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ORIGINAL ARTICLE

Anthropometric characteristics and neuromuscular function in young judo athletes by sex, age and weight category

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Abstract
Purpose The aim of the study was to examine anthropometric characteristics and neuromuscular function in young judo athletes by sex, age and weight category.
Methods 146 child and cadet judo athletes were examined for height, body mass (BM), body fat percentage (BF), countermovement jump (CMJ), sit-and-reach (SAR) test and handgrip muscle strength (HMS).
Results The results showed that male adolescents were taller, had more HMS, and less BF and flexibility than girls. Significant differences in the sex and weight category were observed, chiefly in BF and body mass index. There were no differences in time to peak force of HMS and CMJ.
Conclusions Based on these findings, special attention should be put to heavy BM categories targeting low BF and high muscle mass, which might contribute to improved neuromuscular function and in turn contribute to the dynamics *randori*. This study might help profiling the young judoka taking into account sex, age and BM category.

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Keywords Judo · Physical fitness · Body composition · Flexibility · Muscle strength · Adolescence

Introduction

Judo is a dynamic combat sport, which is of intermittent nature and requires physical effort of high metabolic intensity [1, 2]. The temporal structure of this sport has changed over time, as the number and duration of pauses between active game-play have decreased, whereas the duration of active game-play has increased [3]. Actually, there are eight weight categories and judo athletes compete in games depending on sex and age [4]. According to the category-specific demands, differences in technique, tactics, physiology and functional aspects have been studied in judo athletes [5]. Among these parameters, judo athletes should possess optimal levels of anthropometric characteristics and neuromuscular function.

Height, body mass (BM), body fat percentage (BF) and various physical fitness components in judo athletes have been studied in various levels of competition, mainly elite and non-elite level [5–7]; both sexes [8–10] and in different weight categories [11, 12]. It is now well established that one of the goal of judo athletes training is to maximize the amount of lean tissue, minimize the amount of BF and BM, and increase muscle strength (e.g., isometric handgrip strength) [5, 12, 13]. Most of the abovementioned studies have been conducted on adult judo athletes and very limited data exist with regard to young judo athletes. Moreover, the few studies on young judo athletes examined either athletes only in the higher spectrum of adolescence [11] or focused only on anthropometric characteristics [12].

However, it would be interesting to be informed about sex, age and category variation in young judo athletes not only with regard to anthropometric characteristics, but also about aspects of neuromuscular function such as flexibility and muscle strength of upper and lower limbs. Recent studies from other sports (e.g., soccer and basketball) on anthropometric characteristics, flexibility, handgrip strength and vertical jump have shown differences among age groups in adolescence, where those who were older achieved better scores than the younger [14–18]. Also, time to peak force (TPF) is vital in this sport, because it has an implication to the development of attack and defense techniques in judo [11, 13]. In addition to the study of age-related differences, it is also important to profile young judo athletes by weight categories. Knowledge about the profile of young judo athletes might contribute to talent identification and optimize sport training. Therefore, the objectives of the present study were to examine differences in height, BM, BF and neuromuscular function by sex, age and weight category in young judo athletes.

Materials and methods

Study design and participants

A non-experimental, descriptive design was used in this study. 146 adolescent judo athletes were selected (14–17 years). All judo athletes participated in Spanish Judo Championships and they were practicing judo training for 6 h/wk. The sample was all participants of this competition. They were divided by sex (male or female), age (child (younger athletes) or cadet (older athletes)) and weight category (Table 1). Participants were familiarized with the testing procedures used in the present study through pre-investigation familiarization sessions. Oral informed consent was received from all participants or parents after verbal explanation of the experimental design. The present study was approved by the local institutional review board (Catholic University San Antonio of Murcia, Spain) and was conducted according to the ethical principles for medical research involving human subjects of Declaration of Helsinki (2008).

