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Section II - Exercise Physiology & Sports Medicine

Age and Maturity Effects on Morphological and Physical Performance Measures of Adolescent Judo Athletes

by
Bruno Barbosa Giudicelli[1,2], *Leonardo Gomes de Oliveira Luz*[1,2], *Douglas Henrique Bezerra Santos*[1], *Hugo Sarmento*[2], *Alain Guy Marie Massart*[2], *Arnaldo Tenório da Cunha Júnior*[1], *Adam Field*[3], *António José Barata Figueiredo*[2]

Studies assessing age and maturation effects on morphological and physical performance measures of young judokas are scarce. This study aimed to assess the independent and combined effects of chronological age and biological maturation on anthropometry and physical performance of 67 judokas aged 11-14. Participants' anthropometric profiles were assessed, and physical performance tests were completed. Multivariate analyses of variance revealed an independent effect of age (anthropometry: $F = 1.871$; $p < 0.05$; Pillai's trace = 0.545; $\eta^2_p = 0.272$; physical performance: $F = 2.876$; $p < 0.01$; Pillai's trace = 0.509; $\eta^2_p = 0.254$) and maturity (anthropometry: $F = 10.085$; $p < 0.01$; Pillai's trace = 0.669; $\eta^2_p = 0.669$; physical performance: $F = 11.700$; $p < 0.01$; Pillai's trace = 0.581; $\eta^2_p = 0.581$). There was no significant combined effect of age and maturity. The maturation effect remained significant when controlled for age (anthropometry: $F = 4.097$; $p < 0.01$; Pillai's trace = 0.481; $\eta^2_p = 0.481$; physical performance: $F = 3.859$; $p < 0.01$; Pillai's trace = 0.0.318; $\eta^2_p = 0.318$). Inadolescent judokas, the maturation effect on growth and physical performance seems to be more relevant than the age effect, leading to the need to control this effect in training routines and competitive events. As in studies with youth soccer players and other youth athletes, bio-banding can be a strategy for controlling maturation in combat sports.

Key words: *anthropometry, aerobic performance, anaerobic performance, agility, muscle strength, biological maturation.*

Introduction

For children and adolescents competing in sport, chronological age has been used as a criterion for aggregating young athletes into competitive age groups, to provide adequate physical and technical training routines and facilitate fairness in competition. Previous research suggests that there are many growth and maturity-associated effects to movement mechanics (Towlson et al., 2020), potentially resulting in impairment of motor coordination and physical performance of youth athletes (Cumming et al., 2017). In competitive sports, athletes who are younger tend to be less developed physically and psychologically, which may place them at a performance disadvantage (Malina et al., 2004). Furthermore, biologically mature youth athletes tend to be taller and heavier than their age-matched peers, which has advantages, in particular for contact sports (Till et al., 2014). While several studies have been conducted on the influence of growth and maturation on sporting performance of youth athletes, relatively few have focused their

[1] - *Laboratory of Cineanthropometry, Physical Activity and Health Promotion (LACAPS), Federal University of Alagoas, Arapiraca, Brazil.*
[2] - *CIDAF (uid/dtp/04213/2019), Faculty of Sport Sciences and Physical Education, University of Coimbra, Coimbra, Portugal.*
[3] - *Division of Sport and Exercise Sciences, University of Huddersfield, Huddersfield, UK.*

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attention on the impact of these variables on youth athletes competing in combat sports such as judo (Nabofa, 2012; Zubitashvili, 2011).

Due to the inadequacy of chronological age as a criterion for dividing youth athletes into competitive categories, alternative strategies which use physical attributes as criteria have been examined for their effectiveness and applicability (Cumming et al., 2017). In general, these strategies are based on the use of body size and/or maturational status together with chronological age. A strategy called bio-banding does not neglect other factors which should be considered when it comes to the distribution of youth athletes in competitive categories, such as their skill level and psychological profile (Branco et al., 2019; Cumming et al., 2017).

In judo and other combat sports, using body weight as a criterion for distribution of youth athletes into competitive categories is a common bio-banding strategy. This approach could reduce the maturity effect and contribute to the adequacy of training routines and competitions. This could help protect the development and well-being of youth athletes facilitating the maintenance of a long-term career in sport. Furthermore, few studies have examined the independent effect of age and maturation on the morphology and physical performance of young judokas. Such research appears warranted to develop an understanding of the impact of age and maturation on the anthropometric profile and performance of young judokas, and the efficacy of using body mass as a bio-banding strategy. For this reason, the objective of this study was to assess the independent and combined effect of chronological age and biological maturation on the anthropometric profile and physical performance of young judo athletes. The hypothesis was that biological maturation would improve performance of young judokas, regardless of chronological age.

Methods

Participants

The sample included 67 youth male judokas aged 11.0-14.7 years from eight different judo clubs in Portugal (2 dropouts). To be included in the study, the judoka needed to be between 11 and 14 years old, have at least one year of judo training experience and have no contraindications to exercise. Judokas were divided into three age groups: U12 (11.0 and 11.9 years), U13 (12.0 and 12.9 years) and U15 (13.0 and 14.9 years). The study was conducted in accordance with the Declaration of Helsinki for human studies of the World Medical Association and was approved by the Ethics Committee of the Faculty of Sports Sciences and Physical Education of the University of Coimbra [CE/FCDEF-UC/00452019]. Prior to data collection, parents or legal guardians signed informed consent. In addition, verbal assent was obtained from participants after the presentation of the aim and procedures of the study.

