P < 0.05$).

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Conclusion. — The variables leg length, vertical jump, RASTtt and fatigue index explain in different proportions sprint performance in young boys and girls athletes. In addition, this study add to knowledge of researchers and coachers, indicating which variables should be part of the training program of young athletes sprint runners.

MOTS CLÉS
Course ;
Athlétisme ;
Métabolisme anaérobie ;
Entraînement

Résumé
Objectif. — Identifier les déterminants de la performance en sprint chez les jeunes athlètes, en fonction du sexe.
Méthodes. — Deux cent quatorze athlètes âgés de 13 à 15 ans ont été divisés en groupe de validation (VG) (n = 163) et en groupe de validation croisée (CVG) (n = 51). La composition corporelle, la maturité biologique, la détente verticale, ainsi que les performances lors d'un sprint de 60 m et lors d'un test de sprint anaérobie (RAST) ont été évaluées.
Résultats. — La durée totale de RAST (RASTtt), l'indice de fatigue, la détente verticale, et la longueur des jambes déterminaient 95,5 % de la performance en sprint des garçons, contre 76,9 % pour les filles. Pour confirmer nos résultats, nous avons effectué une validation croisée qui a démontré que les performances en sprint mesurées et prédites dans le groupe CVG n'étaient pas significativement différentes. En outre, l'étude a démontré que la maturité biologique était associée à toutes les variables du modèle.
Conclusion. — Les variables RASTtt, l'indice de fatigue, la détente verticale, et la longueur des jambes expliquent dans des proportions différentes la performance en sprint des jeunes athlètes masculins et féminins. De plus, cette étude apporte des connaissances aux chercheurs et entraîneurs, permettant d'indiquer quelles variables pourraient être prises en considération pour l'entraînement des jeunes sprinters.

1. Abbreviations

VG	validation group
CVG	cross-validation group
RAST	running anaerobic sprint test
RASTtt	total time in running anaerobic sprint test
SEE	standard error estimation

2. Introduction

The determinant factors of sprint running performance in young athletes have already been investigated. For example, a previous study described biological maturity, vertical jump and anaerobic metabolism variables as key points for enhanced performance in Wingate test, in both amateur athletes and professionals in gymnastics, handball, swimming, and tennis [1]. In track and field, previous study demonstrated that variables derived from the running anaerobic sprint test (RAST) (minimum, mean, maximum power; fatigue index) were relevant for performance in 100, 200, and 400-m running [2]. Another study also demonstrated that anaerobic metabolism was a determinant for men and women in 79% and 72% for 100-m, and 75% and 67% for 200-m, respectively [3]. Given this, it is necessary that a performance test for anaerobic metabolism be considered, especially for the assessment of anaerobic capacity. However, to our knowledge, there are no studies with young athletes in track and field that described how these variables interact in the determination of performance in sprint running. In addition, biological maturity was also a consideration for the analysis of this age group.

Biological maturity is characterized by considerable physical and biological changes that determine anthropometric, physiological, and physical performance, and usually occurring between the ages of 13 and 15 for boys and between 12 and 14 for girls [4]. The influence of biological maturity causes, for example, changes in body composition, such as increased muscle strength/power in boys and body fat in girls, as well as a significant increase in height and length of the lower and upper limbs in both sexes [5,6].

Recent research with young track and field athletes (13—15 years) showed that beyond the traditional variables such as peak aerobic speed (achieved in a maximal incremental test) and anaerobic metabolism (assessed using RAST), the biological maturity explained 0.9% ($P < 0.05$) of performance in an 800-m event [7]. In addition, vertical jump is another relevant variable for sprint running performance. Previous studies have shown that qualitative changes in muscle structure and function increase the vertical forces and power production capacity, thus enhancing sprint performance [5,8]. Collectively, the metabolism anaerobic, biological maturity and vertical jump and have a close relationship with sprint running performance in young athletes.

Although separate studies have shown that biological maturity, vertical jump, and anaerobic metabolism influence sprint running performance, the interaction among these variables in young athletes has not been fully elucidated. In addition, this study can add to knowledge of researchers and coachers, indicating which variables should be part of the training program of young sprinters. Therefore, the objective of the present study was:

- to identify determinant variables in young sprinters in track and field for both sexes and;
- analyze if the model of prediction is reliable for other groups of young athletes.