Procedures

All participants performed the following anthropometric and neuromuscular function tests in the respective order:

Anthropometric characteristics

Stature and BM were measured. BMI was calculated as the quotient of BM (kg) to height squared (m^2). An electronic weight scale (HD-351 Tanita, Illinois, USA) was used for BM measurement (in the nearest 0.1 kg) and a portable stadiometer (SECA, Leicester, UK) for stature (0.1 cm). BF was evaluated from bioelectric impedance (BC-522 Tanita, Illionis, USA). All the players were summoned in the morning, after 8 h sleep and before breakfast, not having taken any type of liquids and having gone to bathroom 30 min before the beginning of the programmed testing session. Furthermore, they had not carried out any type of physical effort in the previous 12 h to the measurements.

Countermovement jump (CMJ)

The participants performed three trials for each jumping exercise, separated by 3 min break, and the best score was recorded [19]. Height of each jump was estimated using the Ergo-Jump (Bosco System) and was expressed as centimeter.

Sit-and-reach (SAR) test

The SAR protocol was employed for the assessment of lower back and hamstring flexibility [20]. Two trials were performed, separated by 2-min break, and the best score in cm was recorded.

Handgrip muscle strength (HMS)

HMS was evaluated with grip and traction dynamometer (Dynamometer PCE-FG 1K). Participants stood with arms at chest height. From this position they took a belt gripping the dynamometer and they performed an isometric

Table 1 Weight categories and number of participants by sex and age

	Weight categories						
	1	2	3	4	5	6	7
m ($n = 37$)	−42 ($n = 6$)	−46 ($n = 5$)	−50 ($n = 5$)	−55 ($n = 6$)	−60 ($n = 5$)	−66 ($n = 5$)	66 + ($n = 5$)
M ($n = 37$)	−50 ($n = 6$)	−55 ($n = 5$)	−60 ($n = 5$)	−66 ($n = 6$)	−73 ($n = 7$)	−81 ($n = 4$)	81 + ($n = 4$)
f ($n = 36$)	−40 ($n = 5$)	−44 ($n = 5$)	−48 ($n = 5$)	−52 ($n = 6$)	−57 ($n = 5$)	−63 ($n = 5$)	63 + ($n = 5$)
F ($n = 36$)	−44 ($n = 3$)	−48 ($n = 7$)	−52 ($n = 5$)	−57 ($n = 6$)	−63 ($n = 5$)	−70 ($n = 5$)	70 + ($n = 5$)

M and F stand for older male and female judo athletes, respectively; m and f stand for younger male and female judo athletes, respectively contraction. This position is responsible for setting and controlling the opponent through kumi-kata [13]. Two trials were performed, separated by 2-min break and the best score was recorded. The results of HMS were expressed in kg and of time to peak force (TPF) in second.

Statistical analyses

IBM SPSS v.21.0 (SPSS, Chicago, USA) was used to perform statistical analyses. Descriptive statistics (mean and standard deviation) were used for all data. Student independent *t* test examined differences between male and female participants and between age groups. Effect size (ES) for statistical differences in *t* test was determined by the following criteria: ES ≤ 0.2 trivial, $0.2 <$ ES ≤ 0.6 small, $0.6 <$ ES ≤ 1.2 moderate, $1.2 <$ ES ≤ 2.0 large, and ES > 2.0 very large [21, 22]. Differences among BM categories were tested by one-way analysis of variance (ANOVA) with a subsequent Bonferroni post hoc test (if differences between groups were verified). ES for statistical differences in ANOVA was described by eta squared, which was classified as small ($0.01 < \eta^2 \leq 0.06$), medium ($0.06 < \eta^2 \leq 0.14$) and large ($\eta^2 > 0.14$) [21].

Results

The number of judo athletes by sex, age and BM category can be found in Table 1. A similar number of male (50.7 %) and female judo athletes (49.3 %) participated in this study and were assigned proportionally into seven BM categories: 13.7 % in the first BM category (the lightest), 15.1 % in the second, 13.7 % in the third, 16.4 % in the fourth, 15.1 % in the fifth, 13.0 % in the sixth and 13.0 % in the seventh (the heaviest).

