



Influence of sexual maturation, chronological age and growth indices in lactate threshold and performance in the 20 minutes running*

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ABSTRACT

Children and adolescents present less blood lactate concentrations ([la]) than adults under certain loads. It is suggested that these differences are related to maturational aspects. The aim of this study was to verify the influence of sexual maturation, chronological age and growth indices (body weight, height and sum of two skinfolds – subscapular and triceps) over the lactate threshold velocity, in the fixed lactate concentration of 2.5 mmol.l⁻¹ (V_{2,5}) and in the 20 minutes running (V₂₀). Thirty-three boys, aged 13-15 years, who practice different sports were submitted to: 1) anthropometrical and sexual maturation evaluations through the Tanner index (sexual maturation of genitals and pubic hair); 2) progressive discontinuous test (3 x 800 m in running track) to determine V_{2,5}; and 3) 20 minutes running test to determine the V₂₀ and final blood [la]. There were no associations between V_{2,5} and sexual maturation, neither chronological age nor growth index. As the only association verified was between V₂₀ and height (r = 0,41; p < 0,05), the authors conclude that during adolescence other performance, physiological and/or biomechanical variables may play a greater role in lactate threshold and in the 20 minutes running than the growth variables.

INTRODUCTION

Historically, the oxygen maximum consumption ($\dot{V}O_2$ max) is used as a performance determining factor in the medium and long duration competitions of children and adolescents. However, some studies have shown that the $\dot{V}O_2$ max is not a good discriminator of the aerobic response in homogeneous groups of youngsters⁽¹⁾. Improvements in the running performance without correspondent changes in the $\dot{V}O_2$ max relative to the body weight with runners between 10-18 years of age, longitudinally followed, may occur⁽²⁾. Moreover, in children and adolescents, it is not always possible to determine the $\dot{V}O_2$ max through the traditional $\dot{V}O_2$ plateau, especially due to maturational aspects and difficulties in obtaining a maximum effort⁽³⁾. Hence, the use of the evaluation and prescription of activities using sub maximum models to decrease such difficulties is recommended⁽⁴⁾.

The measurement of the blood lactate concentration ([la]) is part of the routine of many exercise physiology laboratories and functional evaluation as standard approach of sub maximum variables. The so-called transition thresholds basically reflect points where abrupt increases in the curve [la]-intensity, began to be used

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as reference to aerobic capacity⁽⁵⁾. Actually, the thresholds are approximations of the intensity zone in the exercise where a balance between the production and the removal of lactate in the blood would occur, corresponding to the intensity of maximum lactate stable state (MLSS). The determination of thresholds, mainly the lactate threshold (LT), in some works called anaerobic threshold (AnT), is used as reference of intensity for the prescription of aerobic capacity loads⁽⁶⁾.

Despite the interest and technological evolution of the measure of [la], this is a costly methodology and demands skilled professionals. Moreover, the blood collection is an invasive and uncomfortable approach, especially with youngsters. Many authors have proposed alternatives to predict the variables related to the MLSS and the AnT, with limited approaches – basically to adults⁽⁷⁻⁸⁾ –, with a smaller number of studies with children and adolescents to attenuate these methodological problems⁽⁹⁾. A deficiency of methods of AnT estimate is found with the youngsters.

A [la] of 4.0 mmol.l⁻¹ is frequently used as indicator of the AnT and the MLSS in adults. However, many children can take loads close to exhaustion without exceeding this value of [1a]⁽¹⁰⁾, making its utilization discussible as criterion to evaluate the youngsters. Thus, the use of criteria with lower values as 2.5 mmol.l⁻¹ were suggested⁽¹⁰⁻¹³⁾.

Cavinato *et al.*⁽¹⁴⁾, evaluating young soccer players of national status found [la] of 2,52 ± 0,90 mmol.l⁻¹, one minute after a maximum effort run of 20 m, being this value similar to the one suggested as fixed reference of [la] in the AnT (2,5 mmol.l⁻¹) for children and adolescents, demonstrating that the medium velocity in this effort may be an alternative to the AnT approximation in these individuals.

Pazin *et al.*⁽¹⁵⁾ evaluated 56 young participants of sports schools through the 20 minutes running track test with the purpose to verify the possibility to determine the reference of MLSS velocities (using as criterion 2,5 mmol.l⁻¹). His results showed that the velocity in the 20 minutes running is not statistically different from the 2,5 mmol.l⁻¹ velocity, reaching the conclusion that the 20 minutes running is a good discriminator of the aerobic aptitude in young athletes.