Anthropometric Measures

The anthropometric procedures described by Lohman et al. (1988) were adopted in the present study. Stature and sitting height were measured using a portable stadiometer (Seca Bodymeter 206, Seca GmBH & Co Kg, Hamburg, Germany) and a segmometer (Rosscraft Innovations, Spokane, Washington), respectively. The lower limb length was determined as stature minus sitting height. The arm span was measured assessing the distance between right and left dactylion points with both arms abducted 90 degrees. Hand length was determined by measuring the distance between the stylion and dactylion, while foot length was measured by the distance between the acropodion and pterion points. The arm and calf circumferences were measured with an anthropometric tape. All length measures were made to the nearest 0.1 cm. Body mass was evaluated to the nearest 0.1 kg using a portable digital scale (Seca Bella 840, Seca GmBH & Co Kg, Hamburg, Germany). Skinfold thickness was assessed to the nearest 0.1 mm using Rosscraft skinfold calipers (Rosscraft Innovations Inc, Vancouver, Canada). Assessments were conducted in the following order: triceps, subscapular, suprailiac and calf. Thereafter, fat and fat-free masses were calculated based on sex-specific equations derived from the sum of the triceps and subscapular skinfolds (Slaughter et al., 1988).

Biological maturation

The Khamis-Roche method was used to predict the mature stature (PMS) (Khamis and Roche, 1994). The protocol requires decimal age, stature, and body mass of the participant and average parental stature. The stature of parents was collected through a questionnaire sent via e-mail to the parents or legal guardians. The current stature was expressed as a percentage of PMS (%PMS). It is assumed that among children of the same chronological age, individuals closer to the PMS are more advanced in biological maturation (Malina et al., 2004). To classify the evaluated judokas by maturity status, the %PMS was expressed as the z-score of the mean and standard deviation from the sample itself. Two groups contrasting in somatic maturation were derived from z-scores of attained %PMS: early maturing (P > 50%) and late maturing (P ≤ 50%).

Physical Performances

Aerobic performance and agility of the judokas were evaluated through the application of the multi-stage fitness test, with the number of completed laps being used as a performance indicator, and the 10 x 5 m shuttle-run test, recording the total time in seconds to cover 10 laps on a 5 m course (Eurofit, 1996). The line-drill test was used to evaluate anaerobic performance, with the time for course completion recorded in seconds (Carvalho et al., 2011). Muscle strength was evaluated by abdominal muscle strength (AMS; 60-s sit-ups test) (Cesario et al., 2018), upper body muscle strength (UBS; 2-kg medicine ball throw test) (Vossen et al., 2000), lower body muscle strength (LBS; standing long jump test) (Eurofit, 1996) and handgrip strength (HgS; dynamometer Lafayette model 78-10), through two attempts using the dominant hand (Eurofit, 1996). The best of the two attempts in kilograms was recorded for further analysis.

Procedures

All data were collected between April and May by the same trained team, during a single visit. Anthropometric measurements were carried out initially, followed by the physical performance tests. Data collection was organized in the form of a circuit. When passing through all anthropometric stations, judokas performed warm-up exercises under the guidance of a trainee researcher before undertaking stations in the following order: (1) multi-stage fitness test; (2) 2 kg standing medicine ball throw; (3) standing broad jump; (4) 10 x 5 m shuttle-run; (5) sit-ups; (6) handgrip strength with a dynamometer; and (7) a line-drill test.

Statistical analysis

Descriptive statistics (ranges, means, standard deviations and 95% confidence intervals) were used for delineating the anthropometric profiles, physical fitness, and maturational status of judokas. Means, 95% confidence intervals and standard deviations were used to characterize the age groups, while means and standard deviations were calculated within the maturity groups. The Kolmogorov-Smirnov test was used to test normality of the total sample and appropriate log transformations (log 10) were adopted to normalize distributions.

The independent effects of chronological age and maturity on the anthropometric and physical performance variables were tested using multivariate analyses of variance (MANOVA), with analyses of variance (one-way ANOVA) performed when significance was detected. To determine the effect of age, a Bonferroni *post hoc* test was used to verify which age groups differed significantly. Age and maturity combined effects were assessed using a two-way MANOVA. A multivariate analysis of covariance (MANCOVA) was used to verify the independent effects of chronological age and maturity status on the dependent variables when controlling for maturity and age, respectively. Data were analyzed using IBM SPSS 22.0 (SPSS, Inc., Chicago, IL). The level of significance was set at $p \leq 0.05$.

Results

The descriptive statistics for the total sample and the results of the normality tests are presented in Table 1.

The descriptive statistics of the age groups are presented in Table 2. In absolute values, older judokas reached a higher percentage of their PMS, performed better than their younger peers, and had higher absolute measurements in most anthropometric measures.