The differences between male and female judo athletes can be seen in Table 2. Male judo athletes were taller (6.0 cm (3.1; 8.8), mean difference (95 % confidence intervals) Cohen's $d = 0.69$) with lower BF [−11.9 % (−14.0; −9.9), $d = -1.92$], FM [−6.7 kg (−8.8; −4.5), $d = -1.01$] and SAR [−2.9 cm (−5.5; −0.4), $d = -0.37$], and higher FFM (11.1 kg (8.3; 13.9), $d = 1.30$) and HMS [11.2 kg (7.9; 14.5), $d = 1.12$] than their female counterparts. In contrast, there was no statistical difference with regard to BM [4.3 kg (0; 8.8), $d = 0.33$], BMI [−0.1 kg.m^{-2} (−0.1 (−1.3; 1.1), $d = -0.02$], HMP [0.2 s (−0.2; 0.6), $d = 0.15$] and CMJ [3.2 cm (−0.8; 7.1), $d = 0.26$]. Anthropometric characteristics and neuromuscular function by age, sex and BM categories can be seen in Tables 3 and 4.

Discussion

The objective of the present study was to examine the anthropometric and neuromuscular profile of young judo athletes by age and BM. With regard to anthropometric characteristics, there was large difference in BF between male and female adolescent (12 and 24 %, respectively) (Table 1). Previous studies have reported BF lower than 10 % in elite male judo athletes [7, 9, 23]. All judo athletes, who were recruited for the present study, were participating in national championships, and consequently, used to modify their BM regularly to compete to an advantageous weight category. It has been observed previously that judo athletes can lose between 3 and 6 % BF the last weeks before the competition [8, 24–26]. BF of participants was similar to that found in the literature [12].

We observed that both BF and BMI increased from low to high BM categories in both sex and age groups (Table 3). Indeed, the range of BF extended from 4 to 9 %, with the exception of heavy BM categories (>78 kg for females and >100 kg for males) [5]. Only one study in the past had presented a significant difference in BF between best and lowest ranked judo athletes [27]. Pococco et al. [28] showed an increase of BF according to age from U-15

Table 2 Characteristics of participants by sex

	Males ($n = 74$)	Females ($n = 72$)	*P* level
Age (yr)	14.72 (1.07)	14.47 (1.15)	$t_{144} = 1.36, p = 0.176$
BM (kg)	60.8 (13.8)	56.4 (13.1)	$t_{144} = 1.97, p = 0.051$
Height (cm)	167.7 (9.9)	161.7 (7.4)	$t_{144} = 4.11, p < 0.001$
BMI (kg m^{-2})	21.4 (3.0)	21.4 (4.2)	$t_{144} = -0.15, p = 0.883$
BF (%)	12.7 (4.5)	24.6 (7.5)	$t_{144} = -11.7, p < 0.001$
FM (kg)	8.0 (4.5)	14.7 (8.2)	$t_{144} = -6.16, p < 0.001$
FFM (kg)	52.7 (10.6)	41.6 (5.7)	$t_{144} = 7.85, p < 0.001$
SAR (cm)	2.0 (7.9)	4.9 (7.8)	$t_{144} = -2.25, p = 0.026$
HMS (kg)	37.7 (11.9)	26.6 (7.4)	$t_{144} = 6.79, p < 0.001$
TPF (s)	2.2 (1.3)	2.0 (1.4)	$t_{144} = 0.90, p = 0.371$
CMJ (cm)	30.8 (10.5)	27.7 (13.5)	$t_{144} = 1.58, p = 0.116$

BM body mass, *BMI* body mass index, *BF* body fat percentage, *FM* fat mass, *FFM* fat-free mass, *SAR* sit-and-reach, *HMS* handgrip muscle strength, *TPF* time to peak force in handgrip muscle test, *CMJ* countermovement jump

Table 3 Anthropometry and body composition of participants by sex, age and weight category