Since the studies by Ericksson *et al.*⁽¹⁶⁻¹⁸⁾ it has been speculated that the smaller [la] in youngsters would be linked to their lower glycolytic capacity, and such fact would be related to the maturational process. However, such evidence has been questioned by other studies and should be more investigated⁽¹⁹⁾. The chronological age and the growth indicators such as body weight and height, have been mentioned in the literature as possible factor of aerobic performance in youngsters⁽¹⁾.

Facing this evidence, the aim of the actual study was to verify the influence of the sexual maturation, chronological age and growth indices in the lactate threshold velocity and in the 20 minutes running track performance.

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METHOD

Sample

The sample consisted of 33 boys, between 13 and 15 years of age who go to sports schools (basketball, volleyball and athletics), in clubs or sports institutions of the region of Florianópolis, SC. The data collection was conducted after the parents' signing of the agreement term, according to the Ethics and Research Committee of the State of Santa Catarina University.

Anthropometrical measures, corrected chronological age and sexual maturation evaluation

Initially, the body weight, height and triceps and subscapular skinfolds for posterior sum were obtained (ΣDC). The measurements were conducted according to Lohman's standardization (1991) mentioned by Tritschler⁽²⁰⁾.

The chronological age was corrected (ICC) by each individual's birthdate in relation to the date of their anthropometrical data collection. Such adjustment was calculated in decimal order.

The sexual maturation was determined through the indices standardized by Tanner⁽²¹⁾, observing the development of secondary sexual characteristics of pubic hair (SMPH) and development of genitals in boys (SMG). The boys were instructed about the evaluation meaning, and later on they received a form with standardized pictures and a side space where they would answer about the maturational stage that was close to theirs, observing the pictures. The form filling was individualized and the adolescent was in a closed room. Access to the form data was only given to the researchers after its completion.

The youngsters were grouped as pubescent when they were in stages 2 and 3, concerning pubic hair and also genitals; and as post-pubescent when they were in stages 4 and 5.

20 minutes running test

The test was conducted in a 200 meters synthetic track, where the subjects did a 10 minutes warm-up with low intensity continuous run and 10 minutes of stretching exercises. The participants were told to keep constant velocity during the running, with the purpose to do the longest distance as possible in 20 minutes. The cardiac frequency (CF) was monitored during the entire test (CF registration every 5 seconds through the POLAR S610itm frequency meter) to analyze the intensity of the effort. There was a blood sample collection to measure the blood lactate concentrations [la], one minute after the test. The obtained variables in that test were the average velocity in the 20 minutes running (V_{20}), cardiac frequency at the end of the test (FC_{final}) and percentage of the estimate maximum CF (% FC_{max}). The test was conducted in groups of maximum of 5 individuals.

Progressive test

The individuals did (in a 200 m athletics tracking field) three 800 meters runs (with one minute of interval), with the intensity of the effort being controlled by pre-established cardiac frequency zones for each running. Such progressive test methodology was modified from Geysemeyer and Rieckert⁽²²⁾. After a 10 minutes warm-up period with low intensity continuous running and 10 minutes of stretching exercises, the first 800 m run was conducted, where the individual was told to keep the CF between 140-150 bpm. The other runs were conducted in CF values between 160-170 bpm and 180-190 bpm controlled by the CF monitor. The interval between each 800 m running was of one minute. Immediately after each 800 m running, there was blood collection to measure of the [la]. The measures of the [la] in the blood were analyzed by enzymatic method in a YSI 1500 (Yellow Springs Instruments[®]), device with blood samples of 25 capillary blood microliters taken from the earlobe Polar S610 (Polar Electro[®]) monitors were used for the CF measurement.

The obtained variable in this test was the average velocity in the [la] of 2,5 mmol.l⁻¹ ($V_{2,5}$). The linear interpolation and extrapolation method from the plotting of the [1a] in their respective average velocities obtained from the progressive test was used to identify $V_{2,5}$. The used extrapolation limit was lower or equal to 0,5 mmol.l⁻¹.

The tests were conducted in a balanced way to decrease the interference of the test effect in the results.

