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ORIGINAL ARTICLE

Discriminant factors and the relationship between anthropometry and maturation on strength performance in elite young male Brazilian Jiu-Jitsu athletes

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Abstract

Background Biological maturation (BM) and anthropometric components can be a determining factor in the neuromuscular performance of young athletes from different sports modalities, however, information on discriminating factors in young Brazilian Jiu-Jitsu (BJJ) athletes is still needed.

Objective The study aimed to relate BM and anthropometric components with the muscular strength of young BJJ athletes and to verify the effectiveness in correctly discriminating BJJ athletes.

Methods A cross-sectional study with a sample of 18 young men (13.0 ± 2.20 years; 50% BJJ; 50% control). We analyzed body composition by bone densitometry by dual-energy X-ray (DXA), BM by peak height velocity, hand grip test (HG), upper limbs strength (ULS), vertical jump (VJ), vertical countermovement jump (CMJ), somatotype, and fifteen anthropometric variables.

Results In both groups, BM and anthropometric components were related to upper and lower limbs strength ($p < 0.05$). The set of variables lean mass, somatotype, trunk height, wingspan, leg length, the performance of VJ, CMJ, ULS, and HG managed to discriminate athletes in 93.5% of BJJ and 94.8% the participants of the control group. In addition, the performance of ULS and HG can be foreshadowed by the size and body weight by 53.0% for the BJJ and 49.3% for the control group. While the performance of VJ and CMJ can be predicted by the length of the legs and body height in 81.3% for BJJ and 76.0% for the control group.

Conclusions In young BJJ athletes, the biological maturation this associate with neuromuscular performance, and anthropometric components are discriminating factors for strength performance.

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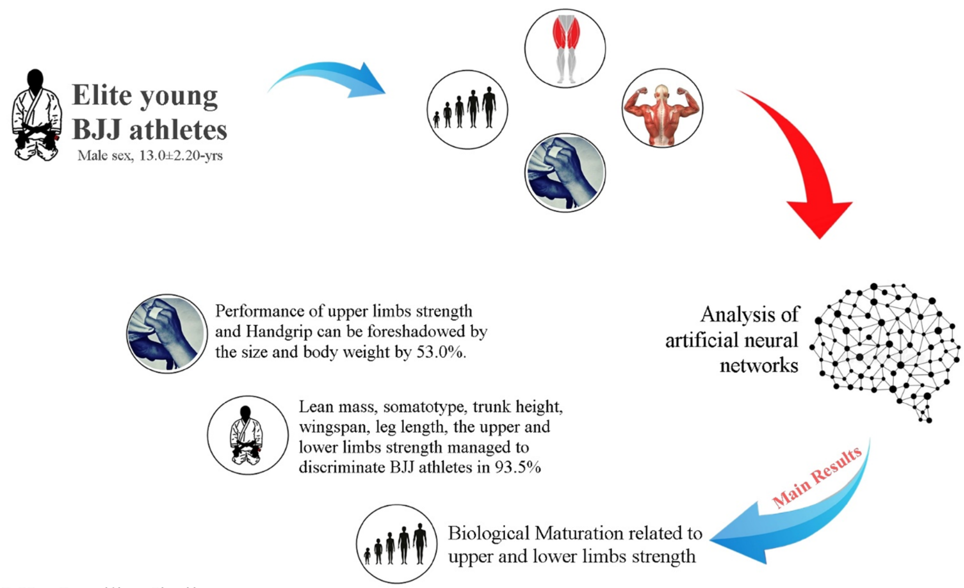
Graphical abstract



BJJ = Brazilian Jiu-jitsu.

Keywords Combat sports · Martial arts · Talent development · Kinanthropometry · Discriminant analysis

Introduction

Popularly called "soft art", Brazilian Jiu-Jitsu (BJJ) is a modern art originating from Jujutsu, a Japanese martial art that was introduced in Brazil in the early twentieth century by Mitsuyo Maeda [1, 2]. Carlos Gracie, a pupil of Mitsuyo Maeda, adapted the techniques of Jujutsu with characteristics focused on the ground fight, with the objective of canceling the advantage generated by the greater physical size of other fighters, favoring the one who has better technique [3]. BJJ is a combat sport based on the control of position and submission of the opponent through strangulation or blockage of the joint [4].

Currently, BJJ is a competitive and self-defense sports art, with the regulation based on taking your opponent to the ground, obtaining position control, and applying restraints or strangulations, involving the use of maximum strength and muscular endurance during your practice constantly [5, 6].