3. Materials and methods

3.1. Participants

Two hundred and fourteen track and field athletes were selected to participate in the study. The participants were randomly divided into a validation group (VG, $n = 163$; 83 boys and 80 girls) and a cross-validation group (CVG, $n = 51$; 27 boys and 24 girls); all participants were from track and field teams listed with the Brazilian Track and Field Confederation. None of the participants had been receiving any pharmacological treatments nor had any kind of neuromuscular or cardiovascular disorder, respiratory, or circulatory dysfunction. The participants were instructed to avoid foods containing caffeine, refrain from any exhaustive exercise during the previous 24 hours, to follow the same diet and not eat two hours before the experimental session. All participants and their respective guardians received a verbal explanation about the potential benefits, risks, and discomfort associated with this study. Each was asked to have written informed consent from their parents or responsible adult before participating in the study. All procedures were approved by Human Studies Ethics Committee (566.839—2014) and were performed in accordance with the ethical standards established by the Declaration of Helsinki [9]. The authors declare that they have no competing interest.

3.2. Experimental approach to the problem

The present study was based on a cross-sectional design, where the whole protocol took place on a single day of data collection (Fig. 1). The study was conducted by means of a questionnaire, anthropometric measurements, and physical tests. A questionnaire about the parents' current height had been sent to them beforehand to be answered. After filling out the questionnaire, the participants were instructed to do five minutes of light running (between 8 and 10 km.h^{-1}), followed by three 20-m at maximal sprint running. In addition, the athletes performed 10 minutes of stretching, according to the instructions given by researchers. The athletes participating in the study were assessed for their anthropometric measurements, vertical jump, 60-m sprint and RAST test. The running tests were performed on an official track of 400-m.

3.3. Procedures

The percentage of predicted mature stature was used to estimate biological maturity which is based on decimal age, athletes' anthropometric measurements (weight and height), and mean height of their respective biological parents. Previous studies have used and suggested that the percentage of predicted mature stature is an effective method for estimating biological maturity [10,11]. The equation for calculated of predicted mature stature use specific values of intercepts and coefficients for height and body mass of the athlete, in addition to the average height of the parents. For detailed information, see the studies by Khamis and Roche [10,11]. The percentage of predicted mature stature expresses the stature that athletes are likely reach at adulthood. The percentage of predicted mature stature obtained by the following equation:

$$\text{The percentage of predicted mature stature} = 100 \times (\text{current height}/\text{predicted mature stature}) \quad \text{(Eq.1)}$$

Then, the participants were weighed to an accuracy of 0.1 kg using an electronic balance (Filizola, model ID 1500, São Paulo, Brazil). The height was measured with 0.1 cm precision using a stadiometer portable (Welmy, W200/5 model, Santa Bárbara d'Oeste, Brazil). The skinfold was measured to a precision of 0.1 mm on four places of the body, being subscapular, supra iliac, triceps, and leg, using an adipometer (Sanny®, Model Classic Scientific, São Bernardo do Campo, Brazil), where the sum of skinfold was used of reducing the equations errors for specific group. The sitting height measurement was calculated using a stadiometer with a ''Sitting Height Table''', on which the participant must be correctly seated, that is, with a straight column and the head positioned in the horizontal plane of ''Frankfurt''. The leg length was estimated from the difference between standing height and seated height.

Vertical jump was measured by countermovement jump test using a Cefise jump platform (CEFISE, Jump system Model, Nova Odessa, Brazil). In the vertical position, the athletes took the position with parallel feet at a comfortable distance between them, without flexing the knees and with their hands on the low waist (bi-iliocostal line). When the evaluator told them to start, they bent their knees 90° and then extended to full body posture quickly to perform a full jump, without removing their hands from their waist. To clarify, a demonstration was given by researchers. Jumping heights (cm) were calculated automaticaly by the jump platform [12]. Previous studies shown that the measures in countermovement jump have higher reliability in the evaluation of muscle power [13]. Three trials were made with a rest interval of 30 s between jumps. The best score was used for statistical analysis.

