Anthropometric and fitness normative values for young karatekas

AUTHORS: Oscar Martinez-de-Quel[1], Luis M. Alegre[2], Adrián Castillo-García[3], Carlos Ayán[4]

[1] Faculty of Education, Complutense University of Madrid, Spain
[2] GENUD Toledo Research Group, Universidad de Castilla-La Mancha, Toledo, Spain
[3] Fissac – Physiology, Health and Physical Activity, Madrid, Spain
[4] Well-move Research Group, University of Vigo, Spain

Corresponding author:
Oscar Martinez-de-Quel
Faculty of Education
Complutense University
of Madrid, Spain
E-mail: odequel@ucm.es

ABSTRACT: To provide information regarding the anthropometric and fitness profile of young karatekas and to study its evolution with age. Data from top-level karatekas were included in the analysis: 97 athletes in the U14 category (12–13 years old), 238 in cadet (14–15 years old), 261 in junior (16–17 years old) and 177 in U21 (18–20 years old), which makes a total of 773 athlete data sets. Karatekas underwent anthropometric (weight, height, body mass index and body fat percentage) and fitness (sit and reach, 20-m shuttle run, standing long jump, overhead 3-kg ball throw, 10x5-m shuttle run, and plate-tapping) assessments during the training camps organized by the Spanish National Karate Federation between 1999 and 2016. Male karatekas were taller and heavier, and performed better than females in all the fitness dimensions assessed, except for flexibility and speed of upper limb movements. The obtained cardiovascular and lower-body muscular values indicated that karatekas in this study were placed between the 80th and the 90th percentile when compared with the general population. The results of the agility, coordination and speed of upper limb movements, and flexibility tests showed that the karatekas obtained much higher scores than those observed in age-matched populations. Young karatekas show a high fitness level in comparison with the general population, especially with regards to aerobic performance, lower-body muscular power and upper-limb movement speed. Reference values of anthropometric and fitness dimensions are provided in order to be used by coaches, conditioning trainers and sport scientists when testing young male and female karatekas.

INTRODUCTION

Karate is a very popular combat sport, one which is practised in 191 countries worldwide [1]. It is becoming more prominent on the international stage, to the point where the World Karate Federation and its competition rules are recognized by the International Olympic Committee [2]. Thus, karate will be included in the official programme for the Tokyo Olympic Games. Furthermore, as this sport is widely practised by children and adolescents, competition at young ages is very usual even at international level. In fact, karate will be included in the Dakar 2022 Youth Olympic Games (under 18 years old) and the World Karate Federation includes athletes from U-14 (12–13 years old) to junior (16–17 years old) in the Karate 1 Youth League and from cadet (14–15 years old) to U-21 (18–20 years old) in the World Championships.

The high level of karate competitions makes it necessary to improve scientific knowledge of this sport by conducting research into the aspects that determine karatekas' high performance. In this regard, physical fitness is considered a factor that determines karatekas'

physiological profile and that contributes to their competitive success [3]. Research on this topic has provided information on anthropometrics [4] and neuromuscular [5] or metabolic aspects [6], but it has specifically focused on top level senior karatekas. Therefore, very little information exists regarding the fitness profile of young karatekas (those aged 12–20 years).

Reference fitness values are a great help for conditioning trainers, coaches and sports scientists, since they provide valuable information for orientating the training process [7] and for selecting the best young people in talent identification programmes [8]. Physical fitness data of young competitors are available for several sport modalities, ranging from the less well-known disciplines, such as canoeing and kayaking [9], to the most popular ones, such as football [10]. In addition, an understanding of normative fitness values is useful for identifying the potential weaknesses and strengths of an athlete, since it allows an individual performance within a sex and age category to be compared.

There are a number of studies in which anthropometric and fitness measurements were carried out on young karatekas [11, 12]. However, the sample of these investigations was specifically made up of cadet age athletes and important fitness dimensions were not assessed (e.g. aerobic capacity). Therefore, to the best of the authors' knowledge, no reference values are available for the different fitness dimensions that play a role in karate performance of athletes who compete in young age categories. Under these circumstances, this study aimed to provide information regarding the anthropometric and fitness profile of young karatekas ranging from 12 to 20 years of age.