According to the Brazilian International Jiu-Jitsu Federation, the BJJ is present on all continents on the globe [7]. The BJJ competitions are well structured and have amateur and professional categories, including athletes of different age groups; thus, with the growth of the sport, the sports entities involved begin to be concerned with the selection of talents within the BJJ, seeking to understand what are the discriminating capacities of a BJJ athlete [8, 9]. Moreover, the selection of young BJJ athletes is a task that requires caution and detail, it is known that when it comes to athletes from lower categories, it is necessary to take into account factors inherent to the pubertal phase such as biological maturation, which deals with the improvement of several systems of the human organism, including the neuromuscular system, of extreme importance for combat sports [1, 10–12].

When considering that in combat sports, isometric strength is the main component of the sustained actions involved in the domain of adherence or control of the opponent, having a mature neuromuscular system is extremely important for young BJJ athletes [8, 13, 14]. It is known that muscle strength is used for both attack and defense, together with muscle endurance, can influence the control of the Keiko-gi of the opponent (i.e., specific clothing for BJJ training), allowing to dominate, apply techniques and maintain positions [15]. When understanding the importance of muscle strength for sports performance at BJJ during talent selection, it is necessary to consider aspects that may be associated with the capacity of strength production of individuals, especially in children's and adolescents [8, 10, 15–17].

In this context, in young athletes, maturation is an important factor during talent selection, since children of the same age can vary the maturity rate, one reaching adulthood earlier than the other, consequently, it can lead to morphological differences that would give a competitive advantage over other athletes of the same chronological age range [10, 18]. However, the aspects considered for the selection of young talents of BJJ athletes are not yet well defined in the literature, and in relation to the basic categories, it should be considered that young people may be delayed, synchronized, or advanced in relation to maturation, this fact can confuse the selection process of sports talents, as it is expected that young people in advanced stages of maturation are superior in relation to neuromuscular control and body development [8, 9, 19].

Thus, the present study has the hypothesis that when considering the stages of puberty in relation to the anthropometric components, it is possible to understand which factors are most significant for the discrimination of the muscular strength performance of young BJJ athletes. Therefore, the aim of the study was to relate biological maturation (BM) and anthropometric components with the muscular strength of young Brazilian Jiu-Jitsu (BJJ) athletes and to verify the effectiveness in correctly discriminating BJJ athletes.

Methods

Participants

Eighteen young men, with an average age of 13.0 ± 2.20 years, with nine members of the control group and nine elite Brazilian Jiu-Jitsu athletes (Competitors at a national level, among the ten best in the country of their respective categories, according to the Brazilian Confederation of Jiu-Jitsu ranking) participated in this study. The sample can be classified as elite-level athletes [20]. The calculation of the total sample for this research was carried out based on the study by Almeida-Neto et al. [21], considering the variable biological maturation (BM) and hand grip (HG). For the calculation, $\alpha < 0.05$ and $\beta = 0.80$ were considered. For the size of the effect, Pearson's coefficient of 0.91 was used, an effect found in a previous study [21] (correlation between BM and HG). Thus, a minimum number of five individuals per group was indicated for a sample power of 0.85.

The following inclusion criteria were adopted: (I) Participants must be between 8 and 16 years old; (II) The participants of the Brazilian Jiu-Jitsu group should be registered with the Brazilian Jiu-Jitsu Confederation for at least 1 year before the survey and be among the top ten in the national ranking of their respective categories; (III) The participants of the Brazilian Jiu-Jitsu group should have a daily training load of more than 4 h and a weekly frequency of more than four days (proved by the declaration of the place of practice and by the Brazilian Jiu-Jitsu Confederation); (IV) The participants in the control group (sports initiation) should have proof through a declaration of the place of practice and have a weekly training frequency greater than twice a week.

The following exclusion criteria were adopted: (I) Use of exogenous substances (verified through a questionnaire) that could influence any variable in the research (i.e., food supplements, hormonal therapies); (II) Present any health problem that could interfere with the results or refuse to participate in any of the tests proposed by this study.

The individuals and their respective guardians were informed about the research objectives and the methodological procedures adopted in the study. Everyone signed the terms of consent and free and informed consent. The research was analyzed and approved by the Ethics and Research Committee of the Federal University of Rio Grande do Norte (Opinion: 3,726,772), strictly respecting the national and international ethical principles contained in the Declaration of Helsinki.

Study design

A Cross-sectional study was conducted to investigate the relationship between biological maturation and anthropometric components on the neuromuscular performance of elite young male Brazilian Jiu-Jitsu athletes. The data correlations, linear regression analyzes, analysis based on the unsupervised machine learning technique with K-means clustering and Multilayer perceptron (MLP) nonlinear artificial neural networks were performed. The body composition was analyzed by dual-energy absorptiometry with an X-ray source (DXA), fifteen anthropometric measurements were utilized and biological maturation was verified by the peak height velocity. The strength of the upper limbs (ULS) was analyzed by the hand grip test and medicine ball throw and, for the lower limbs, by the vertical jump (VJ) and vertical countermovement jump (CMJ). This study met all the requirements of the international STROBE checklist for observational studies [22]. Figure 1 illustrates the procedures performed in the present study. At first, there was a meeting with the volunteers and their respective guardians with the intention of providing explanations of the benefits and risks of participating in this research (Fig. 1A). Subsequently, after 24 h, anthropometric (Fig. 1B) and body composition (Fig. 1C) analyses were performed. After 24 h, neuromuscular tests regarding upper (Fig. 1D and F) and lower limb strength were performed (Fig. 1E).