		Total	Weight categories							*P* level
			1	2	3	4	5	6	7	
Age	m	13.81 (0.50)	13.35 (0.72)	13.58 (0.69)	13.86 (0.22)	13.94 (0.29)	13.99 (0.32)	13.94 (0.43)	14.08 (0.27)	$F_{6,30} = 1.72$, $p = 0.152$, $\eta^2 = 0.26$
	M	15.62 (0.63)	15.38 (0.71)	15.54 (0.73)	15.58 (0.59)	15.76 (0.58)	15.60 (0.64)	16.08 (0.26)	15.51 (0.93)	$F_{6,30} = 0.54$, $p = 0.777$, $\eta^2 = 0.10$
	f	13.46 (0.60)	13.01 (0.72)	13.75 (0.44)	13.10 (0.71)	13.45 (0.55)	13.92 (0.37)	13.53 (0.53)	13.47 (0.62)	$F_{6,29} = 1.60$, $p = 0.184$, $\eta^2 = 0.25$
	F	15.47 (0.48)	15.63 (0.51)	15.25 (0.32)	15.52 (0.66)	15.11 (0.46)	15.76 (0.45)	15.66 (0.49)	15.60 (0.29)	$F_{6,29} = 1.53$, $p = 0.203$, $\eta^2 = 0.24$
BM (kg)	m	55.7 (13.3)	39.9 (3.4)$^{3-7}$	45.2 (0.8)$^{4-7}$	43.3 (0.8)$^{1,5-7}$	54.3 (0.9)^{1,2,6,7}	59.1 (0.7)$^{1-3,7}$	64.5 (2.1)$^{1-4,7}$	81.4 (8.1)$^{1-6}$	$F_{6,30} = 86.17$, $p < 0.001$, $\eta^2 = 0.95$
	M	65.8 (12.6)	49.4 (0.5)$^{2-7}$	54.6 (1.6)$^{1,4-7}$	59.1 (1.8)$^{1,4-7}$	65.5 (1.7)$^{1-3,5-7}$	72.4 (1.7)$^{1-4,6,7}$	78.2 (2.2)$^{1-5,7}$	88.9 (5.7)$^{1-6}$	$F_{6,30} = 163.92$, $p < 0.001$, $\eta^2 = 0.97$
	f	53.1 (11.7)	38.3 (1.4)$^{3-7}$	43.3 (0.7)$^{4-7}$	47.3 (0.9)$^{1,5-7}$	51.7 (0.9)^{1,2,6,7}	55.9 (1.6)$^{1-3,7}$	60.1 (1.9)$^{1-4,7}$	75.5 (6.7)$^{1-6}$	$F_{6,29} = 100.94$, $p < 0.001$, $\eta^2 = 0.95$
	F	59.6 (13.8)	43.6 (1.4)$^{4-7}$	48.2 (0.7)$^{4-7}$	51.4 (0.8)$^{5-7}$	56.2 (1.4)^{1,2,6,7}	61.4 (2.1)$^{1-3,7}$	67.9 (1.6)$^{1-4,7}$	87.3 (8.6)$^{1-6}$	$F_{6,29} = 87.81$, $p < 0.001$, $\eta^2 = 0.95$
Height (cm)	m	163.0 (8.9)	151.3 (3.9)$^{4-7}$	157.0 (5.3)^{6,7}	161.8 (3.4)	163.8 (7.8)^{1}	165.0 (2.6)^{1}	172.0 (6.5)^{1,2}	171.8 (8.5)^{1,2}	$F_{6,30} = 8.88$, $p < 0.001$, $\eta^2 = 0.64$
	M	172.4 (8.7)	162.8 (2.3)$^{4-7}$	165.2 (4.8)$^{5-7}$	165.6 (6.3)$^{5-7}$	172.2 (5.2)^{1,6}	179.7 (3.9)$^{1-3}$	183.3 (2.8)$^{1-4}$	181.0 (1.4)$^{1-3}$	$F_{6,30} = 20.51$, $p < 0.001$, $\eta^2 = 0.80$
	f	160.4 (7.9)	150.0 (6.2)^{4,6,7}	155.8 (6.4)	159.4 (5.2)	163.8 (8.8)^{1}	162.0 (2.6)	166.0 (7.5)^{1}	165.0 (5.8)^{1}	$F_{6,29} = 4.04$, $p = 0.005$, $\eta^2 = 0.46$
	F	163.0 (6.7)	155.0 (4.4)	157.9 (5.7)	160.4 (3.6)	167.2 (4.4)	164.8 (4.9)	167.8 (7.7)	166.2 (6.4)	$F_{6,29} = 3.85$, $p = 0.006$, $\eta^2 = 0.45$