MATERIALS AND METHODS

Participants

Subjects in this study were all the karatekas aged 12–20 years who participated in at least one of the training camps organized by the Spanish National Karate Federation between 1999 and 2016. To be selected for these camps, the Federation required that athletes had achieved at least a medal in the previous two Spanish Championships. For the purpose of this research, participants were grouped according to the young categories of the World Karate Federation (which are included in the World Championships or Karate 1 Youth League: U-14 (12–13 years old), cadet (14–15 years old), junior (16–17 years old) and U-21 (18–20 years old). When an athlete had participated in more than one training camp during one category, the average of all his/her results in this category was calculated. In this way, each participant appears only once in one age-category group to avoid overrepresentation. Thus, a total of 514 karatekas participated in the training camps from 1999 to 2016 and all of them were evaluated taking various dimensions into account. Data

were obtained from 97 karatekas in the U14 category, 238 in cadet, 261 in junior and 177 in U21, which makes a total of 773 athlete data sets.

Measurements

The following assessments were performed by all the karatekas during the training camps. All the tests were administered by an experienced sports scientist who had been an elite karate athlete and was specialized in conditioning testing of young athletes.

Anthropometrics

Anthropometric measurements were performed in the early morning, before breakfast. Body mass and height were measured following standardized procedures to the nearest 0.5 cm and 0.1 kg, respectively, and body mass index (BMI) was calculated as body mass in kilograms divided by square of height in meters (kg/m^2).

Body fat percentage (BF%) was calculated using the Slaughter et al. formula [13], which takes into account two skinfolds. BF% = $1.33 \times \Sigma2 - 0.013 \times \Sigma2^2 - 2.5$ where $\Sigma2$ is the sum of triceps and subscapular skinfolds.

Fitness

Selected tests from the Eurofit battery [14] were used to evaluate the following fitness components: aerobic fitness (20-m shuttle run), lower-body muscular power (standing long jump), coordination and speed of upper limb movements (plate-tapping test), agility (10 × 5-m shuttle run test) and flexibility (sit-and-reach test). To assess upper-body muscular power, a two-handed overhead medicine ball throw (3 kg) was performed [15].

TABLE 1. Fitness and anthropometric profile (mean ± SD) of young male karatekas

MALE KARATEKAS	U14	Cadet	Junior	U21	Hedges' g Effect Sizes		
N	64	157	163	114	U14-Cadet	Cadet-Junior	Junior-U21
Age (years)	13.46 ± 0.51	15.26 ± 0.63*	16.98 ± 0.47*†	19.47 ± 0.74*†‡	2.98	3.08	4.17
Weight (kg)	50.76 ± 9.23	59.71 ± 9.55*	65.38 ± 8.91*†	70.35 ± 9.64*†‡	0.94	0.61	0.54
Height (cm)	160.40 ± 7.66	168.59 ± 7.97*	172.39 ± 6.78*†	174.33 ± 8.12*†	1.04	0.51	0.26
BMI (kg/m^2)	19.57 ± 2.29	20.89 ± 2.37*	21.96 ± 2.18*†	23.05 ± 2.29*†‡	0.56	0.47	0.49
BF%	17.10 ± 5.32	17.75 ± 3.39	20.48 ± 4.88*†	21.32 ± 4.47*†	0.16	0.65	0.18
Sit and reach (cm)	21.55 ± 6.36	25.02 ± 6.24*	27.54 ± 7.00*†	28.07 ± 6.86*†	0.55	0.38	0.08
20-m shuttle run (min)	8.52 ± 1.28	9.05 ± 1.33*	9.26 ± 1.42*	9.85 ± 1.69*†‡	0.40	0.15	0.38
Standing long jump (cm)	198.4 ± 15.3	218.6 ± 16.0*	228.2 ± 15.8*†	235.1 ± 16.5*†‡	1.28	0.60	0.43
Overhead 3-kg ball throw (m)	5.58 ± 0.99	6.98 ± 1.08*	7.84 ± 1.02*†	8.69 ± 1.10*†‡	1.32	0.82	0.81
10x5-m shuttle run (s)	18.59 ± 1.59	17.42 ± 1.74*	16.84 ± 1.55*	17.25 ± 1.15*	-0.69	-0.35	0.30
Plate-Tapping (s)	10.04 ± 1.36	9.58 ± 1.01*	9.21 ± 0.88*†	9.13 ± 1.08*†‡	-0.41	-0.39	-0.09

Abbreviations: BMI, body mass index; BF%, body fat percentage; *, different from U14 (p < .05); †, different from Cadet (p < .05); ‡, different from Junior (p < .05).

