

## ORIGINAL ARTICLE

# Maturational stages: comparison of growth and physical capacity indicators in adolescents



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## Abstract

**Introduction:** The identification of physical capacity is an important marker related to healthy behavior during childhood and adolescence, in which some factors appear to contribute to motor performance such as maturation and hormonal levels.

**Objective:** To compare growth indicators, physical capacity and hormonal markers according to gender and maturational stage in adolescents.

**Methods:** Eighty-nine adolescents of both genders aged 10-13 years participated in the study. Sexual maturation was evaluated using the Tanner's self-evaluation method. Physical capacity (explosive strength of upper and lower limbs, upper limb velocity and agility) and hormonal markers (testosterone and estradiol) were evaluated through the chemiluminescence method.

**Results:** In the comparison by gender, girls had higher weight ( $p = 0.023$ ), height ( $p = 0.018$ ) and fat percentage values ( $p = 0.001$ ), while boys presented better motor performance for the explosive strength of upper limbs ( $p = 0.005$ ) and lower limbs ( $p = 0.011$ ), agility ( $0.018$ ) and upper limb velocity ( $p = 0.014$ ). Regarding maturational stage, boys did not present differences in any variable analyzed; (Stage V versus I), height (stage III, IV and V versus I) and upper limb explosive strength (stage III and IV versus I).

**Conclusion:** Growth, weight and height, as well as explosive strength of upper limbs were higher in girls at more advanced maturational stages and appear to be gender dependent.

**Keywords:** testosterone, estradiol, muscle strength, physical aptitude.

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## ■ INTRODUCTION

The identification of physical fitness components in childhood and adolescence is an important marker related to healthy behaviors<sup>1</sup>, since high levels of motor performance in young individuals are usually indicative of active individuals, due to the engagement in several physical activities<sup>2</sup>, evidencing an association between motor development and level of physical activity<sup>3</sup>. Therefore, it is necessary to admit that although the identification of physical capacity is an essential parameter for the elaboration of strategies that more adequately allow the practice of physical activity for adolescents, it is also essential to verify other factors that contribute to the motor function of the pediatric population.

Recently, studies have found that individuals in the same age group with different maturational stages have different growth and motor performance indicators, suggesting that maturation is an important tool to be used in conjunction with growth and motor performance indicators to provide more accurate interpretations of these individuals<sup>4-6</sup>.

During adolescence, the accelerated maturational stage reflects on body growth, strength and power compared to individuals with delayed biological development<sup>5,7,8</sup>, however, with age advancement, these differences tend to be reduced and/or eliminated and contribute to the reduction of participation of adolescents in sports activities<sup>9</sup>.

## ■ METHODS

This correlational cross-sectional study included sample consisting of 89 students of both genders (45 boys and 44 girls), aged 10-13 years enrolled in the municipal school system of the city of Natal, Rio Grande do Norte, Brazil. The study was approved by the Ethics Research Committee of the Federal University of Rio Grande do Norte (CEP-UFRN), under protocol No. 1249937/2015 in compliance with Resolution 466/12 of the National Health Council of 12/12/2012, as well as the ethical terms contained in the Helsinki declaration. Parents/guardians gave informed consent and students signed the Consent Term. Subjects who presented any motor and cognitive limitations that made investigation procedures unfeasible were excluded, as well as those undergoing hormonal treatment.

Participants were evaluated in three moments. At the first moment, anthropometric and blood data were collected, being performed in three consecutive days, at the same time. Anthropometric measurements included body mass and height, through an electronic scale (filizola<sup>®</sup> 110, capacity for 150 kg, divisions of 1/10 kg and accuracy of 100 grams) and a stadiometer (Sanny ES2020<sup>®</sup>) with scale of 0.5 cm, respectively, for later identification of body mass index (body mass/height<sup>2</sup>). To verify the corrected arm perimeter, the arm perimeter without contraction + triceps skinfold with Harpenden<sup>®</sup> adipometer (John Bull Indicators Ltd) was measured, as well as the bone diameters: biepicondylar of humerus and femur were collected by means of the Sanny caliper ES2020<sup>®</sup>. To identify body fat percentage, the specific equation for children and adolescents proposed by Slaughter *et al.*<sup>13</sup> was

Somatic maturation, bone age, and sexual maturation are commonly used to assess the adolescent's maturational stage<sup>9</sup>. The method of self-evaluated sexual maturation has been considered an easily applicable tool for the estimation of the pubertal stage of children and adolescents, being based on the application of images of the genitalia and pubic hair in a subjective way to individuals<sup>10</sup>.