BMI (kg m^{-2})	m	20.8 (3.3)	17.4 (1.3)$^{4-7}$	18.4 (1.2)$^{5-7}$	18.8 (0.6)$^{5-7}$	20.3 (1.6)^{1,7}	21.7 (0.7)$^{1-3,7}$	21.9 (1.1)$^{1-3,7}$	27.5 (0.6)$^{1-6}$	$F_{6,30} = 48.81$, $p < 0.001$, $\eta^2 = 0.91$
	M	22.0 (2.7)	18.6 (0.6)$^{3-7}$	20.1 (1.4)^{6,7}	21.6 (1.2)^{1,7}	22.2 (1.9)^{1,7}	22.5 (1.5)^{1,7}	23.3 (0.7)^{1,2,7}	27.1 (1.7)$^{1-6}$	$F_{6,30} = 18.03$, $p < 0.001$, $\eta^2 = 0.78$
	f	20.6 (3.8)	17.1 (1.0)$^{5-7}$	17.9 (1.6)^{6,7}	18.7 (1.1)^{7}	19.4 (2.2)^{7}	21.3 (1.0)^{1,7}	21.9 (2.1)^{1,2,7}	27.8 (2.9)$^{1-6}$	$F_{6,29} = 19.96$, $p < 0.001$, $\eta^2 = 0.81$
	F	22.3 (4.4)	18.2 (0.4)$^{5-7}$	19.4 (1.4)$^{5-7}$	22.0 (1.2)^{6,7}	20.2 (1.5)^{6,7}	22.7 (1.4)^{1,2,7}	24.3 (2.5)$^{1-4,7}$	31.5 (1.3)^{1,6}	$F_{6,29} = 41.94$, $p < 0.001$, $\eta^2 = 0.90$
BF (%)	m	13.2 (4.4)	10.1 (2.7)^{7}	10.4 (2.6)^{7}	12.1 (3.1)^{7}	13.0 (4.1)^{7}	12.9 (1.7)^{7}	14.1 (3.7)	20.8 (4.0)$^{1-5}$	$F_{6,30} = 6.17$, $p < 0.001$, $\eta^2 = 0.55$
	M	12.1 (4.5)	8.0 (2.9)^{7}	11.1 (3.4)	12.6 (0.9)	12.8 (4.3)	10.9 (3.9)^{7}	13.2 (5.0)	19.0 (5.0)^{1,5}	$F_{6,30} = 3.74$, $p = 0.007$, $\eta^2 = 0.43$
	f	23.5 (7.5)	16.0 (3.0)$^{5-7}$	16.8 (5.5)$^{5-7}$	21.1 (1.4)^{7}	21.9 (5.3)^{7}	25.7 (2.3)^{1,2,7}	26.2 (4.5)^{1,2,7}	36.8 (4.8)$^{1-6}$	$F_{6,29} = 14.49$, $p < 0.001$, $\eta^2 = 0.75$
	F	25.7 (7.5)	18.3 (2.3)$^{5-7}$	20.7 (3.8)^{6,7}	21.8 (4.8)^{6,7}	22.4 (2.9)^{7}	27.2 (2.8)^{1,7}	29.3 (4.4)$^{1-3,7}$	40.1 (1.5)$^{1-6}$	$F_{6,29} = 22.14$, $p < 0.001$, $\eta^2 = 0.82$
FM (kg)	m	7.8 (4.4)	4.0 (1.2)^{6,7}	4.7 (1.1)^{7}	6.0 (1.6)^{7}	7.0 (2.2)^{7}	7.6 (1.0)^{7}	9.0 (2.2)^{1,7}	16.9 (4.0)$^{1-6}$	$F_{6,30} = 21.77$, $p < 0.001$, $\eta^2 = 0.81$
	M	8.3 (4.5)	3.9 (1.4)^{6,7}	6.0 (1.9)^{7}	7.5 (0.4)^{7}	8.4 (2.8)^{7}	7.9 (2.9)^{7}	10.4 (4.1)^{1}	17.1 (5.7)$^{1-5}$	$F_{6,30} = 8.92$, $p < 0.001$, $\eta^2 = 0.64$
	f	13.2 (7.3)	6.1 (1.0)$^{5-7}$	7.3 (2.4)$^{5-7}$	10.0 (0.7)^{7}	11.3 (2.7)^{7}	14.4 (1.6)^{1,2,7}	15.8 (2.8)^{1,2,7}	28.0 (5.3)$^{1-6}$	$F_{6,29} = 34.86$, $p < 0.001$, $\eta^2 = 0.88$
	F	16.2 (8.8)	8.0 (0.8)$^{5-7}$	10.0 (1.9)$^{5-7}$	11.2 (2.7)^{6,7}	12.6 (1.9)^{6,7}	16.7 (1.8)^{1,2,7}	20.0 (3.2)$^{1-4,7}$	35.1 (4.5)$^{1-6}$	$F_{6,29} = 59.42$, $p < 0.001$, $\eta^2 = 0.92$