Procedures

Anthropometry

Fifteen anthropometric variables were collected by a single evaluator (body mass, height, wingspan, the height of the torso, length of the legs, the circumference of the right leg, the circumference of the right biceps, waist circumference, hip circumference, diameter of the right humerus, the diameter of the right femur, tricipital, subscapular, supraspinal, and medial leg skinfolds). The measurement protocol

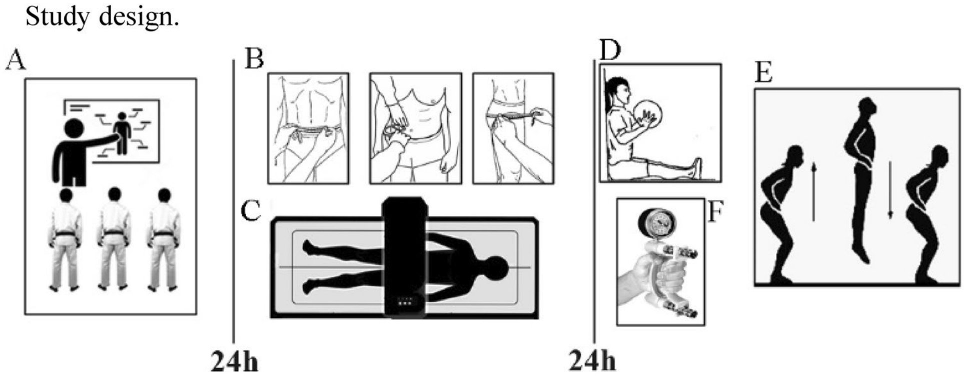


Fig. 1 Study design. **A**: Explanations about the study procedures for the participants and their respective guardians, and signing of the free and informed consent form. **B**: Anthropometric analyses of circumferences and skinfolds. **C**: Analysis of body composition by bone densitometry by dual-energy X-ray (DXA). **D**: Medicine ball test to analyze upper limbs strength. **E**: Vertical jump tests and counter-movement to analyze lower-member performance. **F**: Test to analyze Handgrip

followed the recommendations proposed by the International Society of the Advancement of Kinanthropometry-ISAK [23]. Body mass was measured using a digital scale with a variation of 0.10 kg (FILIZOLA®, Sao Paulo, Brazil). Standing height and trunk measurement were assessed by a stadiometer with an accuracy of 0.01 cm (SANNY®, Sao Paulo, Brazil). The perimetry of the right biceps, right leg, wingspan, hips, and waist were measured with an anthropometric tape (SANNY®, Sao Paulo, Brazil), the bone diameters of the humerus and femur were obtained using a caliper (SANNY®, Sao Paulo, Brazil) and, for the lengths of the legs, the value of the length of the trunk was subtracted from that of the standing height [24].

Evaluation of biological maturation

Biological maturation was verified through somatic maturity (i.e., biological maturation linked to the morphological tissues of the human body; epithelial tissue, connective tissue, muscle tissue, and nervous tissue). Thus, the Mirwald et al. [24] method equation was used to identify somatic maturation using peak height velocity (PHV). The method has strong validation with pediatric longitudinal monitoring of somatic maturation (male: $r = 0.959$; $r^2 = 0.920$; $p < 0.05$) and consists of:

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 is calculated as age at measurement—maturity offset. Three maturity categories were identified [24]: (1) Pre-PHV (Maturity offset < − 1); (2) circum-PHV (Maturity offset ≥ − 1 and Maturity offset ≤ + 1); (3) Post-PHV (Maturity offset > + 1).

Body composition

Body composition was measured by a member of the research team with prior training by examining bone densitometry by dual-energy X-ray (DXA) (LUNAR®/G.E PRODIGY—LNR 41,990, Washington, United States). The equipment was programmed with appropriate algorithms for the pediatric population and then, data on bone mass, fat mass, and lean mass were collected. It is noteworthy that this procedure is considered one of the gold standards for checking body composition [25].