Table 3 shows the effect of chronological age on anthropometry and physical performance. Significant effects were found in the two sets of variables (anthropometry: $F = 1.871$; $p < 0.05$; Pillai's trace = 0.545; $\eta^2_p = 0.272$; physical performance: $F = 2.876$; $p < 0.01$; Pillai's trace = 0.509; $\eta^2_p = 0.254$). The *post hoc* comparison (Bonferroni) indicated a tendency in the anthropometry measurements where U12 had significantly smaller measurements than U13 and U15 in almost all the anthropometric variables.

The exception was body fat mass as the U12 group was significantly thinner than U13 (F = 3.854; $p < 0.05$; $\eta^2_p = 0.107$). Upper and lower body strength in the U12 group was significantly lower than in U13 and U15 (UBS - F = 18.220; $p < 0.01$; η^2_p = 0.363; LBS - F = 5.817; $p < 0.01$; η^2_p = 0.154). Considering aerobic and anaerobic performance and handgrip strength, U15 judokas performed significantly better than U12 (aerobic - F = 6.568; $p < 0.01$; η^2_p = 0.170; anaerobic - F = 7.005; $p < 0.01$; η^2_p = 0.180; HgS - F = 7.977; $p < 0.01$; η^2_p = 0.200).

Maturation, anthropometry, and physical performance data are presented in Table 4. More mature judokas presented greater anthropometric measurements in all variables and better performance in all physical performance tests. Maturation had a significant effect on anthropometry (F = 10.085; p < 0< 0.01; Pillai's trace = 0.669; η^2_p = 0.669) and physical performance (F = 11.700; $p < 0.01$; Pillai's trace = 0.581; η^2_p = 0.581). Subsequent ANOVA showed a significant maturity effect on all anthropometric variables except for body fat mass, and on all physical tests except for agility and abdominal strength.

The combined effects of chronological age and maturation on anthropometric and physical performance variables are presented in Table 5. No significant effect of interaction between age and maturational status was observed. However, even after controlling for chronological age, the maturity effect on anthropometric (F = 4.097; $p < 0.01$; Pillai's trace = 0.481; η^2_p = 0.481) and physical performances variables (F = 3.859; $p < 0.01$; Pillai's trace = 0.0.318; η^2_p = 0.318) was observed. A reduction in the maturation effect was noted with age control, but it remained significant in aerobic performance (F = 4.928; $p < 0.05$; η^2_p = 0.071), upper body strength (F = 5.894; $p < 0.05$; η^2_p = 0.084) and handgrip strength (F = 6.522; $p < 0.05$; η^2_p = 0.092).

Discussion

The present study evaluated the independent and combined effect of chronological age and biological maturation on anthropometric and physical performance variables in a sample of young Portuguese judokas. Significant independent effects of chronological age and maturity status on all anthropometric variables were evidenced, with older and more maturing judokas reaching higher anthropometric measurements. There were also significant differences between age groups and maturational groups in most of the physical performance variables. Older and more mature judokas demonstrated better performance in all variables, except for agility and abdominal strength tests, supporting the hypothesis that older and more mature individuals are physically superior (Malina et al., 2015). When maturation was controlled, the effect of age was no longer noticeable. On the contrary, after controlling for the effect of age, the impact of maturation on anthropometric and physical performance variables remained significant, which may indicate that in performance of youth judo athletes maturation has a greater impact than age.

The current data suggest that maturation has a greater impact on the judokas' morphology and physical performance during adolescence than chronological age. Studies which verified the effect of age and maturation on anthropometric variables and physical performance also suggest a greater impact of biological maturation in youth athletes than chronological age. In a sample of 58 basketball players aged 9.5 to 15.5 years, Carvalho et al. (2018) found a significant variation in body size and functional capacities due to maturity status. Meylan et al. (2014) studying 74 youth athletes aged 11 to 15 years from different sports found a significant influence of maturity status on strength and power performance. Towlson et al. (2018) evaluated 969 soccer players aged 8 to 18 years to identify moments of greater and lesser influence of chronological age and biological maturation on the anthropometry and physical performance of these athletes. They concluded that biological maturation reached higher impact rates at different times for different anthropometric and physical performance variables. Therefore, the distribution of youth athletes in competitive categories requires to consider the impact of biological maturation. Nevertheless, a recent study with 146 young soccer players found a significant prevalence of athletes presenting normal maturity status, emphasizing the need for further studies on the impact of biological maturation on youth athletes' performance (Altimari et al., 2021).

Table 1

Descriptive statistics for the total sample and test of normality (n = 67).