Modulation in the process of sexual maturation is influenced by several changes in the endocrine system, mainly by the activation of the hypothalamic-pituitary-gonadal axis that induces the progressive release of androgens, such as testosterone, and by the activation of the hypothalamic-pituitary-ovary axis, which results in the production of estrogen<sup>9,11</sup>.

The high level of hormonal concentration during the pubertal process presents a linear relationship with motor performance in adolescence<sup>12</sup> and should be analyzed in conjunction with other parameters associated with the growth and motor development of this population. Therefore, the objective of the present study was to compare growth indicators, physical capacity and hormonal markers in adolescents according to gender and maturational stage.

used. All procedures were performed by a single evaluator and strictly followed the guidelines of the International Society for Advancement in Kinanthropometry (ISAK).

To evaluate hormonal dosage, a venous puncture in the antecubital region was performed and approximately 10 ml of peripheral blood was collected. From the blood sample, hormonal dosages of testosterone and estrogen of the estradiol type were analyzed by the chemiluminescence method. Collections and analyses were carried out by professionals and specialized laboratories.

To identify the stage of sexual maturation, criteria adopted by Tanner<sup>14</sup> were used, in which the subject performs the self-evaluation of secondary sexual characteristics, based on the diagnosis of pubic hair. In this method, adolescents' pubertal stage was classified into five strata represented by photographs. This model was validated for young Brazilians by Duke *et al.*<sup>15</sup>.

Motor tests included assessment of explosive strength of upper (ESUL) and lower limbs (ESLL), upper limb velocity, and agility. Tests were evaluated on two non-consecutive days, with a minimum interval of 24 hours, being distributed as follows: first day (explosive strength of upper limbs + agility) and on the second day (explosive strength of lower limbs + upper limb velocity). The explosive strength of lower limbs was collected through the counter-movement jump<sup>16</sup>, on a contact platform (Cefise<sup>®</sup>) connected to Jump Test Pro software 2.10. Explosive strength of upper limbs was identified by the 2kg medicine ball throw test, in which the evaluated with both hands against

the chest was asked to throw it as far as possible<sup>17</sup>, with reliability of  $r= 0.84$ . Upper limb velocity (VMMSS) was measured using the EUROFIT<sup>18</sup> test battery, where the shortest execution in two trials time was recorded, with the participation of two evaluators, one for counting cycles and another for timing<sup>14,19</sup>. Finally, agility was measured using the 30-meter test, in which the subject was instructed to run at maximum speed in a course of three meters from one point to another<sup>20</sup>, in which two trials were performed with a 5 minute interval and the best time was recorded, with reliability of  $r= 0.88$ .

## RESULTS

Among the results presented in table 1, higher values in growth-related measures (mass, height and body fat) were observed in girls, while boys present better performance in motor tests.

**Table 1:** Sample characterization and comparison of anthropometric variables, motor tests and hormonal profile of students according to sex.

	Total (n=89) Median (IQR)	Boys (n=45) Median (IQR)	Girls (n=44) Median (IQR)	p
CA	11.35 (1.90)	11.60 (1.85)	11.20 (1.90)	0.56
BM (kg)	38.05 (14.75)	35.00 (12.65)	40.60 (16.20)	0.023*
Height (m)	1.46 (0.10)	1.45 (0.08)	1.50 (0.14)	0.018*
Body fat (%)	19.0 (6.79)	14.20 (8.70)	23.80 (8.20)	0.001*
ESUL (m)	1.70 (0.73)	1.80 (0.70)	1.50 (0.70)	0.005*
ESLL (cm)	21.95 (5.02)	22.90 (4.30)	20.90 (4.70)	0.011*
Agility (s)	8.27 (0.98)	8.00 (0.86)	8.46 (1.05)	0.018*
ULV (s)	14.12 (3.30)	14.09 (7.62)	14.26 (2.49)	0.014*
Testosterone (ng/dl)	3.48 (4.51)	3.94 (11.45)	3.52 (1.92)	0.005*
Estradiol (ng/dl)	1.68 (4.94)	- (18.30)	4.25 (4.77)	0.002*
	Total (%)	Boys (%)	Girls (%)	
Stage I	33.3	32.6	34.1	
Stage II	33.3	39.1	27.3	
Stage III	17.8	10.9	25.0	
Stage IV	10.0	10.9	9.1	
Stage V	5.6	6.5	4.5	

