ORIGINAL ARTICLE

Similarities and differences of the body composition and the fat-free fat index between kyokushin karate athletes, swimmers, basketball, soccer, American football players and non-active men

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Manuscript Preparation
E Funds Collection

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Abstract

Background and Study Aim: One of the characteristic features of karate training is the partial inability to determine its intensity, which is why it is so important to assess the impact of training on body composition, detailing the fat and lean components. The aim of the study was knowledge about the usefulness of the fat-free index (FFF) as a tool used to estimate the predisposition to practice various sports, with particular emphasis on karate

Materials and Methods: The men (n = 114), aged 15-30, were all competitors in one of the following five sports: kyokushin karate (n = 14), basketball (n = 41), American football (n = 35), soccer (n = 14), swimming (n = 10) and 132 in control group. Body weight and composition were determined using the BC-418MA 8-electrode body composition analyser by Tanita with GMON 3.4.2 software. The electric bioimpedance method was used to determine the percentage of fat mass (FatP), as well as the percentages of mass (FatM), lean mass (FFM), and muscle mass (PMM).

Results: The amateur karate practitioners do not differ in the percentage of body fat from men practicing swimming, basketball or soccer. When assessing the fat-free fat index of the group who practiced karate, it was found that only the American football, as well as the soccer players, had higher values of this indicator when considering it in general and within the torso.

Conclusions: The training form used in kyokushin karate gives similar effects in terms of body composition as swimming training, used in basketball, soccer or American football. At the same time, an important element that should be supplemented in long-term training is the improvement of the symmetry of fat mass distribution.

Keywords: kata • kumite • martial arts • muscle mass • training intensity • training load

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Martial arts – *plural noun* any of various systems of combat and self-defence, e.g. judo or karate, developed especially in Japan and Korea and now usually practised as a sport [33].

Kata – *noun* a sequence of movements in some martial arts such as karate, used either for training or to demonstrate technique [33].

Kata – prescribed patterns or sequences of techniques [34].

Kumite – is a semi-contact karate competitive concurrence, where two athletes perform various kicking, punching and blocking techniques towards each other with maximum control in order to gain points and win the match. Destruction is fictive.

Kyu – *noun* a level of proficiency in some martial arts [33].

Kyū – the series of grades that precede *dan* ranks. *Ikkyū* is the grade immediately below *shodan* [34].

Self-defence – *noun* fighting techniques used for defending oneself against physical attack, especially unarmed combat techniques such as those used in many of the martial arts [33].

Athlete – *noun* 1. someone who has the abilities necessary for participating in physical exercise, especially in competitive games and races **2.** a competitor in track or field events [33].

Player – *noun* someone taking part in a sport or game [33].

Training session – *noun* a period of time during which an athlete trains, either alone, with a trainer or with their team [33].

Training intensity – the effort of training. A number of methods are used to establish training intensities which give maximum benefits. These include the lactic acid method, minute ventilation method, and target heart-rate [35].

Training load – "A simple mathematical model of training load can be defined as the product of qualitative and quantitative factor. This reasoning may became unclear whenever the quantitative factor is called 'workload volume' or 'training

INTRODUCTION

Karate, like other martial arts, is a multi-faceted physical activity. It is a general development sport affecting the whole body, and leads to the development of greater endurance, strength, agility, flexibility, and eye-hand coordination [1-4]. An important element of karate training is not only its influence on the structure of the body, but also the psychological and social impact on an individual. Martial arts training has a positive effect on an individual's self-control, reinforces a routine of systematic work, increases the precise movement and awareness of one's body while reducing aggressive behaviour [5-15].

Energy output during karate training may be difficult to measure due to the multi-faceted nature of the training. The main goal of each karate training session could be different. Preparing for a kumite or kata competition will require a significantly different preparation. It is similar with self-defence training and training for new kyu grades. Therefore, it becomes necessary to use other methods to evaluate various types of training. One of the most frequently used methods of estimating the influence of karate on a participant is the assessment of his body based on changes in the weight-height index (BMI), as well as changes in Sheldon's body types [16-18].

Both of these methods have a measurement error – the BMI does not take into account muscle mass (MM), which is an important component in the athlete's body structure, and the typology is based on a detailed assessment of individual indicators on the basis of which a given individual qualifies for a body type subtype. The first method may give erroneous results due to the lack of normative values for athletes, while the second one requires full knowledge and skills in the field of measurement anthropology [16-18].

One of the important elements of sports training is the development of muscle mass (MM) necessary to obtain the best results. It is the estimation of changes in MM that is the basis for assessing the correctness of sports training. Lack of changes in the initial period of training development indicates too low training intensity, and in the period of stabilization of the competition, a significant change is a sign of irregularities. A decrease in MM may mean that the training values are subliminal, and the rapid development of MM indicates the use of dietary supplementation or too much strength. To determine MM as a component of the body composition, many estimation methods can be used, based, among others, on astrometric measurements, such as the thickness of the skin and fat folds, within which we determine the amount of adipose tissue in the body and the resultant value is the amount of lean body. This method is also used in the assessment of Sheldon's typology and requires a lot of practical experience and knowledge in the field of anthropology [18].