Statistical analysis

Descriptive values (mean ± SD) were calculated for each sex (male/female) and age category (U14/Cadet/Junior/U21) group. Linear mixed modelling was used to evaluate the interaction between sex and age category and their main effects on the anthropometric and fitness variables. In the mixed models, each anthropometric and fitness dimension was used as a continuous dependent variable, sex and age category were included as fixed factors and participant was specified as a random effect. The covariance structure was set to be compound symmetric. The model was fit using maximum likelihood estimation. Pairwise comparisons of the estimated marginal means were carried out adjusted by Bonferroni corrections. Hedges' g effect sizes were calculated to compare successive category groups, taking group size into account. Effect sizes were interpreted using the Hopkins [16] scale: < 0.2 trivial, 0.2–0.6 small, 0.6–1.2 moderate, 1.2–2.0 large and 2.0–4.0 very large. Normative values were displayed by quintiles (percentiles 20th, 40th, 60th and 80th) of each group in each variable. All statistical analyses were performed using SPSS 22. Unless otherwise stated, data are means ± SD. The significance level was set at $p < 0.05$ for all the analyses.

Ethics

The study complied with the Declaration of Helsinki and Spanish and European laws on data protection. According to article 32 of the Declaration of Helsinki, we analysed this database since informed consent of participants was impossible to obtain. Approval was granted by the Spanish Karate Federation to analyse and publish pre-existing data collected from 1999 to 2016 in training camps with young categories.

RESULTS

Tables 1 and 2 include the descriptive anthropometrical and fitness values of male and female karatekas, respectively, and the comparison between sex and age-category groups. Hedges' g effect sizes between successive categories are also shown. There were significant main effects for sex in most of the variables (F = 5.92–540.71, $p < 0.05$), except for plate-tapping. Male athletes were taller and heavier, had lower BF% and performed better than females in all the fitness tests with the exception of the sit-and-reach, where females performed better. No differences were found in plate-tapping between sex groups.

There were also significant main effects for the age-category factor in all the variables (F = 3.79–452.62, $p < 0.05$). Older athletes were taller and heavier, had higher BMI and BF% and performed better than their younger counterparts in all the fitness tests. In the male group, differences between U14 and U21 ranged from 55.7% ($p < 0.001$) in the overhead ball throw to 7.2% ($p < 0.001$) in the 10x5-m shuttle run. Likewise, in the female group, the greatest differences between U14 and U21 were found in the 20-m shuttle run (16.6%, $p = 0.068$), the standing long jump (7.6%, $p = 0.003$) and the overhead 3-kg ball throw (25.3%, $p < 0.001$).

There were also statistically significant interactions between sex and age-category group for weight, height, BMI, sit-and-reach, standing long jump, overhead 3 kg ball throw and 10x5-m shuttle run (F = 3.73–347.09, $p < 0.05$). There were no significant interactions for BF%, 20-m shuttle run and plate-tapping. Sex differences were larger in the older age categories, with the exception of the sit-and-reach, where the differences were larger in young age categories.

TABLE 2. Fitness and anthropometric profile (mean ± SD) of young female karatekas

FEMALE KARATEKAS	U14	Cadet	Junior	U21	Hedges' g Effect Sizes		
N	33	81	98	63	U14-Cadet	Cadet-Junior	Junior-U21
Age (years)	13.55 ± 0.44	15.35 ± 0.47*	17.05 ± 0.47*†	19.45 ± 0.78*†‡	3.86	3.59	3.91
Weight (kg)	50.46 ± 9.19	52.45 ± 6.01*	54.65 ± 6.99*†	58.64 ± 9.05*†‡	0.28	0.33	0.51
Height (cm)	155.63 ± 6.23	159.97 ± 5.88*	159.54 ± 6.97*†	163.18 ± 7.30*†‡	0.72	-0.07	0.51
BMI (kg/m^2)	20.46 ± 2.82	20.51 ± 2.02*	21.44 ± 2.12*†	22.08 ± 2.52*†	0.02	0.44	0.28
BF%	22.55 ± 3.40	24.56 ± 3.07	26.96 ± 2.88	27.10 ± 2.52	0.63	0.81	0.05
Sit and reach (cm)	27.12 ± 6.52	28.39 ± 5.96	28.51 ± 6.54	26.35 ± 8.06	0.21	0.02	-0.30
20-m shuttle run (min)	6.16 ± 1.53	6.47 ± 1.23	6.69 ± 1.36	7.18 ± 1.25*†‡	0.23	0.17	0.37
Standing long jump (cm)	175.9 ± 12.6	180.3 ± 18.8*	186.1 ± 17.0*†	189.2 ± 18.2*†	0.25	0.32	0.18
Overhead 3-kg ball throw (m)	4.67 ± 0.76	4.98 ± 0.75*	5.33 ± 0.74*†	5.85 ± 0.89*†‡	0.41	0.46	0.65
10x5-m shuttle run (s)	19.42 ± 1.16	19.18 ± 1.82	19.25 ± 1.53	18.68 ± 1.52	-0.14	0.04	-0.37
Plate-Tapping (s)	10.11 ± 1.32	9.64 ± 0.81	9.32 ± 0.86	9.50 ± 1.22	-0.47	-0.39	0.18