For the performance test, the athletes ran alone as fast as possible for a distance of 60-m, starting from a stopped, standing position. The running was performed twice with an interval of 10 minutes between trials. To measure the time, an electronic timekeeping device (CEFISE, Speed Test Fit Model, Nova Odessa — Brazil) was used, composed of two photocells sensitive to the movement. The counting time started with the passage of the athlete in front of the first

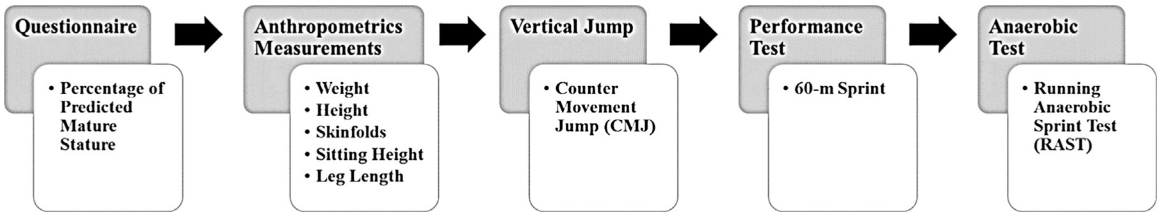

Figure 1 Design of the study.

photocell and completed with the athlete's passage by the second device positioned at the end of the running zone.

The RAST is an easy field test to apply, to evaluate the athletes' anaerobic metabolism. This test was composed of 6 maximum sprints of 35-m with 10 seconds of passive recovery between each sprint [14]. An electronic counting instrument (CEFISE, Speed Test Fit Model, Nova Odessa — Brazil) was used to determine sprint time during the test. The time began to count when the participants passed by the first cell and time was completed with their passing by the device positioned at the end of the running zone. The athletes received verbal encouragement throughout the test. This protocol has been widely used with healthy children and adults [7,15,16], presenting scientific validity, viability, and practicality for the anaerobic metabolism test [17]. All running performances were recorded the values minimum, mean, maximum power and fatigue index was considered for analysis. For the percentage fatigue index, the following equation was used:

$$\text{Fatigue index \%} = (\text{highest time} - \text{lowest time})/\text{lowest time} \times 100 \quad (\text{Eq.2})$$

3.4. Statistical analyses

The participants were characterized by descriptive statistics (mean and standard deviation). The parametric assumptions of normality were evaluated by the Kolmogorov-Smirnov test. When the sample distribution assumptions had been met, the descriptive variables were compared between the sexes with Student *t*-test for independent samples and with the Mann-Whitney test for the non-parametric data. As a criterion of selection of the independents variables that integrated the predictive model, a minimum association (*r* value) of 0.60 was established with the dependent variable (60-m). To test which variables determined the performance in a sprint running, the multiple linear regression model (stepwise) was used, considering as the dependent variable the total time taken in a 60-m sprint, and the followed by these independent variables: age, biological maturity, body mass, sum of skinfold, leg length, vertical jump, RASTtt and fatigue index. Then, the measured variables for the CVG were compared with the predicted values by an equation for each sex, using the Student *t*-test for paired measures. Person's linear correlation was used to verify the associations between measures and CVG prediction values. From this correlation, the R^2 was calculated, to estimate the reduction of the validity of the prediction equation [18]. To test the possible associations between biological maturity with selected variables in the regression model, the Spearman test was used. All analyses had a 95% ($P < 0.05$) level of significance.

4. Results

The descriptive data of both sexes and groups of athletes are showed on Table 1. Comparing sexes, we demonstrated that age, fatigue index, and body mass (only in the CVG) did not produce statistical differences ($P > 0.05$). On the other hand, for the biological maturity parameter, on mean, the girls were closer to their predicted mature stature. When variables of VG and CVG were compared, there was no significant difference ($P > 0.05$), indicating that the CVG corresponded to the larger samples (VG), allowing cross-validation of the determinant variables in the 60-m sprint.

The regression analysis selected the leg length, vertical jump, RASTtt and fatigue index for boys and girls. Together, those variables indicated performances of 95.5% for boys, and 76.9% for girls. Fig. 2 shows the contribution values of each variable for the mathematical model, emphasizing that, for boys, the RASTtt seemed to be of greater importance on performance.

For the prediction equations generated by a mathematical model for boys (Eq. 3) and girls (Eq. 4), the *P*-value, determination coefficient (R^2) and the standard error estimation (SEE) are shown below.

$$60\,\text{m sprint boys} = 2.535 + (0.225 \times \text{RASTtt}) - (0.021 \times \text{fatigue index}) - (0.014 \times \text{vertical jump}) - (0.011 \times \text{leg length}).R^2 = 0.95;\ \text{SEE} = 0.23 \quad (\text{Eq.3})$$

$$60\,\text{msprint girls} = 3.310 + (0.222 \times \text{RASTtt}) - (0.024 \times \text{\%fatigue index}) - (0.020 \times \text{vertical jump}) - (0.018 \times \text{leg length}).R^2 = 0.77;\ \text{SEE} = 0.37 \quad (\text{Eq.4})$$

Fig. 3 shows the residue analysis for boys (Fig. 3a) and girls (Fig. 3b).