Body somatotype

The somatotype was verified by the protocol proposed by Carter and Heath [26], the method uses anthropometric measurements of skin folds (tricipital, subscapular, supraspinatus, and medial leg), the circumference of the contracted right arm and calf, the biepicondilial diameter of the humerus (cm) and femur (cm), height (cm) and body weight (kg). This analysis provides results on different components of body composition (Endomorph: linked to body adiposity; Mesomorph: associated with musculature (lean mass); Ectomorph: related to body linearity) and classifies individuals according to the predominance of such components. The somatotype attitudinal distance (SAD) was used to calculate the distance in the three-dimensional space between two somatotypes [26] and consists of:

Somatotype attitudinal distance = $\sqrt{[(\text{endomorphyA} - \text{endomorphyB})^2 + (\text{mesomorphyA} - \text{mesomorphyB})^2 + (\text{ectomorphyA} - \text{ectomorphyB})^2]}$.

Significant variation between somatotypes is considered to be the value of SAD ≥ 1.00. The somatotype coefficient was generated by the sum of all analyzed components. The analyses were performed using the Somatotype software

(Version 2.2.6; Sweat Technologies®, San Diego, United States).

Neuromuscular tests: upper limbs

The upper limbs strength (ULS) was assessed using the medicine ball test [27]. The participant was seated with his back against a wall and his knees extended. At the evaluator's signal, a medicine ball (Ax Sports®, Tangara, Brazil) with a mass of 2 kg positioned at the height of the sternum, was thrown horizontally with both hands. Trunk movement was not allowed. The test was performed three consecutive times interspersed with a passive recovery period of 3 min. The best attempt was retained for analysis. The handgrip (HG) test was used to assess the strength of the upper limbs using a hydraulic dynamometer (JAMAR®, Cambuci, Brazil; calibrated before each assessment). The participants remained seated on a bench with adjustable height, and the forearm flexed at an angle of 90° [28]. All participants performed three maximum voluntary contractions (3 s.) with their right hand, interspersed with recovery periods of 60 s, and the best performance was retained for statistical analysis [28].

Neuromuscular tests: lower limbs

The performance of the lower limbs was attained by tests of vertical jump (VJ) and jump against movement (CMJ), both jumps were analyzed through a force platform (CEFISE®, Sao Paulo, Brazil). The protocols established by Forza and Edmundson [29] were utilized. Before the evaluations, the participants performed a jump of each type to familiarize themselves with the tests, seeking to reduce errors during the execution of the protocols. Then, starting from an orthostatic position, held for three seconds, with the knees flexed at approximately 90° and the hands fixed on the waist, the volunteers were instructed to perform the vertical jump as high as possible. For CMJ analysis the same recommendations were adopted; however, the volunteers performed a squat followed by the jump. A 10-min recovery interval was established between VJ and CMJ. For both tests, three attempts were made, interspersed with 60 s of passive recovery, and the best attempt was retained for data analysis.

Statistical analysis

Normality was tested by the Shapiro–Wilk tests and z score of asymmetry and kurtosis (− 1.96 to 1.96). Comparisons were performed using Student's independent T test. The data correlations were performed using the Pearson test. For the correlation, the effect of the variables chronological age, maturation, and lean mass were statistically controlled. Thus, the magnitude used was that of Schober, Boer and Schwarte [30]: Insignificant: $r < 0.10$; Weak: $r = 0.10–0.39$; moderate: $r = 0.40–0.69$; Strong: $r = 0.70–0.89$; very strong: $r = 0.90–1.00$. Linear regression analyses were performed and the models had their homogeneity tested by the Breusch–Pagan test, the assumptions of normality, variance, and independence of the data were not denied. To test the multicollinearity of the regression models the Durbin–Watson test was used. In the regression models, the maturation confounding factors (PHV) and chronological age (CA) were controlled during the analysis, and backdoor arithmetic was used to inhibit the effect of confounding factors during these statistical analyses [31, 32]. An analysis based on the unsupervised machine learning technique with K-means clustering was used by means of a Hartigan–Wong algorithm [33] to group the participants with similar patterns in relation to muscle strength and body morphology. Discriminant analysis and canonical correlation were used to test whether it is possible to allocate participants to their groups of origin and to indicate which variables could discriminate neuromuscular performance in the sample. Multilayer perceptron (MLP) nonlinear artificial neural networks were programmed using backpropagation algorithms [34]. The MLPs had the objective to indicate which variables could discriminate the neuromuscular performance in athletes of BJJ. In addition, MLPs were programmed to identify the effectiveness of anthropometric variables in predicting the neuromuscular performance of the analyzed sample. In this way, MLPs were trained with 90% of the sample and tested with 10% of the sample in 10,000 execution times. To perform the cross-validation, the process was repeated 10 times to alternate the sample between training and MLP testing. The MLP procedures were performed individually for both groups; so, after the processes, the average of the results of the ten sessions performed for each group was taken as the final result in both the BJJ and the control group. For the technical error of anthropometric measurements, the following magnitude was used: Acceptable for skin folds ≤ 5.0%; Acceptable for other anthropometric measurements ≤ 1.0% [35]. All analyses were performed using open source-software R (version 4.0.1; R Foundation for Statistical Computing®, Vienna, Austria) considering the significance of $p < 0.05$.