Abbreviations: BMI, body mass index; BF%, body fat percentage; *, different from U14 ($p < .05$); †, different from Cadet ($p < .05$); ‡, different from Junior ($p < .05$).

TABLE 3. Anthropometric and fitness normative values (percentiles) in young categories of male karatekas. Percentiles are invertedin those variables which lower scores mean higher performances

MALE	Weight (kg)	Height (cm)	BMI (kg/m²)	BF%	Sit and reach (cm)	20-m shuttle run (min)	Standing long jump (cm)	Overhead 3-kg ball throw (m)	10x5-m shuttle run (s)	Plate-tapping (s)
					U14					
P80	57.7	168.0	21.2	13.7	26.6	9.5	213.0	6.5	17.7	8.8
P60	52.0	164.0	19.7	15.3	24.0	8.9	202.9	5.9	18.4	9.8
P40	47.2	157.0	18.7	18.4	20.5	8.0	198.2	5.3	19.1	10.6
P20	43.0	154.5	17.9	23.6	16.0	7.3	182.6	4.7	19.7	11.4
					Cadet					
P80	68.0	174.7	22.4	14.7	31.0	10.3	231.1	7.9	16.0	8.7
P60	61.0	170.0	21.2	16.6	26.4	9.5	224.0	7.2	17.3	9.2
P40	56.0	166.3	20.1	19.0	23.3	8.6	215.7	6.7	18.1	9.8
P20	52.7	162.0	19.0	20.2	20.0	8.0	207.6	6.1	18.8	10.5
					Junior					
P80	73.6	179.2	23.7	16.6	33.7	10.5	238.0	8.8	15.3	8.5
P60	68.1	173.6	22.5	18.6	30.0	9.5	231.0	8.0	16.9	8.9
P40	62.0	170.5	21.1	21.0	27.0	9.0	224.0	7.5	17.5	9.3
P20	57.2	166.8	20.0	24.0	21.4	8.0	215.0	7.0	18.1	10.0
					U21					
P80	79.6	182.0	25.0	16.0	34.0	11.2	248.9	9.5	16.4	8.3
P60	71.9	175.0	23.5	20.0	31.0	10.5	239.3	8.8	17.0	9.0
P40	65.9	171.5	22.2	22.5	26.2	9.5	233.0	8.3	17.5	9.3
P20	61.7	169.0	21.1	25.9	21.3	8.2	220.0	7.8	18.2	9.9

Abbreviations: BF%, body fat percentage; P80, P60, P40 and P20, percentile 80, 60, 40 and 20, respectively.

TABLE 4. Anthropometric and fitness normative values (percentiles) in young categories of female karatekas. Percentiles are inverted in those variables where lower scores mean higher performances