Since the residue analyses only found 4/83 (4.8%) and 2/80 (2.5%) outliers, we took a great deal of methodological care to proceed with the cross-validation analysis to confirm the results observed in the predicted model. Table 2 presents the measured and predicted results from the 60-m sprint, *t*-test, correlation (*r*), R^2, and SEE on CVG. These results agreed strongly ($P < 0.01$, $R^2 = 0.93$, SEE = 0.28 for boys; $P < 0.01$, $R^2 = 0.89$, SEE = 0.31 for girls).

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Table 1 Descriptive characteristics and performance test on validation group (VG) and cross-validation group (CVG).

	Validation group (VG)			Cross-validation group (CVG)		
	Boys ($n = 83$)	Girls ($n = 80$)	*P*-value	Boys ($n = 27$)	Girls ($n = 24$)	*P*-value
Age (years old)	14.01 ± 1.13	14.04 ± 0.88	0.89	13.91 ± 1.10	13.89 ± 0.95	0.95
Body mass (kg)	53.07 ± 13.65	48.95 ± 7.88[a]	0.02[b]	50.00 ± 13.04	46.66 ± 6.75	0.27
Sum of skinfold (cm)	33.15 ± 14.91[a]	41.98 ± 12.21[a]	0.00[b]	30.38 ± 13.74[a]	41.09 ± 10.03	0.00[b]
Leg length (cm)	81.64 ± 6.12	76.47 ± 5.16	0.00[b]	81.63 ± 7.85	74.82 ± 4.14	0.00[b]
RASTtt (s)	35.82 ± 4.37[a]	38.03 ± 2.71	0.00[b]	35.70 ± 3.63	38.78 ± 3.14	0.00[b]
Vertical jump (cm)	33.06 ± 6.89	28.20 ± 5.60	0.00[b]	34.96 ± 6.57	27.49 ± 7.37	0.00[b]
Fatigue index (%)	15.44 ± 6.63	16.63 ± 6.56	0.25	17.21 ± 6.83	16.89 ± 6.43	0.87
Biological maturity (%)	92.59 ± 4.37[a]	96.96 ± 2.10[a]	0.00[b]	92.24 ± 5.24	96.09 ± 2.29	0.00[b]
60-m sprint (s)	8.88 ± 1.09[a]	9.38 ± 0.77[a]	0.00[b]	8.75 ± 1.01[a]	9.59 ± 0.89	0.00[b]

P-value: student *t*-test for independent samples (parametric data) or Mann-Whitney (non-parametric data).
[a] Variable with non-normal distribution.
[b] $P < 0.05$.

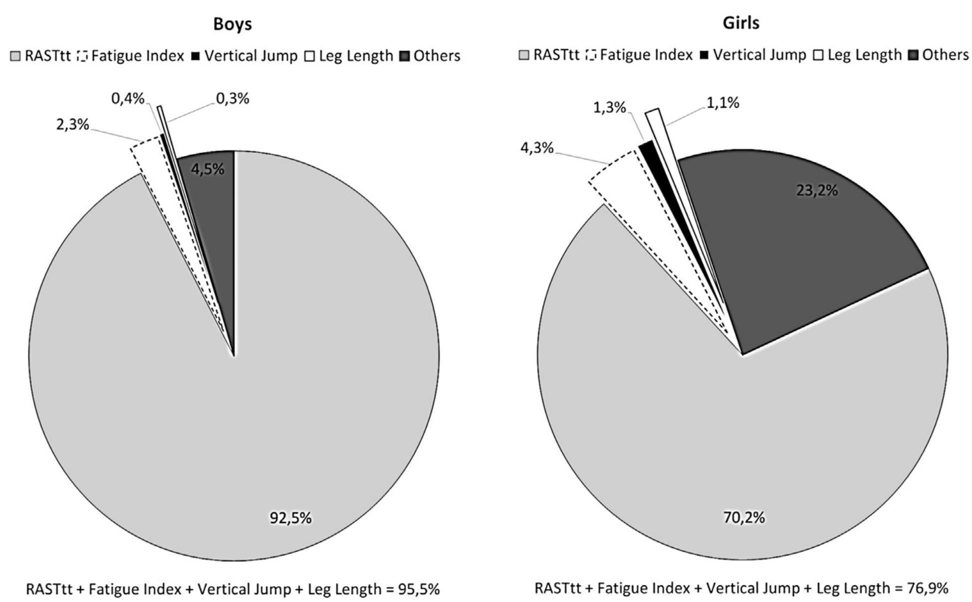

Figure 2 Percentage contribution of the determinants factors on young sprinters.