Statistical analysis

The subjects were divided in groups by chronological age and by maturational index. The *Pearson* simple correlation was applied to verify association between two variables. The *Spearman-Rank* correlation was used to verify the association between the sexual maturation and the other variables in the study. The comparison between the growth indices (weight, height and skinfold sum), $V_{2,5}$ and V_{20} in the chronological ages occurred through the ANOVA test, using Post-Hoc by Scheffé. The comparison in the maturational stages occurred through the *t test* for independent samples. A regression model for the estimate of V_{20} and $V_{2,5}$ was established from the analyses, using the following predictor variables: maturational stage, age, gender, weight, height and fat %. ANOVA Two-way was used to compare V_{20} and $V_{2,5}$ between the different chronological ages and maturational stage. The significance level for $p < 0,05$ was used for all the analyses.

RESULTS

The body weight, height and sum of the skinfolds (ΣDC) values for the 13, 14 and 15 years of age boys sample is found in table 1. Only the height was different comparing the 13 and 15 ages.

TABLE 1
Anthropometrical variables values (average \pm standard deviation) according to the age groups

Variables	13 years	14 years	15 years
N	13	11	9
Weight (kg)	58,66 \pm 14,36	62,89 \pm 17,08	72,46 \pm 15,30
Height (cm)	166,33 \pm 10,75*	171,29 \pm 9,81	179,63 \pm 5,05
ΣDC (mm)	23,19 \pm 10,35	23,57 \pm 9,36	20,53 \pm 11,23

N = number of subjects; ΣDC = sum of skinfolds.

* = significant difference of 15 years ($p < 0,05$).

Comparing corrected chronological age, body weight, height and ΣDC between the pubescent and post-pubescent youngsters, using the self-evaluation of genitals as sexual maturation criterion (SMG), no significant differences were found in any variable analyzed (table 2). On the other hand, comparing the pubescent and post-pubescent groups using the self-evaluation of pubic hair as sexual maturation criterion (SMPH), significant differences between weight and height were found (table 2).

TABLE 2
Physical characteristics of pubescents and post-pubescents through the self-evaluation of sexual maturation methods

Variables	Genitals		Pubic hair	
	Pubescents	Post-pubescents	Pubescents	Post-pubescents
N	17	16	10	23
Age (years)	14,25 \pm 0,77	14,35 \pm 0,91	13,92 \pm 0,74	14,47 \pm 0,82
Weight (kg)	60,68 \pm 17,97	67,18 \pm 13,60	48,89 \pm 8,17*	70,33 \pm 14,28
Height (cm)	169,78 \pm 12,61	173,56 \pm 7,46	161,96 \pm 10,38*	175,81 \pm 7,36
ΣDC (mm)	23,72 \pm 10,56	21,39 \pm 9,65	21,96 \pm 7,27	22,87 \pm 11,16

N = number of subjects; ΣDC = sum of skinfolds.

* Significant difference of post-pubescents ($p < 0,005$).

Comparing the $V_{2,5}$ ($2,81 \pm 0,34$; $2,63 \pm 0,36$; $2,86 \pm 0,45$ m.s⁻¹) and V_{20} ($2,79 \pm 0,45$; $2,80 \pm 0,31$; $2,97 \pm 0,25$ m.s⁻¹) performance variables in the 13, 14 and 15 ages, respectively, there was no significant difference among the ages either.

The values of $V_{2,5}$ and V_{20} between the pubescent and post-pubescent groups (SMG and SMPH) are represented in figures 1 and 2. No significant differences were found between pubescent and post-pubescent for the performance variables ($V_{2,5}$ e V_{20}) using SMG as criterion. However, using SMPH, significant difference was found in the V_{20} ($p < 0,05$).

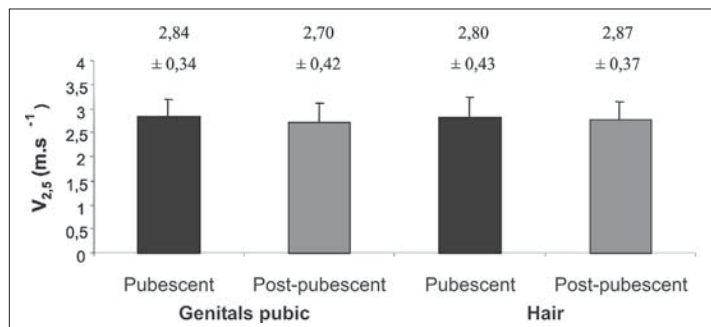


Figure 1 – Comparison between pubescent and post-pubescent in the velocity of the lactate threshold through the sexual maturation self-evaluation