IQR = interquartile range; CA = chronological age; BM = body mass; % F = fat percentage; ESUL = explosive strength of upper limbs; ESLL = explosive strength of lower limbs; ULV = upper limb velocity; \* = significant difference ( $p < 0.05$ ).

**Table 2:** Comparison of anthropometric characteristics according to the maturational stages of boys and girls (median and IQR)

Variables- Boys	Stage I	Stage II	Stage III	Stage IV	Stage V	p
BM (kg)	31.40 (5.20)	36.10 (13.98)	35.25 (16.80)	38.80 (20.75)	45.00 (4.95)	0.158
Height (m)	1.42 (0.08)	1.44 (0.09)	1.45 (0.07)	1.50 (0.19)	1.47 (0.05)	0.579
BMI (kg/m <sup>2</sup> )	15.54 (2.78)	16.63 (3.35)	17.08 (7.21)	17.24 (7.70)	20.91 (0.38)	0.196
Body fat (%)	13.50 (6.00)	14.25 (8.58)	15.90 (20.28)	14.20 (16.75)	22.10 (0.76)	0.191
Variables- Girls	Stage I	Stage II	Stage III	Stage IV	Stage V	p
BM (kg)	35.60 (15.42)	38.75 (10.92)	46.70 (11.60)	50.35 (9.18)	59.20 (5.89)*	0.049
Height (m)	1.43 (0.16)	1.48 (0.13)	1.52 (0.09)*	1.59 (0.06)*	1.63 (0.11)*	0.002
BMI (kg/m <sup>2</sup> )	16.41 (3.54)	17.46 (3.22)	19.46 (3.21)	19.32 (3.47)	22.00 (0.77)	0.655
Body fat (%)	21.15 (9.88)	23.50 (9.53)	24.50 (6.50)	26.20 (7.32)	24.25 (1.52)	0.941

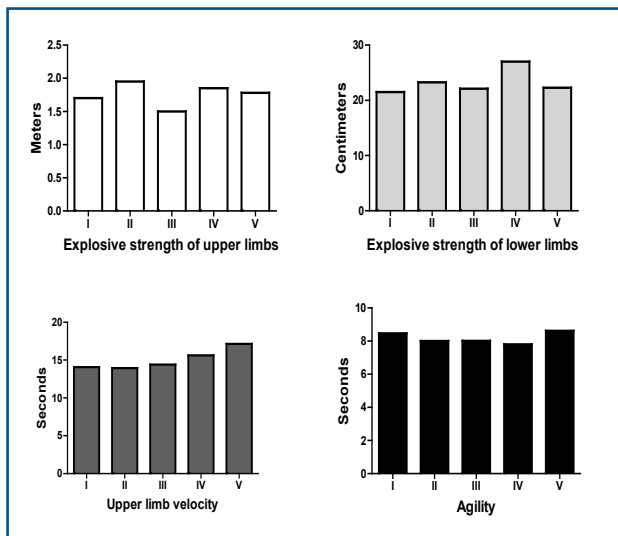
BM = body mass; BMI = body mass index; \* = difference between stage I  $p < 0.05$ .

## Statistical Analysis

Data normality was verified by the Kolmogorv-Smirnov test, and the hypothesis of data normality was rejected. Data were shown as median and interquartile range (IQR). The non-parametric Mann-Whitney test was used to compare characteristics, physical capacity and hormonal markers according to gender, and comparison according to the stages of sexual maturation was performed using the Kruskal-Wallis test followed by Post Hoc Dunn's. Analyses were performed using the Statistical Package for Social Sciences - SPSS version 20.0. The significance level was set at  $p < 0.05$ .