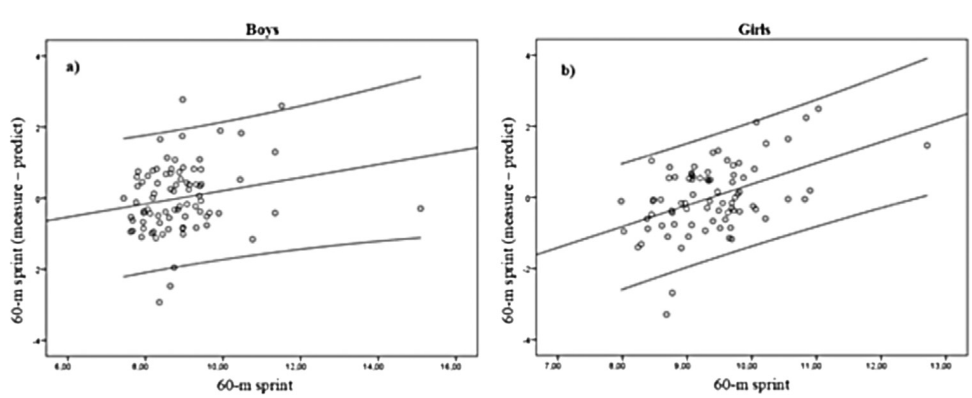

Figure 3 Residues between the measured and predicted values of time 60-m from the equation with the 163 individuals of the CV. a: boys; b: girls.

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Table 2 Measured and predicted values of boys and girls on CVG.

Variable	Mean ± SD (s)	*T*	R	R^2	SEE
Boys					
60-m measure CVG	8.75 ± 1.01	0.56	0.96[a]	0.93	0.28
60-m predict CVG	8.71 ± 0.94				
Girls					
60-m measure CVG	9.59 ± 0.89	0.56	0.94[a]	0.89	0.31
60-m predict CVG	9.63 ± 0.84				

T: student *t*-test; R: correlation; R^2: coefficient of determination; SEE: standard error of estimation.
[a] $P < 0.01$.

Table 3 Values of the correlation coefficient of the biological maturity parameter on performance.

	Boys (83)	Girls (80)
	Biological maturity (%)	
60-m sprint (s)	−0.43[b]	−0.62[b]
Fatigue index (%)	0.22[a]	0.25[a]
Vertical jump (cm)	0.31[b]	0.48[b]
Leg length (cm)	0.45[b]	0.62[b]
RASTtt (s)	−0.35[b]	−0.55[b]

[a] $P < 0.05$.
[b] $P < 0.01$.

As previously suggested, biological maturity has an influence on physical and performance variables ($P < 0.05$). Person's linear correlation was used to verify the associations between measured and predicted values for VG. Table 3 shows the values observed in the correlation analyses between biological maturity with 60-m sprint and those selected in the prediction model for the group VG. There was a statistically significant association ($P < 0.05$) of the biological maturity parameter with predicted variables in boys and girls, demonstrating that although biological maturity was not indicated by the model, it still has an effect on sprint running through the variables that are influenced by it.

5. Discussion

Our findings indicate that anthropometrics and functional test results (vertical jump, RASTtt, and 60-m sprint) were different between the sexes. For the biological maturity parameter, on mean, the girls were closer to their predicted mature stature when compared to the boys. A regression analysis selected the variables leg length, vertical jump, RASTtt and fatigue index to both groups, and all together these were the determinants in 95.5% and 76.9% of boys and girls sprinters performance, respectively. There was a significant correlation between the biological maturity and the variables selected by the regression model (leg length, vertical jump, RASTtt and fatigue index), thus indicating, in general, that biological maturity has an influence on the 60-m sprint performance predictors.

