RBPFEX
Revista Brasileira de Prescrição e Fisiologia do Exercício

DISCRIMINATING FACTORS OF THE KINANTHROPOMETRIC PROFILE OF YOUNG ATHLETES FROM DIFFERENT SPORTS

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ABSTRACT

Body morphology, due to its simple applicability, is used to help coaches make decisions during the process of identifying and selecting talent in sports. Objective: to analyze the discriminative kinanthropometric patterns of young Brazilian athletes in different sports. Materials and Methods: We evaluated 83 young males (age: 13.1 ± 2.4), 60 of whom were athletes (16-soccer, 11-tennis, 20-swimming, and 13-rowing) and 23 non-athletes (Control group). We evaluated the kinanthropometric profile by dual-energy x-ray emission absorptiometry and by anthropometry. Subsequently, through algorithms programmed in "R" language, a discriminant model was created based on the circumference variables: biceps, hips, waist, and leg; the bone diameters of the humerus and femur, and the components of body composition: total lean mass, total fat mass, bone mineral density, bone mineral content, triceps skinfold, and body adiposity index. Results: Discriminant model was able to discriminate soccer athletes in 93.8% (F:32.098; p=0.000), tennis athletes in 81.8% (F:24.060; p=0.0004), rowing athletes in 80% (F:28.031; p=0.0001), swimming at 100% (F:41.899; p<0.000) and the control group at 91.3% (F:30.132; p<0.0001). In addition, the high bone mineral density was important for the discrimination of soccer athletes (p<0.001), the low body adiposity index for the discrimination of swimming athletes (p<0.001), and the high levels of lean mass for the discrimination of rowers (p<0.001). Conclusion: We conclude that morphological patterns can be used safely, helping to discriminate young athletes from different sports; thus, one more tool to be used in the processes of detection and guidance of young people with talent in the sport.

Key words: Anthropometry. Athletes. Sport. Talent Selection.

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RESUMO

Fatores discriminadores do perfil cinantropométrico de jovens atletas de diferentes esportes

A morfologia corporal é utilizada para ajudar os treinadores a tomar decisões durante o processo de identificação e seleção de talentos no esporte. Objetivo: analisar os padrões cinantropométricos discriminatórios de jovens atletas brasileiros em diferentes esportes. Materiais e Métodos: Avaliamos 83 jovens do sexo masculino (idade: 13,1 ± 2,4 anos), sendo 60 atletas (16-futebol, 11-tênis, 20-natação e 13-remo) e 23 não-atletas. Avaliamos o perfil cinantropométrico por absorção de emissão de raios X de energia dupla e por antropometria. Posteriormente, através de algoritmos programados em linguagem "R", criamos um modelo discriminante baseado nas variáveis de circunferência: bíceps, quadril, cintura e perna; os diâmetros ósseos do úmero e do fêmur, e os componentes da composição corporal: massa magra total, massa gorda total, densidade mineral óssea, conteúdo mineral ósseo, dobra cutânea tricipital, e índice de adiposidade corporal. Resultados: O modelo discriminante foi capaz de discriminar atletas de futebol em 93,8% (F:32.098; p=0.000), atletas de tênis em 81,8% (F:24.060; p=0.0004), atletas de remo em 80% (F:28.031; p=0.0001), natação em 100% (F:41.899; p<0.000) e não-atletas em 91,3% (F:30.132; p<0.0001). A alta densidade mineral óssea foi importante para a discriminação dos atletas de futebol (p<0,001), o baixo índice de adiposidade corporal para a discriminação dos atletas de natação (p<0,001), e os altos níveis de massa magra para a discriminação dos remadores (p<0,001). Conclusão: Os padrões morfológicos podem ser usados com segurança, ajudando a discriminar jovens atletas de diferentes esportes.

Palavras-chave: Antropometria. Atletas. Esporte. Seleção de Talentos.

INTRODUCTION

Seeking to qualify the orientation and selection of young athletes methods and strategies have been added to the traditional systematic analysis of the individual's performance conditions and their relationship with a particular sport to assist in an adequate determination of a specific sport modality, such as action seeks to elicit maximized performance conditions (i.e., sports identity) (Pion et al., 2020).

In this sense, observing specific morphological characteristics of athletes in sports has shown that it can help in understanding the conditions of a possible sporting talent (Pion et al., 2015; Shariat et al., 2017).