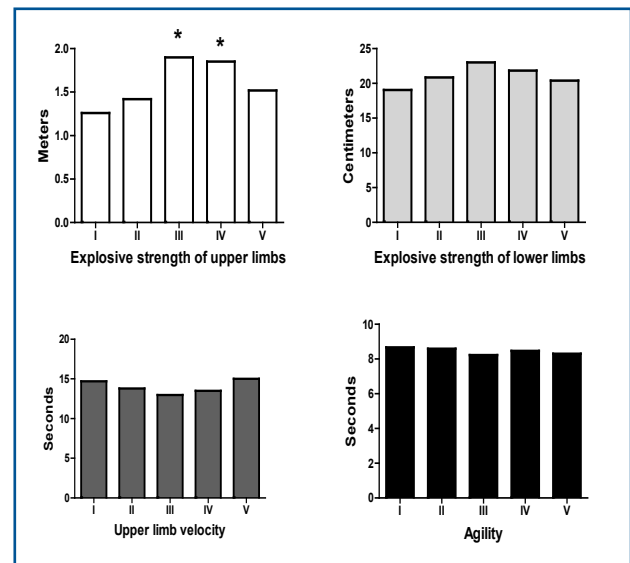
Table 2 shows significant differences for body mass and height of girls according to maturational stage (III, IV and V), demonstrating an increase behavior in these attributes when compared to stage I.

Figures 1 and 2 present the comparison of physical tests according to the maturational stages of boys and girls, respectively. There was no difference in performance in any physical test according to the stages of sexual maturation of boys ( $p > 0.05$ ). On the other hand, girls at maturational stage III (ESUL = 1.94 + 0.59 m) and at maturational stage IV (ESUL = 2.01 + 0.39 m) achieved better performances in the explosive strength of upper limbs than girls classified at maturational stage I.

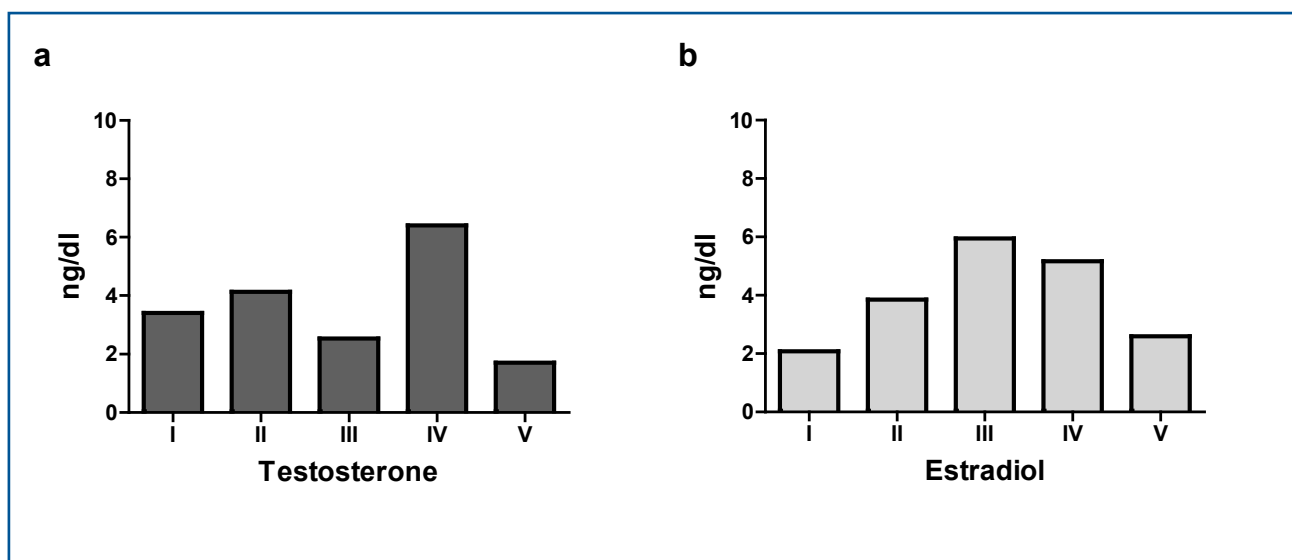


**Figure 1:** Comparison of physical tests according to the maturational stage of boys. ESUL = explosive strength of upper limbs; ESLL = explosive strength of lower limbs; VMS = upper limb velocity.