FEMALE	Weight (kg)	Height (cm)	BMI (Kg/m2)	BF%	Sit and reach (cm)	20-m shuttle run (min)	Standing long jump (cm)	Overhead 3-kg ball throw (m)	10x5-m shuttle run (s)	Plate-Tapping (s)
					U14					
P80	56.1	160.6	23.7	19.2	33.6	7.4	185.0	5.4	18.4	8.5
P60	52.0	156.2	20.2	20.9	30.0	6.5	180.0	5.0	19.4	10.1
P40	45.2	154.0	19.0	23.3	26.0	5.7	173.5	4.3	20.0	10.4
P20	42.7	150.4	18.2	26.8	21.0	5.0	167.0	4.0	20.4	11.5
					Cadet					
P80	57.2	165.0	22.0	21.2	35.0	7.5	194.8	5.5	18.3	9.0
P60	52.8	161.3	20.6	24.7	29.0	6.8	183.2	5.1	19.1	9.5
P40	50.0	158.5	19.8	25.7	27.0	6.0	177.4	4.8	19.6	9.7
P20	47.2	154.9	19.0	27.2	23.0	5.5	164.4	4.3	20.6	10.3
					Junior					
P80	59.7	165.0	23.2	24.5	34.0	8.0	200.5	5.9	18.3	8.6
P60	56.0	161.0	21.5	26.2	30.4	7.0	192.3	5.4	19.2	9.1
P40	52.9	157.0	20.7	28.3	27.0	6.3	182.2	5.1	19.6	9.6
P20	49.0	153.0	19.7	30.0	22.5	5.5	170.8	4.8	20.2	10.2
					U21					
P80	65.5	170.4	24.3	24.5	32.0	8.0	205.2	6.4	17.8	8.6
P60	60.0	165.0	22.3	25.7	30.0	7.5	192.8	6.0	18.3	9.3
P40	54.0	161.1	20.9	28.6	26.0	7.0	184.0	5.6	19.1	9.9
P20	52.0	157.5	19.9	29.4	20.0	6.0	173.9	5.2	19.9	10.3

Abbreviations: BF%, body fat percentage; P80, P60, P40 and P20, percentile 80, 60, 40 and 20, respectively.

Reference standards of young karate athletes are shown in Tables 3 and 4, where quintile values (percentiles 20th, 40th, 60th and 80th) of all evaluated dimensions of fitness and anthropometrics in karatekas stratified by sex and age category are provided.

DISCUSSION

The present study describes the anthropometric and fitness profile of young male and female karate athletes across a wide range of age categories. These findings can be useful for coaches and conditioning professionals, since they provide information and guidance for developing training interventions, fitness testing or even talent identification in this sport.

The karatekas in this research showed a healthy anthropometric profile, although the mean BMI values were slightly higher than those observed in the general population [17]. This finding has previously been observed in female but not in male karatekas [18]. In this regard, both the boys and girls in this study had higher %BF levels than those found among young athletes [19].

Information regarding the anthropometric profile of young karatekas is scarce. In comparison with the studies by Jukic, Katic and Blazevic [11] and Jukić, Katić and Bala [12], cadet karatekas showed similar BMI values, while the %BF values were higher in girls and similar in the case of boys. However, the BMI and %BF values shown by the U21 participants in this research are lower than those observed in amateur (mean age: 21 years) and elite (mean age: 23 years) karatekas [20]. In comparison with young taekwondo practitioners, the anthropometric profile of the karatekas of our research also stands out for showing higher BMI and %BF values in all the categories. These findings are in line with previous observations suggesting that karatekas tend to show an endomorphic-mesomorph somatotype in comparison with other athletes [4], and also confirm previous suggestions that very low %BF values do not seem to be a determinant of karate performance [3]. Nevertheless, it should be borne in mind that karatekas in this study were tested during the summer period, when no competitions are held. We hypothesized that the participants' %BF would be lower if they were assessed prior to the main competitions in which they participate.

According to Eurofit normative values [21], the U14, cadets and junior karatekas assessed in this research showed a higher level of physical fitness than the general population of the same age. Similarly, the U21 karatekas showed higher fitness levels than those shown by populations of similar age [22]. This finding is expected since participants in this study were top karatekas who were taking part in high-level competitions.

Regarding the involvement of cardiorespiratory fitness in karate performance, it has been suggested that the aerobic metabolism is predominant during karate combats [23]. In this regard, it has also been reported that an optimal aerobic capacity is necessary to achieve high-level performance in this sport, since it allows fatigue to be prevented during training and recovery to be improved between combats [3]. Our findings are in agreement with these observations. In comparison with the available cardiorespiratory fitness normative data for age-matched populations [21], the U14, cadets and junior boys were placed between the 80th and the 90th percentile, while the girls' values from the same age groups were above the 90th percentile. Similarly, the U21 karatekas showed higher cardiorespiratory fitness values than those observed in active young students of a similar age [24].