Results

The margin of the possibility of error pointed out for the sample size was 4.87%, being below 5%, which suggests 95% of reliability in the results obtained based on the sample used. In this sense, the groups analyzed did not point out significant differences in relation to chronological age and biological maturation. However, the BJJ group pointed out the superiority of total lean mass, bone mineral content, and bone mineral density. Regarding neuromuscular performance, the BJJ group was superior to the control group

Table 1 Sample characterization

Variables	BJJ	Control
n°	09	09
Age (years)	13.1 ± 2.16	12.9 ± 2.36
Maturation (PHV)	− 1.13 ± 2.64	− 1.20 ± 1.68
Height (cm)	157.5 ± 16.8	156.2 ± 13.8
Wingspan (cm)	157.0 ± 16.3	155.0 ± 13.8
Trunk height (cm)	77.2 ± 15.5	78.8 ± 5.43
Leg length (cm)	80.2 ± 10.6	77.4 ± 9.73
Body mass index (kg/m^2)	20.3 ± 2.61	16.2 ± 6.75
Body weight (kg)	51.6 ± 16.0	45.1 ± 14.7
Fat mass (kg)	10.3 ± 3.66	10.6 ± 4.68
Lean mass (kg)	39.6 ± 13.8*	30.4 ± 12.0
Bone mineral content (g)	2.10 ± 0.99*	1.66 ± 0.59
Bone mineral density (g/cm^2)	1.45 ± 0.49*	1.08 ± 0.29
Endo	2.57 ± 0.99	2.44 ± 0.95
Meso	3.89 ± 1.02*	0.29 ± 1.16
Ecto	2.68 ± 1.08	3.91 ± 1.16*
HG (kgf)	27.2 ± 11.5*	22.5 ± 9.93
ULS (m)	3.99 ± 1.10	2.45 ± 0.61
VJ (cm)	26.3 ± 4.41	20.0 ± 4.89
CMJ (cm)	28.5 ± 5.84	20.9 ± 4.55

Endo endomorphic, *Meso* mesomorphic, *Ecto* ectomorphic, *HG* hand grip, *ULS* upper limbs strength, *VJ* vertical jump, *CMJ* countermovement vertical jump, *BJJ* Brazilian Jiu-Jitsu

*$p < 0.05$

in all strength tests (Table 1). It is noteworthy that, for all anthropometric analyses, the technical error of measurement remained below 2% (< 1% perimeters and circumferences. 1.2–1.5% for skin folds), being accepted for the analyses.

BJJ athletes showed a somatotype with a predominance of the balanced mesomorphic component, while the control group stood out concerning the endomorphic ectomorph component (Fig. 2). When comparing the somatotype between the groups, considering the SAD ≥ 1.00, the results report a significant difference in the spatial distance between the somatotypes (SAD = 3.80).

Maturation showed a significant correlation with lean mass (BJJ: $r = 0.84$; $p = 0.003$; Control: $r = 0.75$; $p = 0.01$); as well as a significant correlation with the performance of VJ and CMJ in the BJJ and, HG and ULS in both groups (Table 2). When controlling for the effect of lean mass, the correlations remained significant only for HG and ULS in both groups ($p < 0.05$). In this sense, the lean mass showed a correlation with HG, ULS, VJ, and CMJ in the BJJ group and, with HG and ULS in the control group. When controlling the effect of maturation, the results remained significant ($p < 0.05$). Height, wingspan, and body weight are related to the performance of lower limbs of BJJ athletes and the performance of upper limbs of both groups. While the length

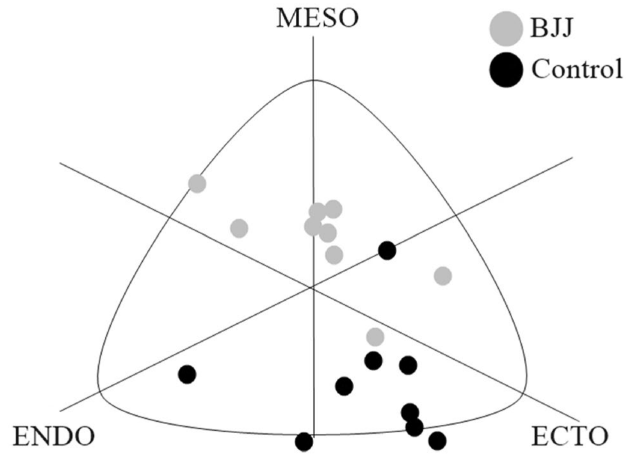


Fig. 2 Somatochart. *Endo* endomorphic component of the somatotype, *Meso* mesomorphic component of the somatotype, *Ecto* ectomorphic component of the somatotype, *BJJ* Brazilian Jiu-Jitsu

of legs showed a significant relationship only with the HG of the control group. When controlling the effects of maturation and lean mass in anthropometric analyses, the results remained significant ($p < 0.05$). It is noteworthy that of the 15 anthropometric variables collected by the present study, only the four exposed in the analyses provided significant data with at least one of the groups analyzed.