Variables	Range		Mean		Standard deviation	Kolmogorov-Smirnov	
	Minimum	Maximum	Value	95%CI		Value	*p*
Chronological age (years)	11.01	14,70	12.54	12.30 to 12,78	0.99	-	-
Predicted mature stature (cm)	161.9	198.3	182.6	180.2 to 184.3	7.2	-	-
Attained PMS (%)	77.0	94.0	84.4	83.2 to 85.5	4.7	-	-
Training experience (years)	1	9	3.33	2.74 to 3.91	2.40	-	-
Body mass (kg)	27.6	79.6	47.6	44.7 to 50.5	11.2	0.102	0.081
Fat mass (kg)	2.1	34.4	9.6	8.0 to 11.1	6.3	0.150	< 0.01
Fat free mass (kg)	25.5	65.1	38.0	36.1 to 39.9	7.8	0.099	0.173
Stature (cm)	134.8	176.5	154.0	151.6 to 156.4	9.9	0.075	0.200
Sitting height (cm)	71.5	93.2	80.0	78.8 to 81.2	5.1	0.078	0.200
Arm span (cm)	133.0	180.0	154.1	151.5 to 156.7	10.8	0.060	0.200
Superior members length (cm)	36.2	70.8q	60.2	58.9 to 61.5	5.4	0.086	0.200
Hand length (cm)	14.1	21.3	16.9	16.5 to 17.2	1.5	0.074	0.200
Inferior members length (cm)	60.3	85.5	74.0	72.7 to 75.4	5.5	0.057	0.200
Foot length (cm)	20.1	29.0	24.4	24.0 to 24.9	2.0	0.098	0.185
Arm circumference (cm)	19.0	36.0	25.3	24.5 to 26.1	3.3	0.068	0.200
Calf circumference (cm)	27.0	40.1	32.6	31.8 to 33.4	3.3	0.071	0.200
Pacer test (m)	140	1740	757	680 to 835	318	0.094	0.200
Line-drill test (s)	30.09	46.60	36.14	35.36 to 36.92	3.20	0.074	0.200
Agility 10x5 shuttle run (s)	15.88	26.25	19.44	18.93 to 19.96	2.12	0.139	< 0.01
60-s sit-ups (count)	15	61	41	39 to 44	10	0.089	0.200
2-kg ball throw (m)	3.19	8.79	5.22	4.93 to 5.52	1.22	0.077	0.200
Standing long jump (m)	1.12	5.65	1.69	1.55 to 1.83	0.57	0.179	< 0.01
Hand grip strength (kgf)	14.0	40.0	24.80	23.38 to 26.23	5.85	0.158	< 0.01

95% CI (confidence interval); Attained PMS (predicted mature status).

Table 2

Descriptive statistics for the total sample contrasting for age groups (n = 67).

Variables	U12 (n=23)			U13 (n=22)			U15 (n=22)		
	Mean	95%CI	SD	Mean	95%CI	SD	Mean	95%CI	SD
Chronological age (years)	11.43	11.28 to 11.59	0.35	12.59	12.45 to 12.73	0.32	13.7	13.5 to 13.9	0.5
Predicted mature stature (cm)	183.8	180.8 to 186.8	6.9	184.6	182.2 to 187.0	5.4	179.3	175.5 to 183.0	8.3
Attained PMS (%)	79.5	78.7 to 80.3	1.8	85.0	83.9 to 86.1	2.4	88.9	87.3 to 90.5	3.6
Training experience (yrs)	3	2 to 4	2	4	2 to 5	3	3	2 to 4	2
Body mass (kg)	39.3	35.8 to 42.8	8.1	51.7	47.4 to 56.0	9.7	52.2	46.5 to 57.8	12.7
Fat mass (kg)	7.5	5.0 to 10.0	5.8	11.5	8.9 to 14.1	5.9	10.0	6.9 to 13.0	7.0
Fat free mass (kg)	31.8	30.4 to 33.3	3.4	40.2	37.4 to 43.0	6.4	42.2	38.4 to 46.0	8.6
Stature (cm)	146.1	143.7 to 148.5	5.6	156.9	153.8 to 160.1	7.1	159.5	154.7 to 164.2	10.7
Sitting height (cm)	76.3	75.1 to 77.5	2.8	81.4	79.5 to 83.3	4.3	82.5	80.1 to 84.9	5.5
Arm span (cm)	146.3	143.2 to 149.4	7.2	156.2	152.0 to 160.4	9.4	160.1	155.5 to 164.8	10.5
Superior members length (cm)	57.3	55.9 to 58.8	3.2	61.7	59.8 to 63.6	4.2	61.7	58.6 to 64.8	7.0
Hand length (cm)	15.9	15.3 to 16.5	1.4	17.2	16.5 to 17.9	1.5	17.6	17.1 to 18.1	1.1
Inferior members length (cm)	69.8	68.3 to 71.2	3.4	75.5	73.9 to 77.2	3.8	77.0	74.3 to 79.6	6.0
Foot length (cm)	23.3	22.5 to 24.1	1.9	24.9	24.1 to 25.7	1.8	25.1	24.3 to 25.9	1.8
Arm circumference (cm)	23.3	22.0 to 24.5	2.9	26.3	25.0 to 27.6	2.9	26.4	24.9 to 27.9	3.3
Calf circumference	30.6	29.4 to 31.7	2.7	33.9	32.7 to 35.2	2.8	33.5	32.0 to 34.9	3.3
Pacer test (m)	617	511 to 722	243	731	606 to 856	282	931	776 to 1085	349
Line-drill test (s)	37.68	36.22 to 39.14	3.38	36.26	35.18 to 37.34	2.44	34.41	33.12 to 35.70	2.91
Agility 10x5 shuttle run (s)	20.04	18.93 to 21.15	2.57	19.42	18.67 to 20.16	1.69	18.84	18.00 to 19.67	1.88
60-s sit-ups (count)	39	35 to 43	9	42	38 to 47	11	42	38 to 46	9
2-kg ball throw (m)	4.27	3.88 to 4.65	0.89	5.43	5.03 to 5.83	0.90	6.01	5.50 to 6.53	1.16
Standing long jump	1.46	1.36 to 1.56	0.23	1.86	1.46 to 2.25	0.89	1.76	1.64 to 1.88	0.27
Hand grip strength (kgf)	21.6	20.0 to 23.2	3.7	25.0	22.6 to 27.3	5.2	28.1	25.1 to 31.0	6.6

95%CI (95% confidence interval); Attained PMS (attained predicted mature status).