Figure 3 shows the comparison of hormonal markers, testosterone and estradiol, according to the maturational stage of boys and girls, respectively. No significant differences were observed between testosterone concentration and estradiol according to maturational stages ( $p > 0.05$ ).



**Figure 2:** Comparison of physical tests according to the maturational stage of girls. FMS = explosive strength of upper limbs; FMI = explosive strength of lower limbs; VMS = upper limb velocity; \* = significant difference with stage I.



**Figure 3:** Comparison of hormonal markers according to the maturational stage of boys (a) and girls (b).

## ■ DISCUSSION

The main findings of the present study indicated significant differences in anthropometric variables and explosive strength of upper limbs according to stages of sexual maturation of girls. On the other hand, no significant differences were observed in any dependent variable for boys.

In the comparison between genders, it was observed that girls presented higher mass, body height and body fat (%) in relation to boys. In fact, it is well established that during the maturation process, girls are affected earlier (~ 11 years) than boys (~ 13 years)<sup>21</sup>, and that estrogen, hormone responsible for the development of female sexual characteristics, promotes pelvic enlargement, breast development and increase of fat stores for menarche, which results in increased body mass<sup>22</sup>. On the other hand, greater performance was found for boys in all physical tests evaluated in the present study (i.e., explosive strength of upper and lower limbs, upper limb velocity and agility).

It is possible to attribute this higher performance to the action of testosterone, which plays an important role in the performance of physical tests, especially those related to strength<sup>23</sup>. In addition, it is speculated that these differences between genders may also be related to the social and cultural context, which indicate that girls participate in less physical activities (moderate/vigorous intensities) and sports than boys, reflecting in lower performance in physical tests; however, the best motor gestures were found for boys<sup>2</sup>.

Contrary to our initial hypothesis, no difference was observed in the performance of physical tests for boys and in the hormonal concentration in both genders according to the maturational stage. Based on the premise that the maturational process is guided by the increase in the circulation of testosterone and estrogen hormones in boys and girls, respectively<sup>21</sup>, it would be reasonable to suppose that the more advanced stages of sexual maturation would present higher concentration of these hormones and, consequently, better performance in physical tests<sup>24</sup>.

However, this premise was not supported by the results found in this study and diverges from previous studies, which have demonstrated that in more advanced maturational stages, physical performance is higher compared to individuals with delayed maturational stage<sup>5,6</sup>, as well as the hormonal concentration levels<sup>25</sup>. Vidal-Linhares *et al.*<sup>6</sup>, observed a significant tendency to increase physical capacity in parallel with the advancement of the maturational stage in male adolescents. When verifying the performance of the explosive strength of upper and lower limbs of young volleyball players, higher performance was observed in adolescents of both genders with accelerated maturational stage in relation to their pairs with delayed maturation, using a model that estimates bone age. Recently, a study conducted by Pinto *et al.*<sup>25</sup>, demonstrated higher physical performance, testosterone and estradiol concentration in adolescents with higher maturational stage, also using the model that estimates bone age.

In view of these findings, it is speculated that

although self-evaluated sexual maturation is a valid and widely used method, there is discrepancy in the identification of intermediate stages (II, III and IV), which may result in overestimated information. There are indications of low association between self-evaluation and objective method (performed by specialists) in literature, presenting low agreement between self-evaluation and evaluation performed by specialists<sup>10</sup>.

In addition, Fidelix *et al.*<sup>26</sup> suggest that this method may suffer cultural influences regarding stage choices. Based on this premise, it is possible to explain the lack of increase in testosterone levels in boys, considering that boys' peak testosterone occurs around 13 years of age<sup>21</sup> and the mean age of our sample is ~11 years (data not shown). In relation to girls, a possible justification for this stabilization of estradiol concentration during maturational advancement may be associated with fat percentage, which presents high values from stage I. Zhai *et al.*<sup>27</sup> reported that fat stores are able to influence estradiol levels through conversion mechanisms. Therefore, it is suggested that, in parallel with subjective methods, objective methods to estimate the maturational stage of adolescents should also be applied.