The newer and more accurate methods, burdened with a lower measurement error, include the dual-energy X-ray absorptiometry (DXA) method, computed tomography or publicly available electrical bioimpedance (BIA) [19-21, 18, 22-24]. Each of these methods allows you to estimate the components of the body composition, detailing fat mass and lean body, which includes, among others, MM. Using the location of the body from the body structure, the muscle-fat index (MT) by Szczawińska [18, 25] was developed based on the measurements of fat halves, the BMIFat index by Mialich et al. [26, 18, 27].

However, these methods, like BMI, do not take into account the physiological changes occurring with age or with undertaking training in the body structure. One of the indicators that takes into account both the age and sex of the examined person is Chwałczyńska's Fat-Free Index (FFF). FFF primarily takes into account fat and lean mass, the main component of which is MM, and therefore is a good tool for its assessment [19, 29, 3]. Assessment of muscle mass, both its input value at the beginning of a professional career, as well as its change during the training process or the size after a longer training period, allows for the assessment of training intensity in a given sports discipline [18, 4, 28].

One of the characteristic features of karate training is the partial inability to determine its intensity, which is why it is so important to assess the impact of training on body composition, detailing the fat and lean components [4].

The aim of the study was knowledge about the usefulness of the fat-free index (FFF) as a tool used to estimate the predisposition to practice various sports, with particular emphasis on karate.

MATERIAL AND METHODS

Participants

Two hundred and forty-six men aged 22.1± 4.0 years were examined. The mean body weight of the subjects was 79.9± 14.0 kg, the mean height 181.3± 8.1 cm, and the mean BMI 24.3± 3.8 kg/m^2. The one hundred and fourteen athletes in the study were grouped as follows: kyokushin karate (n = 14); basketball (n = 41); American football (n = 35); soccer (n = 14); swimming (n = 10). The one hundred and thirty-two members of the control group did not participate in sports, and undertook moderate physical activity two-three times per week.

The subjects did not differ in age and height. American football players had the highest body mass and BMI. These differences are statistically significant when compared to the other athletes, and also to the members of the control group. The members of the control group did not differ significantly in age, weight, height, and BMI from the athletic subjects in the study (more results of the anthropometric measurements are presented in Table 1).

Regarding athletes: no contraindications in medical history in the last 12 months, without contraindications to bioimpedance tests (metal elements in the body, active cancer, heart pacemaker), with tests by a sports medicine doctor allowing participation in training and competitions within the indicated sports discipline. The training loads (main components) of the studied groups are presented in Table 2.

Study design

On the day of testing the men did not participate in any athletic training. Before the test all participants fasted for at least four hours, and did not consume alcohol for at least twenty-four hours prior. Each subject's height was measured using a SECA 213 stadiometer with an accuracy of 0.1 cm. Body weight and composition were determined using the BC-418MA 8-electrode body composition analyser by Tanita with GMON 3.4.2 software. The electric bioimpedance method was used to determine the percentage of fat mass (FatP), as well as the percentages of mass (FatM), lean mass (FFM), and muscle mass (PMM).

Normative values for men were adopted depending on age in terms of fat mass: low <8%; normal 8-20%; increased >20-25% and high >25%. Based on the value of the body fat and fat-free components determined for the various segments of the body, the fat-free index (FFF) was calculated using the formula: FFF = FatM / FFM and for individual parts of the body: RL FFF right lower limb; LL FFF left lower limb; RA FFF right upper limb; LA FFF left upper limb; TR FFF torso.

Ethical standards

This research was sanctioned by the Senate Committee for the Ethics of Scientific Research at the Academy of Physical Education in Wrocław, Poland on the sixth of July, 2015. All participants gave their written permission to take part in the research in accordance with the Helsinki Declaration.

volume' interchangeably with 'volume of physical activity'. Various units have been adopted as measures i.e. the number of repetitions, kilometres, tons, kilocalories, etc. as well as various units of time (seconds, minutes, hours) (...) As in the real world nothing happens beyond the time, the basic procedure of improvement of workload measurement should logically start with separation of the time factor from the set of phenomena so far classified together as '***workload volume***'. (...) Due to the fact that the heart rate (HR) is commonly accepted as the universal measure of workload intensity, the product of effort duration and HR seems to be the general indicator of ***training load*** defined as the amount of workload. It is useful in analyses with a high level of generality. (...) In current research and training practice the product of effort duration and HR was referred to as conventional units' or further calculations have been made to convert it into points." [36, p. 238].

Table 1. Average anthropometric values of the study groups.