Table 3

Results of multivariate analyses of variance (MANOVA) and univariate analyses of variance (ANOVA) to examine the effects of chronological age on anthropometrics and physical performances variables (n = 67).

Dependent variables	Analyses of variance					Post-hoc comparisons
	Test	Pillai's trace	*F*	*p*	η^2_p	
Anthropometry	MANOVA	0.545	1.871	0< 0.05	0.272	
Body mass	ANOVA		11.311	0< 0.01	0.261	U12 < U13 & U15
Body Fat mass*	ANOVA		3.854	< 0.05	0.107	U12 < U13
Body Fat free mass	ANOVA		16.435	< 0.01	0.339	U12 < U13 & U15
Stature	ANOVA		17.717	< 0.01	0.356	U12 < U13 & U15
Sitting height	ANOVA		13.251	< 0.01	0.239	U12 < U13 & U15
Arm span	ANOVA		13.800	< 0.01	0.301	U12 < U13 & U15
Superior members length	ANOVA		5.719	< 0.01	0.152	U12 < U13 & U15
Hand length	ANOVA		10.093	< 0.01	0.240	U12 < U13 & U15
Inferior members length	ANOVA		15.980	< 0.01	0.333	U12 < U13 & U15
Foot length	ANOVA		6.524	< 0.01	0.169	U12 < U13 & U15
Arm circumference	ANOVA		7.704	< 0.01	0.194	U12 < U13 & U15
Calf circumference	ANOVA		8.847	< 0.01	0.217	U12 < U13 & U15
Physical fitness	MANOVA	0.509	2.876	< 0.01	0.254	
Pacer test	ANOVA		6.568	< 0.01	0.170	U12 < U15
Line-drill test	ANOVA		7.005	< 0.01	0.180	U12 > U15
Agility 10x5 shuttle run*	ANOVA		1.824	0.170	0.054	
60-s sit-ups	ANOVA		0.739	0.482	0.023	
2-kg ball throw	ANOVA		18.220	< 0.01	0.363	U12 < U13 & U15
Standing long jump*	ANOVA		5.817	< 0.01	0.154	U12 < U13 & U15
Hand grip strength*	ANOVA		7.977	< 0.01	0.200	U12 < U15

*η^2_p (partial eta square); * the test was performed on the log-transformed variable.*

Table 4

Descriptive statistics (mean and standard deviation), results of multivariate analyses of variance (MANOVA) and univariate analyses of variance (ANOVA) to examine the effects of maturity status on anthropometry and physical fitness variables (n = 67).

Dependent variables	Contrasting Maturity Group				Analyses of variance				
	Latest Maturing (n=35)		Earliest Maturing (n=32)						
	Mean	SD	Mean	SD	Test	Pillai's trace	F	p	η^2_p
Anthropometry					MANOVA	0.669	10.085	< 0.01	0.669
Body mass (kg)	41.3	8.5	54.4	11.2	ANOVA		29.027	< 0.01	0.309
Body Fat mass (kg)*	8.5	5.6	10.8	6.9	ANOVA		2.931	0.092	0.043
Body Fat free mass (kg)	32.9	4.1	43.6	7.1	ANOVA		58.426	< 0.01	0.473
Stature (cm)	147.1	6.0	161.6	7.4	ANOVA		76.719	< 0.01	0.541
Sitting height (cm)	76.7	2.7	83.7	4.5	ANOVA		62.067	< 0.01	0.488
Arm span (cm)	147.7	7.8	161.1	9.0	ANOVA		42.323	< 0.01	0.394
Superior members length (cm)	58.0	3.5	62.6	6.1	ANOVA		15.082	< 0.01	0.188
Hand length (cm)	15.9	1.2	17.9	1.1	ANOVA		45.298	< 0.01	0.411
Inferior members length (cm)	70.5	4.2	77.9	3.9	ANOVA		56.441	< 0.01	0.465
Foot length (cm)	23.5	1.9	25.4	1.6	ANOVA		18.646	< 0.01	0.223
Arm circumference (cm)	23.8	2.7	26.9	3.2	ANOVA		18.399	< 0.01	0.221
Calf circumference (cm)	31.1	2.6	34.2	3.1	ANOVA		19.170	< 0.01	0.228
Physical fitness					MANOVA	0.581	11.700	< 0.01	0.581
Pacer test (m)	615	217	913	340	ANOVA		18.684	< 0.01	0.223
Line-drill test (s)	37.24	3.04	34.94	2.96	ANOVA		9.750	< 0.01	0.130
Agility 10x5 shuttle run (s)*	19.61	2.27	19.26	1.95	ANOVA		0.421	0.519	0.006
60-s sit-ups (count)	40	9	43	10	ANOVA		1.086	0.301	0.016
2-kg ball throw (m)	4.49	0.85	6.03	1.05	ANOVA		43.757	< 0.01	0.402
Standing long jump (m)*	1.53	0.27	1.86	0.74	ANOVA		9.101	< 0.01	0.123
Hand grip strength (kgf)*	21.71	3.85	28.19	5.84	ANOVA		29.203	< 0.01	0.310