Body morphology, as it is easy to apply, is taken into account and is constantly used to help coaches make decisions during the process of identifying and selecting talent in sport (Buekers et al., 2015; Zhao et al., 2019).

When combined with motor and physiological characteristics, it is even more capable of providing relevant data that benefits the talent identification process (Pasa et al., 2019; Buekers et al., 2015; Zhao et al., 2019; Almeida-Neto et al., 2020a).

Regarding the specific characteristics of sports, we can mention research on judo, for example. It has been shown that judo athletes have a larger chest circumference compared to athletes from other sports, as well as volleyball players have a larger dimension in certain body segments: Achilles tendon length, body height, and shoulder width (Pasa et al., 2019; Zhao et al., 2019).

Although there is evidence regarding the relevance of morphological characteristics supporting this purpose, such processes must occur through the use of multidimensional strategies, taking into account not only morphological factors of the athletes but also physiological, motor, and psychological factors (Pion et al., 2017).

However, due to its simple applicability, body morphology is constantly used in isolation to help coaches make decisions during the process of identifying and selecting talent in sports (Zhao et al., 2019; Almeida-Neto et al., 2020a).

Despite this, evidence of the isolated use of morphology to discriminate against young athletes and assist the process of identifying and mentoring talent is still uncertain (Buekers et al., 2015; Zhao et al., 2019).

The present study aimed to analyze the discriminating kinanthropometric patterns of young Brazilian athletes in different sports, highlighting the hypothesis that morphological variables, when used, may be able to help to discriminate the kinanthropometric profile of young athletes in different sports.

MATERIALS AND METHODS

Participants

Observational cross-sectional study, with a sample of 83 young males (age: 13.1 ± 2.4) residing in the city of Natal, RN/Brazil; with 60 athletes (16 soccer athletes, 11 tennis athletes, 20 swimming and 13 rowing athletes) and 23 non-athletes who were part of the control group.

The athletes who composed the sample are part of sports teams and participate in competitions at the national level, thus being classified as level V athletes (in an increasing scale from I to VI) characterized by Matsudo et al., (1987).

The sample size was previously estimated by the open source software G*Power® (Version 3.1; Berlin, Germany), based on previous studies (Hohmann et al., 2018; Zhao et al., 2019). Thus, using the “F for generic tests with commitment” statistic, an $\alpha = 0.05$ and a $\beta = 0.80$ were adopted, allowing an a posteriori sampling power of 0.87 for the sample size used in the study. The inclusion criterion for all participants was to be between 11 and 15 years old. Non-athlete participants could not exercise for more than two days per week in the last six months before the survey.

For participating athletes, the following inclusion criteria were used: (i) Being an athlete officially registered in a state sports federation. (ii) Have been ranked among the best athletes of 2019 in their respective categories. (iii) Have a weekly training load of more than three days. Participants who had musculoskeletal injuries in the last six months before the survey would be excluded.

Ethics

The research was approved by the Ethics and Research Committee of the Federal University of Rio Grande do Norte - Brazil (Opinion: 3.552.010) according to Resolution

466/12 of the National Health Council, on 12/12/2012, strictly respecting the national and international ethical principles contained in the Declaration of Helsinki (Johannes, Van Delden Van de Graaf, 2017).

It is worth mentioning that the study complied with all the international requirements and standards of the STROBE checklist for observational studies of incidence and prevalence (Von Elm et al., 2014).

Procedures

At first, the sample volunteers and their respective guardians were instructed on the details of the research.

After 24 hours, data were collected from the kinanthropometric profiles, followed by the analysis of body composition.

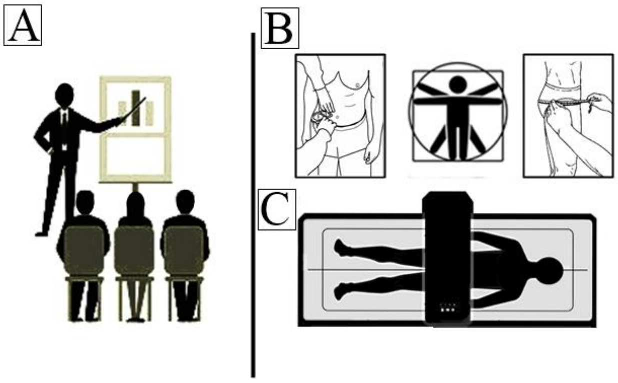

Figure. Study design.
A: Guidance on the benefits and risks of participating in the research. B: Anthropometric data collection. C: Analysis of body composition on dual energy x-ray emission absorptiometry (DXA) equipment.