Rapid force application and high levels of mechanical power are essential for karatekas, since they allow rapid and explosive displacements, kicks and punches – the basic skills needed for success in karate – to be performed [25]. Consequently, it has been suggested that in karatekas, upper- and lower-body muscle power strongly contributes to competitive performance [26]. This might be the reason why karatekas in this study showed high lower-body muscular power [27], which places them around (for boys) and above (for girls) the 90th percentile in comparison with a European sample of the same age and sex [28]. The U14 and cadet karatekas who took part in this study also outperformed young Serbian [29] and Croatian [30] karatekas of a similar age, which reaffirms that our sample had high levels of muscular power. Regarding upper-limb muscular power, comparisons are much more difficult to make, due to the specific test used. The revised available studies suggest that the Spanish karatekas in our study showed good but not exceptional muscular performance. For instance, junior female handball players showed slightly higher mean 3-kg ball throw distance values than our junior karatekas [31], while Spanish schoolchildren aged 14–15 years were outperformed by our cadet karatekas by almost one meter in the same test [32].

In addition to muscular power, movement speed and agility were identified as key factors determining fighting efficacy in young karatekas [30]. Our results are in accordance with this idea, since the plate-tapping and 10 x 5-m scores shown by the karatekas in this study place them among the highest percentile values found in age-matched populations [21]. In this regard, there are two aspects worthy of note. Firstly, in our sample, boys outperformed girls in every fitness dimension, except for flexibility and upper-limb movement speed. It is well known that girls show higher flexibility levels than boys, but the fact that no significant differences were observed for the plate-tapping score test is a somewhat unexpected finding [21]. Nevertheless, it seems that this lack of sex-based differences is a common finding in the literature, including among Spanish children [33] and adolescents [34]. Secondly, the karatekas in this study showed higher agility levels than those observed in 12–15-year-old soccer players [35] but lower scores than those obtained by young taekwondo competitors [36]. This means that karatekas in this study showed well-above-age agility values, but not the highest among those already reported in the literature.

Finally, regarding flexibility, the karatekas in this study obtained much higher sit-and-reach scores than those observed in an age-matched Spanish population [37] and also in other elite athletes such as 16–18-year-old female lightweight Olympic wrestlers [38]

or 16–17-year-old male Gaelic football players [39]. This high flexibility level could be useful for performing kicks. Nevertheless, it should be noted that the karatekas' flexibility levels were lower than those shown by young taekwondo athletes [36]. This may be due to the fact that although kicks and punches are allowed in both sports, kicks represent almost the totality of pointing actions in taekwondo [40] but punch frequency is more than double the kick frequency in karate [41].

The main strength of this study lies in its novelty, since no normative anthropometric and fitness values for young karatekas have been published so far. This research also shows that karateka fitness level can be assessed by means of a set of simple field-based tests. This is a noteworthy aspect, given the expressed need to find tests that are easy to perform and that provide information of interest to both karatekas and their coaches [23].

However, there are several limitations that should be acknowledged. In the first place, the karatekas were usually tested during holidays, while it seems very likely that they could achieve higher scores in some fitness dimensions if they were assessed during the competitive season. Secondly, anaerobic power, a physiological variable that also contributes to karate performance success [6], was not assessed. It could be measured by a field test consisting of 6 sprints of 15 meters

with 10 seconds of rest between them [42]. Finally, a relatively small number of U14 karatekas were tested. Thus, futures studies should focus on this category. All of these facts should be taken into account for an accurate interpretation of the findings presented here.

Karate coaches and practitioners can use these reference values to evaluate young athletes by field testing. These data can facilitate the design of accurate training and talent detection programmes by physiologists, sport scientists, sport physicians, and sport-performance researchers working with sportspersons in young categories. Thus, each person can be compared with normative data of high-level karate athletes of the same modality, sex and age category in order to monitor their strengths and weaknesses.

CONCLUSIONS

Young karatekas show a high fitness level in comparison with the general population, especially with regards to aerobic performance, lower-body muscular power and upper-limb movement speed. From the present findings, anthropometric characteristics do not seem to be the key variable that helps to reach high levels in this population. Reference values of anthropometric and fitness dimensions are provided in order to be used by coaches, conditioning trainers and sport scientists when testing young male and female karatekas.