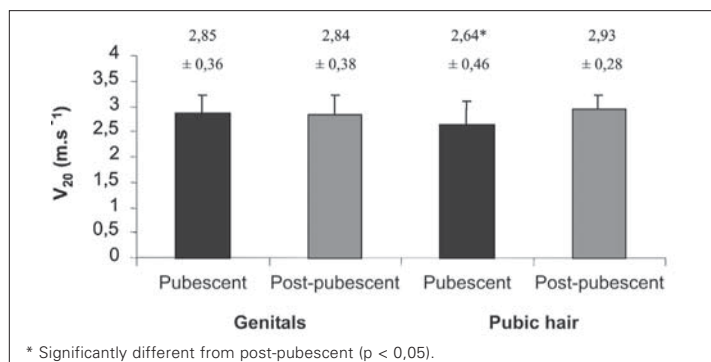


Figure 2 – Comparison between Pubescent and Post-Pubescent in the V_{20} through the sexual maturation self-evaluation

The correlations between sexual maturation (SMG and SMPH), CCA, growth indices, $V_{2,5}$ and V_{20} are present in table 3.

TABLE 3
Correlations between sexual maturation (SMG and SMPH), corrected chronological age (CCA), growth indices, $V_{2,5}$ and V_{20}

	SMG***	SMPH***	CCA	Weight	Height	ΣDC	$V_{2,5}$
MSPP	,48*						
ICC	,03	,35*					
Weight	,30	,70*	,27				
Height	,07	,56*	,44*	,75**			
ΣDC	-,11	,02	-,07	,49**	,13		
$V_{2,5}$,16	,03	,05	,14	,09	,30	
V_{20}	-,09	,31	,18	,21	,37*	-,07	,39*

* $p < 0,05$; ** $p < 0,001$, *** Spearman-Rank Correlation.

$V_{2,5}$ and V_{120} were not different in relation to different maturational stages (factor 1) and chronological age (factor 2), using ANOVA two-way.

A multiple regression analysis was conducted (stepwise) to better understand which of the studied variables (sexual maturation, growth indices and performance variables) were relevant in the $V_{2,5}$ and V_{20} determination.

When the sexual maturation and growth indices were placed, none of them satisfactory explained $V_{2,5}$.

Inserting the sexual maturation indices and the growth indices to predict V_{20} , the only variable that fit the prediction model was the height. The generated equation was:

$$V_{20} \text{ (m.s}^{-1}\text{)} = 0,402 + 0,01422 \times (\text{height})$$

$$(r = 0,41; r^2 = 0,17; EPE = 0,33 \text{ m.s}^{-1}\text{)}$$

The final CF results in the T_{20} were of 185 ± 15 ; 188 ± 11 ; 188 ± 8 bpm in the 13, 14 and 15 ages, respectively. The percentage in relation to the maximum estimate CF (220-age) of the individuals was $89 \pm 7\%$; $91 \pm 5\%$ e $92 \pm 4\%$.

DISCUSSION

The growth indices, body weight and height results evaluated in the young participants in this study were considerably higher than the results obtained by the studies with students from Santa Catarina State and Florianópolis city⁽²³⁻²⁴⁾.

No significant difference was found in the body weight and ΣDC among the ages either. Only in the height among the 13 and 15 years of age youngsters significant difference was found. Nonetheless, a great variability in the growth indices results in these ages may be observed. Such great variability may be caused partly according to Fagundes and Krebs⁽²⁴⁾, to the association that exists between these variables and the growth spur period. Pires and Lopes⁽²³⁾ explain that the growth spur is later and longer in the young male population, around 14 years of age, causing the boys to be taller and heavier than girls, who present an earlier and shorter spur, when they are around 12 years of age⁽²⁵⁻²⁶⁾. Such evidence reflect on the positive correlations observed in the actual study, between: age and height ($r = 0,44$), weight and height ($r = 0,75$), weight and sexual maturation ($r = 0,70$), height and sexual maturation ($r = 0,56$) and sexual maturation and chronological age ($r = 0,35$) ($p < 0,05$).