Anthropometry analysis

Anthropometric assessments were performed according to the protocol of the International Society of the Advancement of Kinanthropometry (Karupaiah, 2018). Body mass was measured using a digital scale with a variation of 0.10 kg (FILIZOLA®; São Paulo, Brazil).

Height was assessed using a stadiometer with a precision of 0.01 cm (SANNY®; São Paulo, Brazil).

Circumferences (biceps, waist, hips, and legs) were measured with an anthropometric tape (SANNY®; São Paulo, Brazil). Bone diameters (humerus and femur) were measured using a caliper (SANNY®; São Paulo, Brazil). Triceps skinfold thickness was measured using a scientific adipometer (SANNY®; São Paulo, Brazil). For all anthropometric procedures, a single evaluator was responsible and all analyzes were performed individually.

Body Composition Analysis

The adjusted body adiposity index [BAI(ADJ)] was acquired by the mathematical model developed by De Macedo Cesário et al. (2021), which consists of analyzing the percentage of adiposity index of young males using the following formula:

$$\text{BAI}_{(\text{ADJ})}\ (\%) = [(\text{Hip (cm)}) / (\text{Stature (m)} * \sqrt{\text{Stature (m)}})] - 17.3$$

$\text{BAI}_{(\text{ADJ})}$ = Adjusted body adiposity index. % = Percentage.

Total lean mass, total fat, and bone mass were analyzed by dual energy x-ray emission absorptiometry (DXA) equipment. During the DXA analyses, algorithms appropriate for the pediatric population were used (Wasserman et al., 2017).

Participants were positioned in dorsal decubitus on the DXA equipment and instructed to remain in a static position throughout the procedure (without causing discomfort to the individual) (Wasserman et al., 2017; Macêdo Cesário et al., 2020).

For all analyzes performed in the DXA, a single evaluator was responsible and all analyzes were performed individually.

Maturation analysis

Somatic maturation (years from attainment of peak height velocity (PHV; termed maturity offset) an assessment of maturity was predicted from anthropometric measures (Mirwald et al., 2002), using the following equations:

Maturity offset in males =– 9.236 + [0.0002708 * (Leg Length* Trunk Height)] + [–0.001663 * (Age* Leg length)] + [0.007216 * (Age* Trunk Height)] + [0.02292 * (Weight/ Height) * 100]

Age at PHV was calculated as age at measurement - maturity offset. Three maturity categories were identified: (i) Pre-PHV (Maturity offset<-1); (ii) circum-PHV (Maturity offset ≥-1 and Maturity offset ≤+1); (iii) Post-PHV (Maturity offset >+1).

Statistic

Data normality

The characterization of the sample was exposed by descriptive statistics using mean and standard deviation. Data normality was verified by Shapiro-Wilk and Z-score tests for asymmetry and kurtosis (-1.96 to 1.96).

Discriminant analyzes

Using algorithms in R language, discriminant analyzes were performed with canonical correlations and cross-validation concerning the selection of young athletes and non-athletes for their respective groups of origin (soccer, tennis, swimming, rowing, and control) using the variables of the kinanthropometric profile (circumferences: biceps, hip, waist, and leg; humerus and femur bone diameters, and body composition components: total lean mass, total fat mass, bone mineral density, bone mineral content, skinfold triceps and $BAI_{(ADJ)}$. The origin group was used as a dependent grouping variable, and the kinanthropometric profile variables were used as a set of independent variables.

Programming of Artificial Neural Networks

Artificial neural networks of the multilayer perceptron type (MLP's) were programmed to verify the importance of the variables of the kinanthropometric profile concerning the discrimination of each analyzed group (soccer, tennis, swimming, rowing, and control).

The MLP's were programmed with backpropagation algorithms to adjust synaptic weights. 70% of the sample was used for training and 30% for testing MLP's in 10,000 execution epochs. For cross-validation, the procedures were repeated ten consecutive times, alternating the sample concerning the training and tests of the MLP's (until all the data passed through the training and tests), and the average results of the repetitions were taken as the final results (Haykin, 2001).

In all analyses, the kinanthropometric profile variables (circumferences: biceps, hip, waist, and leg; humerus and femur bone diameters, and body composition components: total lean mass, total fat mass, mineral density bone, bone mineral content, triceps skinfold thickness and BAI(ADJ) were used as a set of independent variables and groups (soccer, tennis, swimming, rowing, and control) as group-dependent variables.