*SD (standard deviation); η^2_p (partial eta square); * the test was performed on the log-transformed variable.*

Table 5

Results of two-way MANOVA to examine the interaction effect (chronological age × maturity status) and results of MANCOVA to assess the maturity effect when controlling by age on anthropometry and physical performance variables (n = 67).

Dependent variables	Test	Interaction effect Age x Maturity				Maturity effect (controlling for age)			
		Pillai's trace	F	p	η^2_p	Pillai's trace	F	p	η^2_p
Anthropometry	MANOVA*	0.281	1.843	0.070	0.281				
Physical fitness	MANOVA*	0.110	0.991	0.447	0.110				
Anthropometry	MANCOVA					0.481	4.097	< 0.01	0.481
Body mass	ANCOVA						9.278	< 0.05	0.127
Body Fat mass**	ANCOVA						1.226	0.272	0.019
Body Fat free mass	ANCOVA						14.677	< 0.01	0.187
Stature	ANCOVA						23.046	< 0.01	0.265
Sitting height	ANCOVA						20.055	< 0.01	0.239
Arm span	ANCOVA						11.538	< 0.01	0.153
Superior members length	ANCOVA						3.513	0.065	0.052
Hand length	ANCOVA						16.402	< 0.01	0.204
Inferior members length	ANCOVA						15.715	< 0.01	0.197
Foot length	ANCOVA						5.043	< 0.05	0.073
Arm circumference	ANCOVA						4.685	< 0.05	0.068
Calf circumference	ANCOVA						7.613	< 0.01	0.106
Physical fitness	MANCOVA					0.318	3.859	< 0.01	0.318
Pacer test	ANCOVA						4.928	< 0.05	0.071
Line-drill test	ANCOVA						0.031	0.861	0.000
Agility 10x5 shuttle run**	ANCOVA						2.320	0.133	0.035
60-s sit-ups	ANCOVA						0.018	0.894	0.000
2-kg ball throw	ANCOVA						5.894	< 0.05	0.084
Standing long jump**	ANCOVA						0.378	0.541	0.006
Hand grip strength**	ANCOVA						6.522	< 0.05	0.092

*η^2_p (partial eta square); * two-way MANOVA; ** the test was performed on the log-transformed variable.*

Similar studies with youth judokas and other youth martial arts athletes are scarce. Torres-Luque et al. (2015) studied 146 judo athletes aged 14-17 years and noticed an age effect, with older judokas presenting higher handgrip strength than younger judokas, which are results comparable to those of the present study. Branco et al. (2019) in the search for alternatives of classification of youth karate athletes which would consider biological maturation (bio-banding), evidenced maturational differences within weight categories in a sample of 20 females (11.76 ± 2.49 yrs) and 34 males (11.74 ± 2.49 yrs). Fukuda et al. (2018) in a study which investigated the influence of somatic maturation on indicators of muscular morphology, biomechanical variables, and bilateral asymmetry, evidenced that somatic maturity had the greatest relationship with handgrip performance and lower-body plyometric ability. However, research examining individual and combined contribution of chronological age, and biological maturation to performance in judo is limited. The present study intended to contribute to fill this gap. The apparently greater effect of biological maturation on the anthropometry and physical performance of youth judokas, in comparison with the age effect, corroborates the literature and points to the need to maturation control in training and competition of youth judo athletes.

Training experience is another variable that deserves consideration in studies assessing the impact of maturation on youth judo and combat sports athletes. In a recent study investigating a sample of youth judokas with a similar age range, but with greater training experience than in the present study, it was found that growth and maturation predicted performance in generic neuromuscular tests, except for the standing long jump, while growth, maturation and training experience explained the variation in a judo-specific test (Detanico et al., 2020). Courel-Ibnez et al. (2018) indicated that the accumulated training experience improved the ability to perform the required judo technique. In the present study, which used generic tests to assess physical performance of youth judokas, where the application of a specific technique is not required, training experience was considered only for the inclusion of participants in the sample. This is a limitation that should be addressed in future studies, with the inclusion of accumulated judo training experience as a relevant variable.

Although the age-independent effect was evidenced, analyses performed allow us to understand that the maturational effect had a greater impact on the morphology and physical performance of youth judokas evaluated, since this effect remained after controlling for age. The opposite did not occur with the effect of age disappearing upon maturation control. Furthermore, no significant effect of the interaction between chronological age and maturation was evidenced, which could have been caused by the small sample size due to the difficulty of recruiting more youth judo athletes. The maturation effect on physical performance evidenced in the present study converges with the cited investigations, most notable on upper body and handgrip strength and aerobic and anaerobic performance, characteristics which are among the foremost to be developed in judokas (Bonitch-Góngora et al., 2013; Franchini et al., 2009; Thomas et al., 1989), and on which the maturation effect remained even after controlling for age, notably in the aerobic performance tests and in the upper limb and handgrip strength tests.