It seems that the hormonal system action, which plays a role in the sexual and growth hormones liberation, may influence in the variability of the growth indices in the different ages as well⁽²⁴⁾.

These higher growth indices observed in the subjects in this study may be explained by the fact that all of them were part of sports schools from the Florianópolis area in volleyball, basketball and athletics. All these youngsters are in a sports initiation process, and many of them were considered "talented". In these collective sports the sum of the characteristics is extremely emphasized and relevant at this first selective moment, which causes the sample of this study to be much above the average of the youngsters in the studies mentioned above. Another possibility is the fact that the regular training may influence in the physical growth and maturation, however, other factors may be more relevant to the change of this biological process. According to Malina⁽²⁵⁾ there are interactions between genetics and environment in the growth and development process. Whenever the environmental conditions are optimum, the genotype is the first regulator of the growth and maturation. However, the social environment may direct or indirectly influence through factors such as nutrition, the family relationships, family size, physical activity habits, family, school and community sports habits. Malina also states that physical activity alone does not determine growth and maturation. It is believed that such fact has little influence in the findings of the actual study. The performance variables $V_{2,5}$ and V_{20} were not statistically different in the 13, 14 and 15 years of age either, which denotes a homogeneous characteristic in the aerobic capacity of the subjects. No association between these performance and chronological age were observed.

It is not possible to make comparisons between the results of this study and other studies that had similar objectives. This is mainly caused by methodological and conceptual differences ap-

plied to specially characterize the aerobic capacity of the subjects, namely: the study by Palgi *et al.*⁽²⁷⁾ used the ventilatory threshold and the absolute $\dot{V}O_{2\max}$ as indicator of aerobic capacity; Tanaka and Shindo⁽²⁸⁾ used the velocity in the lactate threshold below the [la] of 2 mmol.l⁻¹; Williams *et al.* used the % $\dot{V}O_{2\text{peak}}$ in the OBLA (4 mmol.l⁻¹)⁽¹¹⁻¹²⁾ and in the [la] of 2,5 mmol.l⁻¹ (12) as Welsman *et al.*⁽²⁹⁾; Armstrong *et al.*⁽³⁰⁾ used the $\dot{V}O_{2\text{peak}}$ as cardiorespiratory conditioning index.

The Tanner⁽²¹⁾ indices were used through the self-evaluation of the development of the genitals and pubic hair development with the objective to verify the association between sexual maturation and the performance in some variables. The application of these indices has been recommended, especially to transversal studies⁽³⁰⁾ and a good association with other indicators of biological maturation has been verified⁽²⁵⁾. Nonetheless, one must be careful with the analyses conducted through these indices, and the possibility that they can be describing growth and development accurately.

In this study results, considering the group homogeneity and the fact that between 13 and 15 years of age is when many modifications in the growth indices occur, which will influence in other performance components, and also considering that there is a great chronological age variation to the same biological age⁽³¹⁾, one may observe that the SMG did not influence, in any of the studies variables, the growth and maturational development of the individuals evaluated (vide Results – tables 2 and 3, and figures 1 and 2), even though they have not demonstrated significant difference of MSPP, and the two indices being significantly correlated ($r_s = 0,48$, $p < 0,05$). Such results corroborate with the ones found by Borges *et al.*⁽³²⁾.

The SMPH showed difference between the pubescent and post-pubescent youngsters and significant association with body weight ($r = 0,70$) and height ($r = 0,56$) ($p < 0,05$). Armstrong and Welsman⁽¹⁹⁾ emphasize that the testosterone levels in boys are highly correlated to the growth indices (weight and height) during adolescence. Borges *et al.*⁽³²⁾ recommend that whenever the self-evaluation of the sexual maturation for the determination of possible differences in the physical aptitude and in the anthropometrical components is applied, the indices of pubic hair development should be used as a more efficient criterion, which agree with the results of this study. In the regression analysis, the growth indices and the sexual maturation did not explain the performance in $V_{2,5}$. It seems that in younger individuals the growth variables and the sexual maturation have low association with the lactate threshold. On the other hand, the endurance performance variables demonstrated a higher prediction power and association of the lactate threshold, as has been seen in other studies^(1,33). Hence, it is important to reflect on the influence of the sexual maturation in the lactate threshold.