REFERENCES

1. Thomas RE, Ornstein J. Injuries in karate: systematic review. Phys Sportsmed. 2018;46(3):279–303.
2. Arriaza R, Cierna D, Regueiro P, et al. Low risk of concussions in top-level karate competition. Br J Sports Med. 2017;51(4):226–230.
3. Chaabène H, Hachana Y, Franchini E, Mkaouer B, Chamari K. Physical and physiological profile of elite karate athletes. Sport Med. 2012; 42(10):829–843.
4. Burdukiewicz A, Pietraszewska J, Stachoń A, Andrzejewska J. Anthropometric profile of combat athletes via multivariate analysis. J Sports Med Phys Fitness. 2018;58(11):1657–1665.
5. Ravier G, Grappe F, Rouillon JD. Application of force-velocity cycle ergometer test and vertical jump tests in the functional assessment of karate competitor. J Sports Med Phys Fitness. 2004;44 4:349–355.
6. Doria C, Veicsteinas A, Limonta E, et al. Energetics of karate (kata and kumite techniques) in top-level athletes. Eur J Appl Physiol. 2009;107(5):603–610.
7. Jacobson BH, Conchola EG, Glass RG, Thompson BJ. Longitudinal morphological and performance profiles for american, NCAA division i football players. J Strength Cond Res. 2013; 27(9):2347–2354.
8. Martínez de Quel Ó, Ara I, Izquierdo M, Ayán C. Does Physical Fitness Predict Future Karate Success? A Study in Young

Female Karatekas. Int J Sports Physiol Perform. Published online 2020. doi:10.1123/ijspp.2019–0435
9. López-Plaza D, Alacid F, Muyor JM, López-Miñarro PÁ. Differences in Anthropometry, Biological Age and Physical Fitness between Young Elite Kayakers and Canoeists. J Hum Kinet. 2017;57(1):181–190.
10. Lago-Peñas C, Rey E, Casáis L, Gómez-López M. Relationship between performance characteristics and the selection process in youth soccer players. J Hum Kinet. 2014;40(1):189–199.
11. Jukic J, Katic R, Blazevic S. Impact of morphological and motor dimensions on success of young male and female karateka. Coll Antropol. 2012; 36(4):1247–1255.
12. Jukić J, Katić R, Bala G. Morphological, motor and technical determinants of fighting efficiency of Croatian female cadet age karate athletes. Coll Antropol. 2013;37(4):1253–1259.
13. Slaughter MH, Lohman TG, Boileau RA, et al. Skinfold Equations for Estimation of Body Fatness in Children and Youth. Hum Biol. 1988;60(5):709–723.
14. Adam C. EUROFIT: Handbook for the Eurofit Tests of Physical Fitness. Italian National Olympic Committee Central Direction for Sport's Technical Activities Documentation and Information Division; 1988.
15. Van Den Tillaar R, Marques MC. A comparison of three training programs

with the same workload on overhead throwing velocity with different weighted balls. J Strength Cond Res. 2011; 25(8):2316–2321.
16. Hopkins WG. Measures of reliability in sports medicine and science. Sport Med. 2000;30(1):1–15.
17. Carrascosa A, Yeste D, Moreno-Galdó A, et al. Body mass index and tri-ponderal mass index of 1,453 healthy non-obese, non-undernourished millennial children. The Barcelona longitudinal growth study. An Pediatría. 2018;89(3):137–143.
18. Barbeta CJ de O, Gonçalves EM, Ribeiro KDS, Ribeiro R, Roman EP, Guerra-Júnior G. Bone mass by quantitative ultrasound of finger phalanges in young karate practitioners. Rev Paul Pediatr. 2017;35:436–442.
19. Kalnina L, Sauka M, Timpka T, et al. Body fat in children and adolescents participating in organized sports: Descriptive epidemiological study of 6048 Latvian athletes. Scand J Public Health. 2015;43(6):615–622.
20. Giampietro M, Pujia A, Bertini I. Anthropometric features and body composition of young athletes practicing karate at a high and medium competitive level. Acta Diabetol. 2003; 40 Suppl 1:S145–8.
21. Tomkinson GR, Carver KD, Atkinson F, et al. European normative values for physical fitness in children and adolescents aged 9–17 years: results from 2 779 165 Eurofit performances

representing 30 countries. Br J Sports Med. 2018;52(22):1445–1456.

22. Cancela J, Ayán C, Vila H, Gutiérrez J, Santiago A. Validez de Constructo del Cuestionario Internacional de Actividad Física en Universitarios Españoles. Rev Iberoam Diagnóstico y Evaluación – e Avaliação Psicológica. 2019;3:5–14.

23. Tabben M, Sioud R, Haddad M, et al. Physiological and Perceived Exertion Responses during International Karate Kumite Competition. Asian J Sports Med. 2013;4(4):263–271.