Table 3 shows that linear regression analyses indicated that models 1 (maturation, HG, and ULS), 3 (Lean mass, HG, and ULS), and 5 (Wingspan, Body Weight, HG, and ULS) were significant to predict the performance of upper limbs in both groups, as well as model 6 (Height, Leg Length, VJ, and CMJ) were significant in predicting the performance of lower limbs in both groups. While models 2 (Maturation, VJ, and CMJ) and 4 (Lean mass, VJ, and CMJ) were significant to predict the performance of lower limbs only in the BJJ group.

The evaluations by K-means clustering formed two groups (Fig. 3), the first being composed of 07 BJJ athletes and the second by 11 participants (09 controls and 02 BJJ athletes); thus, 77.8% of BJJ athletes were correctly classified by K-means clustering analysis. Groups were formed with the participants according to the similarity of neuromuscular performance and the morphological characteristics. Subsequently, discriminant analyses and canonical correlation indicated that a model with canonical functions based on VJ ($F = 8.19$; $p = 0.00$), CMJ ($F = 9.38$; $p = 0.01$), predominantly balanced mesomorphic somatotype ($F = 32.3$; $p = 0.000$), and ULS ($F = 13.3$; $p = 0.02$) managed to discriminate BJJ athletes by 83.3% after cross-validation of the results. It is noteworthy that only one BJJ athlete was discriminated for the control group. In relation to both groups, Maturation ($F = 3.59$; $p = 0.03$) and trunk height ($F = 3.85$; $p = 0.01$) were significant in 98.0% to discriminate ULS.

Table 2 Correlations of maturation, lean mass, and anthropometry with neuromuscular performance

Variables	BJJ	Control
	r	*r*
	Maturation	Maturation
HG (kgf)	0.92***	0.72*
ULS (m)	0.65*	0.57*
VJ (cm)	0.78*	0.17
CMJ (cm)	0.74*	0.07
	Lean mass	Lean mass
HG (kgf)	0.90**	0.89***
ULS (m)	0.77*	0.46*
VJ (cm)	0.81***	0.21
CMJ (cm)	0.70*	0.06
	Anthropometry Heigth (cm)	Anthropometry Heigth (cm)
HG (kgf)	0.90***	0.81***
ULS (m)	0.67*	0.50
VJ (cm)	0.80**	0.02
CMJ (cm)	0.67*	− 0.10
	Anthropometry Wingspan (cm)	Anthropometry Wingspan (cm)
HG (kgf)	0.91***	0.80***
ULS (m)	0.67*	0.50
VJ (cm)	0.80**	0.05
CMJ (cm)	0.65*	− 0.13
	Anthropometry Leg length (Cm)	Anthropometry Leg length (Cm)
HG (kgf)	0.20	0.70*
ULS (m)	0.18	0.42
VJ (cm)	0.12	− 0.11
CMJ (cm)	− 0.04	− 0.25
	Anthropometry Body weight (kg)	Anthropometry Body weight (kg)
HG (kgf)	0.96***	0.94***
ULS (m)	0.82**	0.32
VJ (cm)	0.72*	− 0.10
CMJ (cm)	0.67*	− 0.21

r correlation coefficient, *HG* hand grip, *ULS* upper limbs strength, *VJ* vertical jump, *CMJ* countermovement vertical jump, *BJJ* Brazilian Jiu-Jitsu

*$p=0.01$

**$p=0.0001$

***$p<0.0001$

While the length of the legs was significant to discriminate the performance of VJ ($F=6.92$; $p=0.01$) and CMJ ($F=6.90$; $p=0.01$) in 96.7%.

Nonlinear analyses by MLP indicated that the set of variables lean mass, somatotype (endo, meso, and ecto), trunk height, wingspan, leg length, the performance of VJ, CMJ, ULS, and HG managed to discriminate athletes in 93.5% of BJJ and 94.8% the participants of the control group. In addition, according to MLP analyses, the performance of ULS and HG can be foreshadowed by the size and body weight by 53.0% for the BJJ and 49.3% for the control group. While the performance of VJ and CMJ can be predicted by the length of the legs and body height in 81.3% for BJJ and 76.0% for the control group.