A major limitation of this study refers to predicting/estimating biological maturation as opposed to direct measurements. PMS has been used in several studies as a non-invasive indicator of biological maturation and was reported with a reasonable validity when compared with gold-standard methods (Coelho et al., 2004). However, this method requires the stature of the biological parents to predict the adult stature of the evaluated individual. In this study, this information was obtained through self-report, which might cause bias.

It has been suggested that within combat sports, such as judo, chronological age, weight categories and skill levels could minimize the maturity effect over the youth judokas performance (Fukuda, 2015; Krstulović et al., 2005). However, due to the little number of investigations on the subject it cannot be refuted nor proved whether this was the case. In addition, there are studies that outline the possibility of maturation effect and relative age effect on performance of youth judokas despite the division into weight categories

Moreover, investigators and sports organizations are critical to the use of body mass as a criterion for youth combat sports athletes as a consequence of the increasing use of rapid weight loss in the pre-competitive period as a strategy to gain competitive advantage, with possible health and performance implications (Dubnov-Raz et al., 2015). Future investigations should consider the effectiveness of categorization by chronological age and body mass in the control of the maturational effect, as well as the search for classification criteria which could substitute the use of weight.

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References

Altimari JM, Altimari LR, Bortolotti H, Junior AF, Gabardo JM, Buzzachera CF, Frisselli A, Moraes AC. The Relative Age Effect on Anthropometry, Body Composition, Biological Maturation and Motor Performance in Young Brazilian Soccer Players. *J Hum Kinet*, 2021; 77(1): 147–157

Andreato LV, Andreato TV, Santos JFS, Esteves JV, Conti D, Moraes SMF, Franchini E. Weight loss in mixed martial arts athletes. *J Combat Sport Martial Arts*, 2014; 5(2): 117–123

Beunen G. Biological age in pediatric exercise research.In O. Bar-Or (Ed.), *Advances in Pediatric Sport Sciences. Volume Three – Biological Issues*, 1989; Champaign, Illinois: Human Kinetics

Bonitch-Góngora JG, Almeida F, Padial P, Bonitch-Domínguez JG, Feriche B. Maximal isometric handgrip strength and endurance differences between elite and non-elite young judo athletes. *Arch Budo*, 2013; 9(4): 239–248

Branco M, Vencesbrito A, Seabra AP, Mercê C, Rodrigues-Ferreira MA, Milheiro V, Catela D. Exploratory study on maturation and competition level in young karate practitioners. *Rev Artes Marciales Asiáticas*, 2019; 14(1): 1–8

Carvalho HM, Coelho e Silva MJ, Figueiredo AJ, Gonçalves CE, Castagna C, Philippaerts RM, Malina RM. Cross-validation and reliability of the line-drill test of anaerobic performance in basketball players 14-16 years. *J Strength Cond Res*, 2011; 25(0): 1113–1119

Carvalho HM, Gonçalves CE, Collins D, Paes RR. Growth, functional capacities and motivation for achievement and competitiveness in youth basketball: an interdisciplinary approach. *J Sports Sci*, 2018; 36(7): 742–748

Cesario KA, Dulla JM, Moreno MR, Bloodgood AM, Dawes JJ, Lockie RG. Relationships between Assessments in a Physical Ability Test for Law Enforcement: Is There Redundancy in Certain Assessments?. *Int J Exerc Sci*, 2018; 11(4): 1063

Coelho MJ, Reyes MEP, Malina RM. Assessment of biological maturation in adolescent athletes – application of different methods with soccer and hockey players. In *Youth Sports: Growth, Maturation and Talent*, 2004

Courel-Ibnez J, Franchini E, Escobar-Molina R. Is the Special Judo Fitness Test Index discriminative during formative stages? Age and competitive level differences in U13 and U15 children. *Ido Mov Cult Martial Arts Anthropol*, 2018; 18(3): 37–41

Cumming SP, Lloyd RS, Oliver JL, Eisenmann JC, Malina RM. Bio-banding in Sport: Applications to Competition, Talent Identification, and Strength and Conditioning of Youth Athletes. *Strength Cond J*, 2017; 39(2): 34–47

Detanico D, Kons RL, Fukuda DH, Teixeira AS. Physical Performance in Young Judo Athletes: Influence of Somatic Maturation, Growth and Training Experience. *Res Q Exerc Sport*, 2020; 1–8

Dubnov-Raz G, Mashiach-Arazi Y, Nouriel A, Raz R, Constantini NW. Can height categories replace weight categories in striking martial arts competitions ? A pilot study. *J Hum Kinet*, 2015; 47(September): 91–98

Franchini E, de Moraes Bertuzzi RC, Takito MY, Kiss M APDM. Effects of recovery type after a judo match on blood lactate and performance in specific and non-specific judo tasks. *Eur J Appl Physiol*, 2009; 107(4): 377–83