In the present study, differences were identified in girls only in the explosive strength of upper limbs for those in stages III and IV, and higher performance was observed in relation to those without pubertal signs (stage I). These data corroborate the assertion that maturation can lead to changes in upper limb strength production<sup>25,28</sup>.

Thus, sexual maturation should be considered in activities involving explosive strength of upper limbs, mainly in sports practices, and not only the chronological age of young individuals, because as observed in our study, subjects who are of the same age can have distinct upper limb strength. On the other hand, differences were not identified for the explosive strength of lower limbs in girls, and this result was also found in literature, when it did not identify modifications in the physical capacity in subjects classified as pubertal and post-pubertal<sup>25,29</sup>. In this sense, the performance of the explosive strength of lower limbs appears not to be influenced by sexual maturation, and that during puberty, there is no increase in this attribute in female adolescents who are not engaged in physical training for this purpose<sup>28</sup>.

This fact was supported by Quatman *et al.*<sup>29</sup>, who, in a two-year longitudinal study with female adolescents, did not report significant improvements in vertical jump height, even with changes in the maturational stage of adolescents. These data suggest that other factors are associated with the improvement of the explosive strength of lower limbs that does not necessarily involve the maturational process, and that specific training is necessary to improve the synchronization of motor units, greater use of elastic energy in the knee extensor muscles from the elongation-shortening cycle efficiency<sup>30</sup>.

Considering these informations, it is worth highlighting that the present study presents relevant information to the exercise science and to the pediatric population, especially with respect to the evaluation of



maturation as a parameter for the elaboration of strategies for the practice of physical activity, since subjects with the same chronological age may present different performance in upper limb strength.

Therefore, the identification of maturation can support the development of strategies that promote greater adherence to physical activities, taking into account their

potentialities and motor limitations. Nevertheless, it is important to highlight that the method of self-evaluated sexual maturation, even though widely used and validated, can suffer external and body awareness influences, which could overestimate the adolescents' responses and, thus, be considered a possible study limitation.

## CONCLUSION

In conclusion, growth, weight and height indicators, as well as the explosive strength of upper limbs were higher in girls at more advanced maturational stages. Thus, data suggest that physical education professionals should take into account, during the development of physical exercise programs, the biological development of individuals and

not only chronological age as evaluative standard, but it is also necessary to consider other aspects such as gender. In addition, no differences were observed for boys in any of the analyzed variables, which may be related to possible external influences inherent to the self-evaluation method.

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## Resumo

**Introdução:** A identificação da capacidade física se apresenta como importante marcador relacionado ao comportamento saudável durante a infância e adolescência, no qual alguns fatores aparentam contribuir para o desempenho motor como a maturação e níveis hormonais.

**Objetivo:** Comparar indicadores de crescimento, capacidades físicas e marcadores hormonais de acordo com o sexo e estágio maturacional em adolescentes.

**Método:** Participaram do estudo 89 adolescentes de ambos os sexos de 10 a 13 anos. Foram avaliados a maturação sexual, obtida através do método de autoavaliação de Tanner, capacidades físicas (força explosiva de membros superiores e inferiores, velocidade de membros superiores e agilidade) e marcadores hormonais (testosterona e estradiol) através do método de quimiluminescência.

**Resultados:** Na comparação pelo sexo, as meninas obtiveram maiores valores para o peso ( $p=0,023$ ), estatura ( $p=0,018$ ) e percentual de gordura ( $p=0,001$ ), enquanto que os meninos apresentaram melhor rendimento motor para a força explosiva de membros superiores ( $p=0,005$ ) e inferiores ( $p=0,011$ ), agilidade ( $0,018$ ) e velocidade de membros superiores ( $p=0,014$ ). Em relação ao estágio maturacional os meninos não apresentaram diferenças em nenhuma variável analisada; enquanto as meninas em estágio maturacional mais avançado apresentaram maiores valores para o peso (estágio V versus I), estatura (estágio III, IV e V versus I) e força explosiva de membros superiores (estágio III e IV versus I).

**Conclusão:** Os indicadores de crescimento, peso e estatura, bem como a força explosiva de membros superiores foram mais elevados nas meninas em estágios maturacionais mais avançados e parecem ser dependentes do sexo.

**Palavras-chave:** testosterona, estradiol, força muscular, aptidão física.

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