Mixed Analyzes

To prioritize which characteristics of the kinanthropometric profile were more relevant for a respective group (soccer, tennis, swimming, rowing, and control) than the others, discriminant analyzes were programmed together with MLP's to identify the percentage of importance of each variable individually. In each analysis, data were grouped into two sets that served as a dichotomous dependent variable: (i) origin group (soccer, tennis, swimming, rowing, and control); (ii) all other groups.

The technical error of anthropometric measurements was analyzed as follows: Acceptable ≤ 1.0% (Perini et al., 2005). All analyzes were performed using the Open Source R statistical software (version 4.0.1; R

Foundation for Statistical Computing®, Vienna, Austria), with a significance level of $p < 0.05$.

RESULTS

When segmenting the sample into groups, it appears that the age range between the subjects was similar; however, the maturational stages (PHV) varied between the groups, as shown in table 1. It is noteworthy that, for all anthropometric variables, the technical error of measurement was <1%.

Table 1 - Sample characterization.

Variables	Football	Tennis	Rowing	Swimming	Control
Age (years)	13.5 ± 1.25	12.6 ± 1.52	13.7 ± 1.20	13.1 ± 1.62	12.9 ± 2.24
Maturação (PHV)	-1.10 ± 1.61	-0.52 ± 1.53	1.78 ± 1.44	0.91 ± 1.59	-1.59 ± 1.93
Stature (cm)	160.8 ± 11.5	162.2 ±0.10	169.0 ± 9.59	164.2 ± 9.35	148.5 ± 12.0
Weight (kg)	52.2 ± 11.5	50.4 ± 10.9	64.7 ± 15.0	53.3 ± 11.6	40.0 ± 11.4
Lean mass (kg)	40.4 ± 8.83	36.6 ± 7.78	46.0 ± 9.63	39.9 ± 10.3	22.0 ± 6.68
Fat mass (kg)	11.8 ± 3.16	11.6 ± 4.61	16.1 ± 6.87	11.4 ± 4.01	18.0 ± 5.33
BAI$_{(ADJ)}$ (%)	23.8 ± 2.63	24.2 ± 2.43	25.5 ± 2.85	23.6 ± 3.92	25.2 ± 3.99
Triceps skinfold	10.2 ± 1.97	8.69 ± 3.89	9.98 ± 4.01	8.33 ± 2.86	10.0 ± 6.03
BMD (g/cm^2)	1.74 ± 0.23	1.47 ± 0.35	1.20 ± 0.15	1.16 ± 0.50	0.93 ± 0.24
BMC (g)	2.67 ± 0.46	2.28 ± 0.55	2.55 ± 0.52	2.38 ± 0.99	1.37 ± 0.48
Biceps Circumference (cm)	27.5 ± 5.02	25.0 ± 2.22	29.7 ± 2.87	27.30 ± 3.78	23.0 ± 3.44
Hip Circumference (cm)	83.9 ± 9.00	85.6 ± 6.61	94.1 ± 9.33	86.0 ± 8.63	76.9 ± 10.2
Waist Circumference (cm)	68.4 ± 4.64	68.5 ± 5.66	73.4 ± 8.42	66.9 ± 6.76	63.3 ± 7.47
Leg circumference (cm)	32.2 ± 3.04	33.3 ± 3.55	35.7 ± 3.41	32.0 ± 3.43	28.9 ± 3.51
Humeral Bone Diameter (cm)	6.10 ± 0.36	6.27 ± 0.46	6.58 ±0.46	5.75 ± 0.71	5.47 ± 0.60
Femur Bone Diameter (cm)	9.28 ± 0.53	9.09 ± 1.01	9.76 ± 0.96	8.61 ± 0.80	8.40 ± 0.88

BAI$_{(ADJ)}$: Adjusted Body Adiposity Index. BMD: Bone Mineral Density. BMC: Bone Mineral Content.

Regarding the variables collected by the present study, the set of strongest variables to discriminate the participants to their respective groups were the circumferences of the biceps, hip, waist, and leg; the bone diameters of the humerus and femur, and the components of body composition: total lean mass, total fat mass, bone mineral density, bone mineral content, triceps skinfold and BAI$_{(ADJ)}$.

This set was put together for analysis and, after cross-validation, the discriminant model proposed by the present study was able to discriminate between soccer athletes in 93.8% (F:32.098; p=0.000), and tennis athletes in 81.8% (F:24.060; p=0.0004), rowing at 80% (F:28.031; p=0.0001), swimming at 100% (F:41.899; p<0.000) and the control group at 91.3% (F:30.132; p<0.0001).