The values measured and predicted by the regression model for both sexes were closely associated in the CVG for boys and girls (0.93; 0.89, respectively). This comparison of the R^2 of the proposed equation with that generated by the association between the predicted and measured values expresses the degree of reduction, indicating to what extent validity can be affected by the use of an external sample [18]. Thus, it can be inferred that the CVG closely represented the VG, and the results can be represented by an equation proposed by the regression model, with a satisfactory estimation of the determinant variables in sprint running.

In the present study, the high contribution of the RASTtt for boys (92.5%) and girls (70.2%) is in agreement with other investigations. In addition, previous study demonstrated that anaerobic metabolism has a strong correlation with running performance times at distances of 100 and 400-m and moderate correlation with 800-m [19]. Therefore, RASTtt can be considered a useful tool for anaerobic evaluation in field tests [14,15]. Additionally, a recent study used the same tool to evaluate the anaerobic capacity of young track and field athletes (13—15 years old) [7]. The other variables determining the sprint running in both sexes were leg length, vertical jump and fatigue index.

For vertical jump, studies have shown that an increase in this variable significantly influences sprint in collegiate athletes ($P < 0.01$) and children of both sexes ($P < 0.05$) [20]. This result can be justified by increase of elastic energy generation capacity on the muscle [21]. In addition, another variable that is integral to the model is leg length. Previous studies have shown that anthropometric characteristics, such as height and length of segments are common in talented athletes and influential in sports performance [22].

Regarding the variable fatigue index, previous study found that the difference in lean body mass, body fat, anaerobic strength, and power can cause changes in the fatigue index between the sexes, as demonstrated in our study, in which boys and girls presented values of 2.3% and 4.3%, respectively [23]. In addition, studies have shown higher muscle volume (consequently higher stocks of energy substrates for anaerobic metabolism), greater circulating concentration of testosterone, greater number of fast contracting fibers, greater activity of the glycolytic enzymes (phosphofructokinase, phosphorylase, and lactate dehydrogenase), and a higher concentration of blood lactate in adults when compared to children [24]. Despite this difference between adult and children, the variables are part of the predictive model for both sexes. Moreover, this difference can be explained by the development of the glycolytic metabolism so that the athletes with the highest biological maturity are able to achieve faster sprint time in the test. In contrast, the byproducts of the anaerobic metabolism generate a drop in performance and thus there are higher values for fatigue index.

Finally, the association between biological maturity and the determinants of performance in the 60-m sprint, for both sexes, were observed. The participants with advanced biological maturity had longer leg length and performed better in the vertical jump, 60-m sprint, and RASTtt test. The justification for these findings is due to biological maturity that causes considerable changes in the physical characteristics of the young [6,25—27]. These changes caused by biological maturity cause significant differences between the sexes, as demonstrated by previous study, which showed that boys present greater increases in their anthropometric and physical profiles as they get older when compared to girls [28]. Therefore, it is recommended that groups be evaluated separately.

The practical applications of this study provide a successful prediction of performance in anaerobic activities with the regression model, allowing researchers to use practical tools with scientific validity to predict the performance of young athletes. The methodological care taken in this study was important: the tests for functional and maturational evaluation were carefully selected to represent reliably the determinant variables in sprint running. In addition, the performances of a large number of young athletes were considered for GV (n = 163) and GVC (n = 51) analysis to ensure our findings. Our results also suggest that biological maturity needs to be constantly monitored, because of its influence on performance and physical changes. Despite the ease of real evaluation of the 60-m sprint running when compared to the predictive model, our results indicated which variables should be part of the training program of young athletes, thus helping, researchers and coaches of this sport.

Some limitations should be highlighted in this study. The distribution of adipose tissue is irregular over the whole body, particularly between girls and boys. We do not have been taken into account the folds measured on other areas of the body, such as quadriceps and umbilical. However, we believe that this did not impact our findings, since we used the sum of skin folds that were specifically selected and validated for of young athletes. The distance considered in our study was the 60-m sprint. This distance was considered because is used in official competitions for young athletes by Brazilian Track and Field Federation. Therefore, we suggested caution when extrapolating our results to adult athletes.

6. Conclusion

In summary, leg length, vertical jump, RASTtt and fatigue index variables can explain, in a different ratio, performance in sprint running for young athletes of both sexes. Although biological maturity did not form part of the prediction model, it is must also be considered as it had a significant impact on all prediction variables. The regression model satisfactorily estimated the determinant variables in sprint running with young athletes of both sexes.

Disclosure of interest

The authors declare that they have no competing interest.

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