Fukuda DH. Analysis of the Relative Age Effect in Elite Youth Judo Athletes. *Int J Sports Physiol Perform*, 2015; 10(8): 1048–1051

Fukuda DH, Beyer KS, Boone CH, Wang R, Monica MB LA, Wells AJ, Hoffman JR, Stout JR, Stout JR. Developmental associations with muscle morphology, physical performance, and asymmetry in youth judo athletes. *Sport Sci Health*, 2018; 14(3): 555–562

Khamis HJ, Roche AF. Predicting adult stature without using skeletal age: the Khamis-Roche Method. *Pediatrics*, 1994; 94(4): 504–507

Knapik A, Saulicz E, Kuszewski M, Rottermund J, Kokosz M, Saulicz M. The impact of an intensive two-year judo training at the dynamics of the morphological development in adolescents. *Arch Budo*, 2014; 10(1): 155–160

Krstulović S, Sekulić D, Sertić H. Anthropological determinants of success in young judoists. *Coll Antropol*, 2005; 29 697–703

Lohman TG, Roche AF, Martorell R. Anthropometric standardization reference manual, 1988; Champaign, Illinois: Human Kinetics

Malina RM, Bouchard C, Bar-Or O. *Growth, Maturation, and Physical Activity* (2nd ed.) Champaign, Illinois: Human Kinetics; 2004

Malina RM, Rogol AD, Cumming SP, Coelho E Silva MJ, Figueiredo AJ. Biological maturation of youth athletes: Assessment and implications. *Br J Sports Med*, 2015; 49(13): 852–859

Malina RM, Beunen GP. Matching of opponents in youth sports.In O. Bar-Or (Ed.), *The child and adolescent athlete. Encyclopaedia of Sports Medicine*; (6th ed., pp. 202–213) Blackwell Science; 1996

Matthys SPJ, Fransen J, Vaeyens R, Lenoir M, Philippaerts R. Differences in biological maturation, anthropometry and physical performance between playing positions in youth team handball. *J Sports Sci*, 2013; 31(12): 1344–1352. https://doi.org/10.1080/02640414.2013.781663

Meylan CM, Cronin J, Hopkins WG, Oliver J. Adjustment of measures of strength and power in youth male athletes differing in body mass and maturation. *Pediatr Exerc Sci*, 2014; 26(1): 41–8

Nabofa OE. Relationship between Judo Skills Acquisition Ability and Body Composition of Individuals at Different Growth and Development Stages. *Anthropologist*, 2012; 14(3): 261–267

Research C of EC of E on S. EUROFIT: Handbook for the European test of physical fitness, 1996; (2nd ed.) Rome: Committee for the Development of Sport

Slaughter M, Lohman T, Boileau R, Horswill CA, Stillman RJ, Van Loan MD, Bemben DA. Skinfold Equations for Estimation of Body Fatness in Children and Youth. *Hum Biol*, 1988; 60(5): 709

Thomas SG, Cox MH, LeGal YM, Verde TJ, Smith HK. Physiological profiles of the Canadian National Judo Team. *Can J Sport Sci*, 1989; 14(3): 142–7

Till K, Cobley S, O' Hara J, Cooke C, Chapman C. Considering maturation status and relative age in the longitudinal evaluation of junior rugby league players. *Scand J Med Sci Sport*, 2014; 24(3): 569–576

Torres-Luque G, Hernandez-Garcia R, Garatachea N, Nikolaidis PT. Anthropometric characteristics and neuromuscular function in young judo athletes by sex, age and weight category. *Sport Sci Health*, 2015; 117–124

Torres-Unda J, Zarrazquin I, Gil J, Ruiz F, Irazusta A, Kortajarena M, Seco J, Irazusta J. Anthropometric, physiological and maturational characteristics in selected elite and non-elite male adolescent basketball players. *J Sports Sci*, 2013; 31(2): 196–203

Towlson C., Cobley S, Parkin G, Lovell R. When does the influence of maturation on anthropometric and physical fitness characteristics increase and subside?. *Scand J Med Sci Sport*, 2018; 28(8): 1946–1955

Towlson Chris, Salter J, Ade JD, Enright K, Harper LD, Page RM, Malone JJ. Maturity-associated considerations for training load, injury risk, and physical performance in youth soccer: One size does not fit all. *J Sport Heal Sci*, 2020; 0–32

Vossen JF, Kramer JE, Burke DG, Vossen DP. Comparison of Dynamic Push-Up Training and Plyometric Push-Up Training on Upper-Body Power and Strength. *J Strength Cond Res*, 2000; 14(3): 248–253

Zubitashvili G. Adjusting the Training Process in Judo According to Physical and Functional Parameters. *Kūno Kultūra Sport*, 2011; 82(3): 68–75

Corresponding author:

Bruno B. Giudicelli
Federal University of Alagoas – Campus Arapiraca
Laboratory of Cineanthropometry, Physical Activity and Health Promotion (LACAPS)
Address: Manoel Severino Barbosa Avenue, Bom Sucesso district,
city of Arapiraca, State of Alagoas, Brazil.
Postal Code: 57309-005
Phone: +55 82 98111-0109
E-mail: bruno.giudicelli@arapiraca.ufal.br