Discussion

The aim of the study was to relate biological maturation (BM) and anthropometric components with the muscular strength of young BJJ athletes, and to verify the effectiveness in correctly discriminating BJJ athletes. Thus, the main results were: (1) The BJJ athletes pointed out the predominance of the balanced mesomorphic component of the somatotype, while the control group stands out in relation to the endomorphic ectomorph component. (2) Biological maturation, lean mass, and anthropometry indicate significant relationships with the performance of upper and lower limbs muscle strength in the sample analyzed (3) The somatotype and performance of upper and lower limb muscle strength are efficient to discriminate between analyzed participants for their groups of origin (BJJ or Control). (4) Biological maturation was not statistically significant to discriminate the analyzed participants for their groups of origin (BJJ or Control). (5) The maturation and the height of the trunk were significant to discriminate the strength of upper limbs in the total sample, as well as the length of lower limbs, which was significant to discriminate the performance of VJ and CMJ in the total sample.

In this sense, the present study shows that the body structure of young BJJ athletes has a predominance of the balanced mesomorphic component of the somatotype relative to the total lean body mass. These findings corroborate those of Godoy-Cumillaf et al. [36], the authors verified the somatotype in young male Taekwondo athletes obtaining results similar to those of the present study, with predominance for the balanced mesomorphic somatotype (2.7—5.0—2.3), the same was observed in male karate athletes (2.9—5.8—2.4). In addition, Trivic et al. [37] found similar results for the somatotype in young male Sambo athletes, with a predominance of the endomorphic mesomorph somatotype.

Talent identification aims to identify the most promising young athletes to engage in elite sports training in the long term; thus, certain characteristics can be used to discriminate between athletes who practice a certain sport [38]. In this way, the present study identified by discriminant linear

Table 3 Linear regression adjusted to predict neuromuscular performance of upper and lower limbs

Model	BJJ			Control		
	r^2	β	CI 95% β	r^2	β	CI 95% β
1. Maturation/HG/ULS	0.85**	6.74	[3.75; 9.73]	0.76**	7.06	[4.15; 9.96]
2. Maturation/VJ/CMJ	0.62*	− 13.2	[− 21.1; − 5.39]	0.05	− 1.84	[− 8.01; 4.32]
3. Lean mass/HG/ULS	0.83*	3.24	[− 13.4; 19.9]	0.92**	− 10.1	[− 22.1; 1.93]
4. Lean mass/VJ/CMJ	0.66*	− 27.9	[− 67.1; 11.2]	0.10	25.7	[− 17.2; 68.8]
5. Wingspan/body weight/HG/ULS	0.89**	90.5	[56.3; 124.8]	0.82*	108.4	[79.2; 137.6]
6. Height/leg length/VJ/CMJ	0.76*	37.4	[− 29.2; 104.1]	0.92**	39.1	[33.8; 74.4]

r^2 *Adj* r^2 adjusted, *β* angular regression coefficient in relation to the dependent variable, *CI 95% β* 95% confidence interval of β, *HG* hand grip, *ULS* upper limbs strength, *VJ* vertical jump, *CMJ* countermovement vertical jump, *BJJ* Brazilian Jiu-Jitsu

*$p = 0.01$

**$p = 0.0001$

***$p < 0.0001$

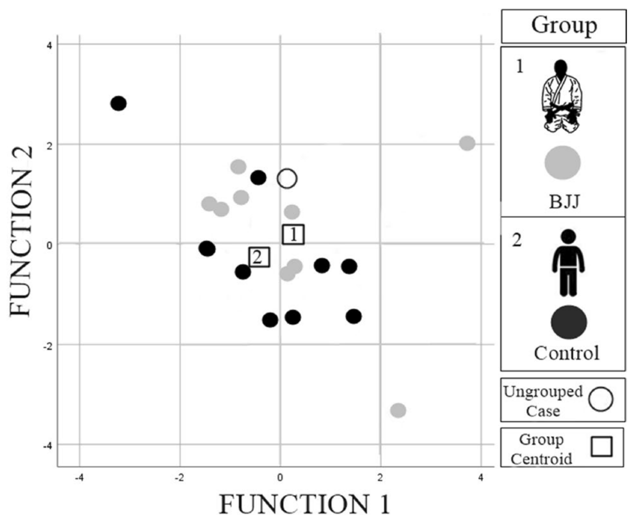


Fig. 3 Discriminant analysis and canonical correlation to verify variables capable of discriminating Brazilian Jiu-Jitsu athletes. *BJJ* Brazilian Jiu-Jitsu