24. Tsigilis N, Douda H, Tokmakidis S. Test–retest reliability of the Eurofit test battery administered to university students. Percept Mot Skills. 2003; 95:1295–1300.

25. Abidin NZ, Adam MB. Prediction of vertical jump height from anthropometric factors in male and female martial arts athletes. Malays J Med Sci. 2013; 20(1):39–45.

26. Loturco I, Artioli GG, Kobal R, Gil S, Franchini E. Predicting punching acceleration from selected strength and power variables in elite karate athletes: A multiple regression analysis. J Strength Cond Res. 2014;28(7):1826–1832.

27. McKay MJ, Baldwin JN, Ferreira P, Simic M, Vanicek N, Burns J. Reference values for developing responsive functional outcome measures across the lifespan. Baldwin J, McKay M, Ferreira P, et al., eds. Neurology. 2017; 88(16):1512–1519.

28. Ortega FB, Artero EG, Ruiz JR, et al. Physical fitness levels among European adolescents: the HELENA study. Br J Sports Med. 2011;45(1):20–29.

29. Doder D, Malacko J, Doder R. Predictive validity of morphological and motor variables for the evaluation and monitoring of the karate free kata performance. Sport Sci. 2010; 3(2):52–56.

30. Katic R, Jukic J, Cavala M, Vucic D, Blazevic S. Motor determinants of fighting efficacy in Croatian youth karateka. Coll Antropol. 2013;37 Suppl 2:1–8.

31. Ignjatovic A, Markovic Z, Radovanovic D. Effects of 12-Week Medicine Ball Training on Muscle Strength and Power in Young Female Handball Players. J Strength Cond Res. 2011;26:2166–2173.

32. Martínez López EJ. Aplicación de la prueba de lanzamiento de balón medicinal, abdominales superiores y salto horizontal a pies juntos. Resultados y análisis estadístico en Educación Secundaria. Rev Int Med y Ciencias la Act Física y el Deport. 2003;3:223–241.

33. Casajús JA, Leiva MT, Villarroya A, Legaz A, Moreno LA. Physical Performance and School Physical Education in Overweight Spanish Children. Ann Nutr Metab. 2007; 51(3):288–296.

34. Martínez López EJ. Aplicación de la prueba de velocidad 10x5 metros, sprint de 20 metros y tapping-test con los brazos: resultados y análisis estadístico en educación secundaria. Rev Int Med y Ciencias la Act Física y del Deport. 2004;4.13:1–17.

35. Christou M, Smilios I, Sotiropoulos K, Volaklis K, Pilianidis T, Tokmakidis SP. Effects of resistance training on the physical capacities of adolescent soccer players. J strength Cond Res. 2006; 20(4):783–791.

36. Nikolaidis PT, Buśko K, Clemente FM, Tasiopoulos I, Knechtle B. Age- and sex-related differences in the anthropometry and neuromuscular fitness of competitive taekwondo athletes. Open access J Sport Med. 2016;7:177–186.

37. Castro-Piñero J, Girela-Rejón MJ, González-Montesinos JL, et al. Percentile values for flexibility tests in youths aged 6 to 17 years: Influence of weight status. Eur J Sport Sci. 2013;13(2):139–148.

38. García Pallarés J, López-Gullón JM, Torres-Bonete MD, Izquierdo M. Physical fitness factors to predict female olympic wrestling performance and sex differences. J Strength Cond Res. 2012; 26(3):794–803.

39. Cullen BD, Cregg CJ, Kelly DT, M. Hughes S, Daly PG, Moyna NM. Fitness profiling of elite level adolescent gaelic football players. J Strength Cond Res. 2013;27(8):2096–2103.

40. Menescardi C, Falco C, Estevan I, Ros C, Morales-Sánchez V, Hernández-Mendo A. Is It Possible to Predict an Athlete's Behavior? The Use of Polar Coordinates to Identify Key Patterns in Taekwondo. Front Psychol. 2019;10:1232.

41. Tabben M, Coquart J, Chaabène H, Franchini E, Ghoul N, Tourny C. Time-motion, tactical and technical analysis in top-level karatekas according to gender, match outcome and weight categories. J Sports Sci. 2015; 33(8):841–849.

42. Bongers BC, Werkman MS, Blokland D, et al. Validity of the pediatric running-based anaerobic sprint test to determine anaerobic performance in healthy children. Pediatr Exerc Sci. 2015; 27(2):268–276.