Table 3 continued

		Total	Weight categories							P level
			1	2	3	4	5	6	7	
FFM (kg)	m	48.0 (9.6)	35.8 (3.0)$^{5–7}$	40.5 (1.5)$^{1,5–7}$	43.3 (1.3)$^{1,5–7}$	47.3 (2.9)^{1,6,7}	51.4 (1.2)$^{1–3,7}$	55.5 (4.2)$^{1–4,7}$	64.5 (6.8)$^{1–6}$	$F_{6,30} = 41.22$, $p < 0.001$, $\eta^2 = 0.89$
	M	57.5 (9.4)	45.4 (1.7)$^{3–7}$	48.6 (2.4)$^{4–7}$	51.7 (2.0)$^{1,4–7}$	57.1 (2.5)$^{1–3,5–7}$	64.5 (2.5)$^{1–4,7}$	67.8 (2.1)$^{1–4}$	71.8 (1.2)$^{1–5}$	$F_{6,30} = 110.13$, $p < 0.001$, $\eta^2 = 0.96$
	f	39.9 (5.3)	32.2 (2.0)$^{3–7}$	36.0 (2.2)$^{5–7}$	37.3 (1.1)^{1,6,7}	40.4 (2.8)^{1,7}	41.5 (0.8)^{1,7}	44.4 (2.9)$^{1–3}$	47.6 (3.3)$^{1–5}$	$F_{6,29} = 24.64$, $p < 0.001$, $\eta^2 = 0.84$
	F	43.4 (5.6)	35.6 (2.1)$^{4–7}$	38.2 (1.5)$^{4–7}$	40.2 (2.0)$^{6–7}$	43.6 (1.0)^{1,2,7}	44.7 (2.3)^{1,2,7}	48.0 (2.5)$^{1–3}$	52.2 (4.3)$^{1–5}$	$F_{6,29} = 27.02$, $p < 0.001$, $\eta^2 = 0.85$

The number is the difference between weight category

BM body mass, *BMI* body mass index, *BF* body fat percentage, *FM* fat mass, *FFM* fat-free mass, *m* male child, *M* male cadet, *f* female child, *F* female cadet

(9.9 %), U-17 (11.1 %) to +20 years (17.3 %). Since judo athletes compete in BM categories, it is not surprising that they should exhibit high relative strength (i.e., strength expressed in relative to BM values). This means that they must have smaller BF than an average male of the same age and BM [5].

In contrast, BF in girls' heaviest BM category was very high, with values between 36 and 40 % (Table 3). It has been supported that judo in heavy BM categories was slower than in low categories, with male athletes being active and risky using foot judo, whereas female athletes using the technique of soil [29]. However, the increased BF values in female athletes should be considered by coaches and perhaps be controlled in the future to avoid negative health implications.

In the same direction, HMS was differentiated by sex presenting higher values in male adolescent (+11 kg) than female adolescent (Table 1). Previous research in young judo athletes had focused on age 7–8 years [30–32], which showed values of 15 kg in HMS. Moreover, a few studies in cadet judo athletes reported values from 30 to 40 kg [11, 32], which was in accordance with the results of the present study. Sex differences were reported in only one study, where higher rates were found in male adolescent than in female adolescent [33]. In addition to a sex effect, we also noticed an effect of age and BM category, in which the oldest athletes showed the highest HMS values and HMS increased from the lightest to the heaviest BM category. These findings were in agreement with those of previous studies on BM categories [34, 35], which reported values close to those found in senior elite judo [6].