and nonlinear analyses that the anthropometric characteristics associated with the neuromuscular performance of upper and lower limbs are efficient in discriminating young BJJ athletes. In a similar objective, Zhao et al. [39] analyzed young Chinese elite male athletes from six different sports and identified that anthropometric characteristics and neuromuscular performance were extremely important to discriminate athletes from judo, fencing, swimming, tennis table, volleyball, and basketball. In judo, for example, (martial art with characteristics similar to BJJ), Zhao et al. [39] highlighted several significant anthropometric variables to discriminate judo athletes from athletes in other modalities, including the body height ($p < 0.05$), lower leg length ($p < 0.05$), and leg length ($p < 0.05$), which were smaller than in athletes belonging to other sports, on the other hand, the circumference of the chest ($p < 0.05$), the circumference of the ankle ($p < 0.05$), and the subscapular angle ($p < 0.05$) were superior in relation to athletes from other sports.

Pion et al. [40] found a 100% correct classification when discriminating elite male under-18 athletes among three different martial arts (judo, karate, and taekwondo), presenting results similar to the present study, as well as Norjali et al. [41], through the discriminant analysis using seven physical performance tests and three motor coordination tests correctly classified 95.5% of the participants among three different categories in terms of achievements of young Belgian judo athletes; however, only 36.4% of the cases grouped with cross-validation were classified correctly based on all indicators. In addition, the dynamic strength in the back appears to discriminate correctly in 99.5% of elite judo athletes [39]. It is noteworthy that the aforementioned studies did not take into account biological maturation.

Thus, the present study identified that maturation points to significant relationships with the performance of upper and lower limbs, corroborating the findings of Almeida-Neto et al. [20], who found relationships between maturation and the muscle strength performance in elite young athletes ($p < 0.05$). In addition, De Almeida-Neto et al. [42] found significant results for the relationship between biological maturation and neuromuscular performance of young female athletes ($p < 0.05$). In this context, Fukuda et al. [43] analyzed twenty-six judo athletes aged 8–18 years, including anthropometric measurements and performance tests, indicating that maturation showed a significant relationship with hand grip performance ($p < 0.01$), as well as with the strength of lower limbs ($p < 0.05$).

Recently, Detanico et al. [44] analyzed the influence of maturation, body growth, and training experience in young judo athletes, presenting as results that maturation, mass, and body height were the most influential predictors in the performance of hand grip strength representing 54% of inter-individual variability. Malina et al. [10] highlight that in the process of selecting sports talents, maturation should be a primary factor for the discrimination of young athletes of different sports, especially considering that young people of the same chronological age may present different stages of maturation which can provide advantages for individuals with accelerated maturation over those who are late [19]. However, although the present study identified that maturation is effective in discriminating the strength of upper limbs in 98.0% of young BJJ athletes and non-athletes, the variable did not show statistical significance to discriminate whether the individuals belonged to the BJJ or Control groups (Fig. 3).

Despite the interesting findings of the present research, there were the following limitations: (I) The research was of an observational type, which makes it impossible to establish a cause-and-effect relationship. (II) An indirect method was used to analyze biological maturation, which may differ from the analyses performed by the direct method (i.e., X-ray of the hand and wrist). (III) Only elite male athletes were analyzed; the results may be different in female subjects. (IV) The scarcity of specific studies with young BJJ athletes limited the discussions on the findings of the present study.

Although discriminant factors for neuromuscular performance are investigated in combat sports athletes, there are no studies in the literature involving the discrimination of neuromuscular performance correlating with maturity and anthropometric components in young Jiu-Jitsu athletes. Therefore, this research highlighted the influence that biological maturation can have on muscle strength, as well as the effect that anthropometric components have on the strength of young Jiu-Jitsu athletes, providing important information for coaches to select sports talents based on certain anthropometric characteristics, making them have a better direction in training athletes. In addition, the present study used a sample composed of elite athletes, which provides more accurate information about discriminating factors in BJJ.

Conclusion

Based on the findings, biological maturation and anthropometric components are related to the muscular strength performance of upper and lower limbs of elite young Brazilian Jiu-Jitsu athletes, as well as maturation, trunk height, and the length of the lower limbs are discriminating factors for the performance of muscular strength of upper and lower limbs in elite young male Brazilian Jiu-Jitsu athletes. Furthermore, lean mass, somatotype, trunk height, wingspan, leg length, and upper and lower limb strength proved to be effective in discriminating young BJJ athletes by 93.5%, suggesting the importance of these variables in the selection of young talents at BJJ. Thus, it is suggested the production of new studies that analyze the main discriminating factors of BJJ athletes during the selection of young sports talents, as well as the production of studies with female BJJ athletes.

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Declarations

Conflict of interest The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Ethical approval The research was analyzed and approved by the Ethics and Research Committee of the Federal University of Rio Grande do Norte / Brazil (Code: 3,726,772).

Informed consent Everyone signed free informed consent.

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