Many researchers have been investigating the reasons why younger individuals present lower blood concentrations of lactate, based on studies by Ericksson *et al.*⁽¹⁶⁻¹⁸⁾. One of the reasons for this limitation would be related to a lower glycolytic capacity, which consequently would be connected to the sexual maturation. Another study, frequently mentioned by the literature, demonstrated that it is necessary an adequate proportion of testosterone for the development of glycolysis in rats⁽³⁴⁾. Falgairette *et al.*⁽³⁵⁾ presented significant associations between the blood lactate responses in the exercise and levels of testosterone ($r = 0,40$, $p < 0,001$) in 144 boys between 6 and 15 years of age. Another classical study that supports the androgenic influence in the glycolysis was conducted by Tanaka and Shindo⁽²⁸⁾, which demonstrated a significant association between bone age and the velocity in the lactate threshold in boys between 6 and 15 years of age ($r = -0,32$), reaching the conclusion that: “pre-pubescent and pubescent boys have greater velocities in the lactate threshold than adolescents (post-pubescent) and this can partly, be due to the lower testosterone action over the skeletal muscle”.

In the actual study, no significant association between any of the maturation indices used (SMG and SMPH) with $V_{2,5}$ and with V_{20} was found. These results are similar to other authors who used the Tanner indices as maturation marker⁽¹¹⁻¹²⁾ concerning the blood concentrations of testosterone⁽²⁹⁾.

Many studies have been criticized for not demonstrating an adequate control, mixing the influences and the interrelations among testosterone, other growth indices and the development variable under consideration. An evaluation of the independent effects of testosterone in response to the blood lactate should use statistical techniques that allow that these confusing relations are controlled⁽¹⁹⁾.

Accordingly, it seems risky facing the knowledge, to suppose the relation with the maturation indices and submaximum/maximum [la]⁽²⁹⁾ and glycolytic enzymatic activity⁽³⁶⁻³⁸⁾. The applied methodologies and the verified magnitude in the associations do not sufficiently support the idea of dependence commonly released between maturation and the transition thresholds. In the initial studies by Ericksson *et al.*, themselves, that suggest a lower ability in young individuals to generate energy through glycolysis, the author recommends caution in its results interpretation since “general conclusions cannot be reached”^(17,p.18).

Differently from the inconsistency of the evidence of a lower glycolytic potential in younger individuals, the studies have consistently observed higher levels of oxidative enzymes, such as deshydrogenase succinate (DHS) and deshydrogenase isocitrate (DHIC)⁽³⁷⁾. Differences in the ratio between PFK to DHIC in children (0.884) compared with adults (1.633) reflect a better ability to oxidize the piruvate and provide evidence that children are preferably skilled to produce aerobic energy⁽³⁸⁾. However, these considerations do not have comparative effect with the actual study, since these variables have not been measured and serve as reflexion over the subject. Concerning the performance in the 20 minutes running test of youngsters, there was an association only between V_{20} and height ($r = 0,37$, $p < 0,05$), being height the only variable with prediction power in V_{20} . Such fact may be due to aspects of running economy that occur during adolescence, through the modifications in the patterns of frequency and size of step in the running caused by changes in the size of the body segments. Further analysis on other variables that may have more association with the endurance in young populations, such as running maximum velocity, running economy, fraction of used $\dot{V}O_{2\max}$ (percentual), among others, is necessary⁽³⁹⁾.

In the current study the individuals were asked to run the 20 minutes as stable as possible, with no great variations in the rhythm during the distance. This procedure was recommended by Frainer *et al.*⁽⁴⁰⁾ in a study with young soccer players, where the authors suggest caution when applying the 20 minutes test and making conclusions about the results. The result of the percentage of the maximum cardiac frequency (% FC_{\max}) found in the T_{20} shows that some adolescents came close to 100% of the CF_{\max} estimated in the end of the test, showing high concentrations of lactate. Such fact is probably due to changes in the running rhythm during the 20 minutes, causing an imbalance between the production and removal of blood lactate, which may hamper the running performance⁽⁴¹⁾.

Therefore, it is difficult to reach conclusions about the results in the 20 minutes running, due to the different running strategies adopted by the adolescents in this study.

CONCLUSION

Sexual maturation, chronological age and growth indices are not associated with performance in the $V_{2,5}$. Hence, other physiological and biomechanical performance variables may have stronger influence in the lactate threshold than growth variables during adolescence.

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