In the handgrip muscle strength test, we examined also the time needed to achieve peak force. Due to the explosive nature of judo, we considered that TPF was more sport specific than HMS. TPF was vital in this sport, because it has an implication to the development of attack and defense techniques in judo [11, 13]. In this study, there were no sex- and age-related differences. Participants performed this test before competition, which was an important aspect, because it has been reported that TPF descended as they passed different bouts [13]. This meant that although HMS differentiated participants by sex and age, when it was considered in relation to time, there was no difference. Judo is an intermittent sport with fast actions (e.g., *kumi-kata*), in which obtaining maximum strength in the shortest possible time is vital. This finding might have a direct implication for training, because regardless of sex, age and BM category, all participants were within a range from 1.5 to 3 s (except in the heaviest female cadet BM category). The slowest TPF in the heaviest female BM category might be associated with their increased BF, which led them to take longer time to generate HMS.

Table 4 Sit-and-reach, handgrip muscle strength and countermovement jump of participants by sex, age and weight category

		Total	Weight categories							*P* level
			1	2	3	4	5	6	7	
SAR (cm)	m	−0.9 (7.0)	−8.7 (4.0)^{3,4}	−2.1 (6.6)	4.3 (6.2)^{1}	3.2 (6.1)^{1}	2.1 (5.2)	−2.6 (5.6)	−2.1 (7.9)	$F_{6,30} = 3.13$, $p = 0.017$, $\eta^2 = 0.39$
	M	5.0 (7.6)	3.5 (9.5)	2.8 (8.5)	9.4 (5.1)	7.8 (3.0)	3.6 (9.7)	3.2 (10.8)	4.8 (5.4)	$F_{6,30} = 0.55$, $p = 0.766$, $\eta^2 = 0.10$
	f	4.1 (6.7)	−1.1 (9.3)	8.0 (3.6)	4.8 (3.4)	5.0 (5.7)	1.3 (11.8)	7.0 (3.8)	3.2 (2.9)	$F_{6,29} = 1.16$, $p = 0.352$, $\eta^2 = 0.19$
	F	5.8 (8.7)	10.5 (3.5)	4.2 (8.9)	0.2 (10.4)	5.6 (3.6)	10.6 (4.5)	12.2 (4.9)	−0.1 (13.7)	$F_{6,29} = 1.85$, $p = 0.125$, $\eta^2 = 0.28$
HMS (kg)	m	31.3 (9.4)	22.2 (3.4)^{7}	23.1 (5.8)^{7}	32.1 (9.7)	31.5 (8.6)	32.3 (5.6)	36.0 (7.6)	43.7 (6.4)^{1,2}	$F_{6,30} = 5.91$, $p < 0.001$, $\eta^2 = 0.54$
	M	44.2 (10.8)	31.0 (5.7)$^{4–7}$	37.0 (5.1)^{5}	41.1 (5.0)	47.7 (9.1)^{1}	54.9 (9.5)^{1,2}	48.9 (5.9)^{1}	48.2 (11.2)^{1}	$F_{6,30} = 6.62$, $p < 0.001$, $\eta^2 = 0.57$
	f	24.8 (8.2)	15.3 (0.9)^{6,7}	24.3 (5.1)	20.0 (4.2)^{6}	22.6 (6.0)	27.1 (4.4)	34.7 (9.2)^{1,3}	29.9 (9.0)^{1}	$F_{6,29} = 5.46$, $p = 0.001$, $\eta^2 = 0.53$
	F	28.3 (6.2)	20.2 (3.1)^{7}	25.2 (7.0)	25.6 (2.8)	30.2 (4.3)	30.8 (5.8)	29.7 (6.0)	34.2 (4.5)^{1}	$F_{6,29} = 3.25$, $p = 0.014$, $\eta^2 = 0.40$
TPF (s)	m	2.0 (1.3)	2.8 (1.6)	2.2 (0.9)	2.0 (1.8)	1.8 (1.3)	1.5 (0.7)	2.6 (1.7)	1.2 (0.6)	$F_{6,30} = 0.94$, $p = 0.483$, $\eta^2 = 0.16$
	M	2.4 (1.3)	2.1 (1.0)	3.4 (1.1)	1.9 (0.9)	2.2 (1.3)	3.3 (1.5)	1.5 (0.6)	1.5 (1.0)	$F_{6,30} = 2.47$, $p = 0.046$, $\eta^2 = 0.33$
	f	1.9 (1.4)	1.3 (1.7)	2.2 (1.2)	0.8 (0.4)	2.3 (1.3)	1.6 (1.2)	2.0 (1.3)	3.0 (1.9)	$F_{6,29} = 1.43$, $p = 0.239$, $\eta^2 = 0.23$
	F	2.1 (1.3)	2.8 (0.8)	2.0 (1.6)	1.2 (0.7)^{7}	1.9 (1.3)	1.7 (0.5)^{7}	1.4 (0.3)^{7}	4.0 (1.2)^{3,5,6}	$F_{6,29} = 3.74$, $p = 0.007$, $\eta^2 = 0.44$
CMJ (cm)	m	28.8 (10.6)	24.5 (9.3)	27.0 (9.8)	29.2 (13.3)	37.7 (9.0)	33.3 (4.4)	22.1 (9.7)	27.0 (13.3)	$F_{6,30} = 1.52$, $p = 0.205$, $\eta^2 = 0.23$
	M	32.8 (10.3)	32.7 (13.0)	25.5 (14.2)	39.5 (7.9)	35.5 (6.5)	29.9 (11.0)	40.0 (4.6)	28.1 (2.2)	$F_{6,30} = 1.52$, $p = 0.205$, $\eta^2 = 0.23$
	f	30.6 (15.1)	25.2 (13.0)	42.6 (9.5)	23.6 (8.1)	34.1 (21.2)	30.3 (11.2)	39.4 (19.4)	18.1 (3.8)	$F_{6,29} = 2.02$, $p = 0.095$, $\eta^2 = 0.29$
	F	24.8 (11.1)	34.1 (17.4)	27.7 (5.7)	21.7 (8.5)	19.3 (10.0)	32.3 (19.7)	22.3 (4.9)	19.9 (5.4)	$F_{6,29} = 1.41$, $p = 0.243$, $\eta^2 = 0.23$