It should be noted that, in the analyses, some subjects (from the soccer, tennis, rowing, and control groups) were allocated to different groups, which reduced the effectiveness of the discriminant model between 6.2 and 20%.

Furthermore, no athletes were allocated to the control group, which suggests that the kinanthropometric profile of athletes and non-athletes differed significantly.

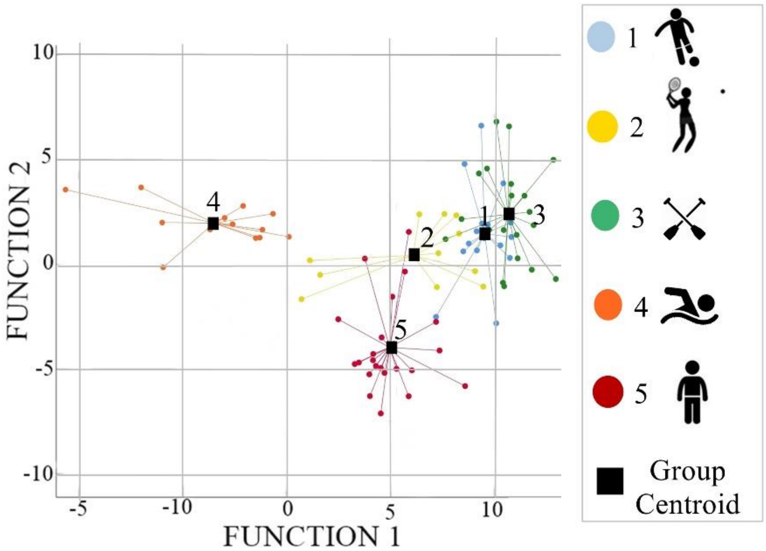

Figure. Discriminant analyzes based on the kinanthropometric profile.

Function 1: X-axis arithmetic function to discriminate groups based on the kinanthropometric profile. Function 2: Y-axis arithmetic function to discriminate groups based on the kinanthropometric profile. 1: Soccer. 2: Tennis. 3: Rowing. 4: Swimming. 5: Control group.

The most determinant variables to discriminate athletes in soccer were high BMD and BMC, in tennis were triceps skinfold with lower values and median circumference of the biceps, in rowing were a high concentration of lean mass and hip circumference wider, in swimming the low BAI$_{(ADJ)}$ and low BMD and in the control group the high amount of fat mass and the narrow diameter of the femur.

Table. Mixed analyzes for the kinanthropometric profile discriminating factors and their importance to discriminate each group.

Groups	Main Discriminating Factors		% Importance (MLP's)		F		p
	Factor 1	Factor 2	Factor 1	Factor 2	Factor 1	Factor 2	------
Soccer	BMD	BMC	76.9%	72.2%	16.9	15.8	0.00
Tennis	TS	BC	55.0%	68.1%	9.75	10.3	0.00
Rowing	LM	HC	93.4%	65.7%	20.5	8.73	0.00
Swimming	BAI$_{(ADJ)}$	BMD	95.2%	88.0%	23.7	20.1	0.00
Control	FM	FD	98.2%	80.3%	19.2	15.6	0.00

MLP's: Multilayer perceptron artificial neural networks. BMD: Bone Mineral Density. BMC: Bone Mineral Content. TS: Triceps Skinfold. BC: Biceps Circumference. HC: Hip Circumference. LM: Lean Mass. FM: Fat Mass. BAI$_{(ADJ)}$: Adjusted body adiposity index. FD: Femur Diameter.

DISCUSSION

The study aimed to analyze the discriminant kinanthropometric patterns of young Brazilian athletes. Thus, the main results showed that the kinanthropometric characteristics were able to discriminate soccer, tennis, rowing, and swimming athletes in more than 80% of the cases.

Thus, the initial hypothesis of the present study that morphological variables, when used, could help to discriminate young athletes from different sports was confirmed.

In this sense, it was found that swimmers have low body adiposity and bone mineral density lower than the other athletes.

This point can be justified because swimming is a sport that does not impact the joints, which ends up promoting a low stimulus for the accumulation of bone mineral density and; consequently, bone mineral content (Gomez-Bruton et al., 2016).

Piezoelectricity (i.e., electricity generated in the bone by biomechanical pressure) generated by the impact of strides during sports that require running is known to promote the accumulation of bone mineral density and the increase of bone mineral content (Piasecki et al., 2018).

Concerning the low adiposity index, it can be justified by the aerobic demand of swimming training, which promotes a greater degradation of body fat. On the other hand, the biomechanical effort produced against the resistance of the water contributes to the predominance of lean body mass in swimmers of both sexes (Moraes et al., 2016; Thng et al., 2021).

In this way, it is suggested that the demands of sports tend to promote a natural selection of their practitioners, where individuals with favorable characteristics tend to remain in the sports modalities which stand out due to their kinanthropometric profile (Buekers et al., 2015; Zhao et al., 2019; Pion et al., 2020).

However, sports practice also promotes morphological adaptations that can uniquely characterize the kinanthropometric profile of its practitioners (Maly et al., 2019).

The study identified that soccer players were discriminated against for pointing out superiority in bone density and mineral content. It is known that in soccer, athletes constantly perform sprint activities, which, as mentioned earlier, favors the impact on the skeletal system and, consequently, promotes the accumulation of bone density and mineral content (Hagman al., 2018).

In this sense, elite tennis players point to a rectilinear kinanthropometric profile, with a wide wingspan and a narrow torso (Sánchez-Muñoz et al., 2007; Raković, et al., 2015; Pradas et al., 2021).

This fact corroborates the present study, in which tennis players were discriminated by low triceps skinfold and median circumference of the biceps brachii. This can be justified because racket modalities require the constant use of blows from the upper limbs (Lees, 2004, 2008).

Suggesting that this demand for strokes with the racket can promote a reduction of local fat in the upper limbs, which can promote a low triceps fold, culminating in a median biceps circumference.

Concerning rowers, the present study discriminated the athletes from the others due to the high concentration of lean mass. Rowing is a hardening sport for long distances (i.e., between 1,000-m and 6,000-m) (Volianitis et al., 2020).

Thus, to move the boats, rowing athletes need to overcome the resistance of the water, which in the long term promotes morphological adaptations to increase lean mass in the trunk and upper limbs (Li et al., 2007; Giroux et al., 2017).

Almeida-Neto et al., (2020a) found that young rowing athletes of both sexes had superior lean mass and, therefore, muscle strength when compared to young athletes in tennis, soccer, Brazilian jiu-jitsu, volleyball, and swimming.

Generally, rowers have hips that are narrower than their shoulders, demonstrating a funnel-shaped kinanthropometric profile (Adhikari, McNeely, 2015; Guereño et al., 2018).

However, concerning the other athletes analyzed, the present study indicated that the rowers had superiority in the hip circumference.

We emphasize that this fact may have occurred due to the group of rowers indicating higher somatic maturation than the other groups, being in the post-PHV (post-pubertal) stage. Individuals in advanced maturation stages have advantages in terms of body size when compared to their peers in delayed or synchronized maturation stages (Mirwald et al., 2002; Almeida-Neto et al., 2020a).

In this sense, the present study may have identified the wide hips of young rowers due to the maturational difference from other athletes.

Given the present discussion, it is highlighted the fact that it is possible to discriminate young athletes from different sports with the help of variables of the kinanthropometric profile.

However, caution is suggested, especially because the present study has the limitation of not having carried out a longitudinal follow-up of the athletes, which makes it impossible to highlight whether the morphological characteristics are unique to individuals or whether they are structural adaptations caused by sports practice.

CONCLUSION

The results of the study allow us to conclude that morphological patterns can be used safely, helping to discriminate young athletes from different sports; thus, another tool to be used in the processes of detection and guidance of young people with talent in sports, taking into account that the variables should not be observed in isolation during the process. It is also possible to observe specific characteristics in the different modalities that should have due attention with regard to morphological patterns; the high bone mineral density is important for the discrimination of soccer athletes, the low body adiposity index for the discrimination of swimming athletes and the high levels of lean mass for the discrimination of rowers.

ACKNOWLEDGMENTS

For your support and encouragement for the development of this academic article, we thank the Federal University of Rio Grande do Norte (UFRN), the Physical Activity and Health (AFISA) research base, the Child and Adolescent Maturation Research Group (GEPMAC). The National Council for Scientific Development (CNPQ) and the Higher Education Personnel Improvement Coordination (CAPES).

Funding: This research received no external funding.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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Recebido para publicação em 16/12/2022
Aceito em 26/02/2023