The number it is the difference between weight category

SAR sit-and-reach, *HMS* handgrip muscle strength, *TPF* time to peak force in handgrip muscle test, *CMJ* countermovement jump, *m* male child, *M* male cadet, *f* female child, *F* female cadet

The vertical jump test in judo was important, because muscle groups mainly activated during judo throwing technique were those of the lower body, and thus, it might be associated with technical actions such as *ippon*. In this study, there were no differences by sex, age or BM category (Table 4). There were no recent studies on child or cadet judo athletes. Previous findings on senior athletes revealed values around 44–60 cm [36]. Only one study was identified (Sertic et al. [10]) to show values in female (40 cm) and male athletes (58 cm); despite no comparison between groups was realized, their data were higher than those of the present study. In addition, a study spanning from 20 to 80 years of age [37] showed a decrease in CMJ with age. Although there were non-significant differences, the female cadets had lower values. This "non-significant" finding might be attributed to the large variability of data. However, this should be taken into account by coaches, because a low CMJ might limit the speed of actions and the ability to generate optimal technique and defense.

In flexibility (SAR), girls scored better than male adolescent (Table 3), which was in accordance with the existing literature [38]. The sex differences in SAR were not consistent across BM categories. The finding of negative values in male athletes (from −8.7 to −0.9 cm) should be taken into account by coaches, because flexibility is extremely important in combat sports, where it contributes to injury prevention and performing full-range movements [39].

It would be interesting to investigate further on these results, for example, the sex differences in SAR were not consistent across BM categories or BF in girls' heaviest BM category was very high. This might be interesting for coaches.

In conclusion, our results show that male judo athletes were taller, had higher HMS and less BF and SAR than females. Significant differences in the sex and BM category were observed, chiefly in BF and BMI. There were no differences in TPF and CMJ. Based on these findings, special attention should be paid to heavy BM categories targeting low BF and high muscle mass, which might contribute to improved neuromuscular function and in turn contribute to the dynamics *randori*. This study might help profiling the young judoka taking into account sex, age and BM category.

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Conflict of interest The authors declare no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the local institutional review board (Catholic University San Antonio of Murcia) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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