Variable	Kyokushin karate (n = 14)	Basketball (n = 41)	American football (n = 35)	Soccer (n = 14)	Swimming (n = 10)	Control group (n = 132)
	M & SD					
Age [years]	21.4 ±9.3	17.4± 1.8	22.5 ±4.1	23.5± 2.1	16.4± 4.4	23.7 ±1.3
Height [cm]	180.1 ±7.7	188.6± 6.9	182.5 ±6.1	178.8 ±7.2	172.7 ±14.3	179.7 ±6.8
Body mass [kg]	75.3 ±14.4	80.4 ±12.3	97.8± 17.9	79.8 ±12.8	62.8 ±17.8	76.9± 7.7
BMI [kg/m^2]	23.1 ±3.1	22.6 ±2.9	29.4± 5.2	24.84± 2.9	20.6± 3.3	23.8± 2.3
Variable	**Kyokushin karate vs other athletes and men from the control group [p]**					
Age		0.289	1.000	0.281	1.000	0.023
Height		0.051	1.000	1.000	1.000	1.000
Body mass		1.000	0.000	1.000	1.000	1.000
BMI		1.000	0.000	1.000	1.000	1.000

Table 2. Athletic training schedules (main components).

Sport Discipline	Training per week	Average training time duration [min]	Location of training	Competition form licensed competitor/amateur
Karate kyokushin	2	90	Gymnasium	Amateur
	1	60		
Basketball	5	90	Gymnasium	Licensed competitor (sports championship school, club)
	League games on schedule for the season			
Swimming	11 (Mon to Fri: 2xday; Sat 1xday)	90	Swimming pool	Licensed competitor (sports championship school, club)
		60	Gym - strength training	
	Weekends 2x in the month	Competitions		
American football	2	120	Playing field	Licensed player, league team
	2-3	120	Gym - strength exercises	
	League games on schedule for the season			
Soccer	2	120	Playing field	Licensed player, 4-league team
	2-3	60	Gym - strength exercises	
	League games on schedule for the season			

Statistical analysis

The descriptive statistics from the Statistica ver. 13 software were used to describe the groups. The estimation of the results is based on the following indicators: frequency (n); mean (M); standard deviation (SD or ±). Non-parametric tests for independent groups (Mann-Whitney U test) were used to assess the significance of the differences between the groups. When comparing the values of the FFF index of the right and left side in individual groups, non-parametric tests for dependent groups were used (Wilcoxon's pair order test). The level of statistical significance was determined to be $p \leq 0.05$.

RESULTS

The amateur karate practitioners do not differ in the percentage of body fat from men practicing swimming, basketball or soccer. In all groups, except for the American football players, a normative level of the percentage of body fat was found. The lowest percentage of body fat was found in the basketball players and in the control group as well. The highest percentage was registered in the members of the football group. In the karate, basketball and swimming groups, a peripheral distribution of fat mass was noted. Simultaneously, a significant reduction in the distribution of fat mass within the torso was noted. In the remaining groups, the body fat mass was greater than the general fat mass, therefore indicating an android body type (Table 3). Karate practitioners differed significantly from the American football group in terms of their percentage of total fat mass, as well as in the torso and FatP in the upper and lower limbs in the control group. The other groups do not differ statistically from karate practitioners (Table 4).

Only the American football athletes, as well as the soccer players, had higher values of the fat-free fat index (FFF) when considering it in general and within the torso. The FFF index for the lower extremities is the lowest in the control group, soccer, and American football groups. Only in the swimming and soccer groups the index within the lower limbs jumps on a symmetrical structure. In the remaining groups, RL FFF has a lower index than LL FFF, which indicates greater muscularity in the lower right limb. In all groups, greater muscularity in the right upper limb compared to the left limb was observed, as evidenced by the lower RA FFF index (Table 5). Karate practitioners do not differ significantly in terms of the FFF index from those practicing swimming, basketball and soccer. Statistically significant differences were observed between karate and American football players within the FFF and TR FFF indexes. In the control group RL FFF and LL FFF are statistically significantly lower than in the karate group. In the karate, basketball, American football and control groups, statistically significant differences were observed between the FFF indexes for the right and left side, which indicates the presence of asymmetry in the distribution of fat and muscle mass (more data in Table 6).

Table 3. Average values and standard deviation (±) of the percentage of fat mass in the all studied groups.

Variable	Kyokushin karate (n = 14)	Basketball (n = 41)	American football (n = 35)	Soccer (n = 14)	Swimming (n = 10)	Control group (n = 132)
FatP [%]	15.71± 4.10	14.44± 4.95	22.23± 5.78	16.77± 5.28	14.87± 3.69	14.63 ±4.23
RL FatP [%]	17.15± 4.15	16.74± 5.58	17.13± 3.74	14.31± 4.46	17.32± 5.35	12.85± 4.21
LL FatP [%]	18.16± 4.71	17.13± 5.74	17.52± 4.15	14.44± 3.88	17.38± 5.34	13.45± 3.74
RA FatP [%]	17.86± 3.90	16.40± 6.09	19.70± 4.08	17.55± 5.13	19.51± 7.56	14.37± 3.03
LA FatP [%]	19.04± 3.61	18.18± 7.25	21.00± 4.08	18.36± 5.35	19.36± 8.21	14.92± 3.13
TR FatP [%]	13.64± 5.67	12.18± 4.66	25.64± 7.95	18.01± 6.50	12.32 ±3.27	15.61± 4.92

Table 4. Kyokushin karate (n = 14) vs other athletes and men from the control group [p] (the percentage of fat mass).

Variable	Basketball (n = 41)	American football (n = 35)	Soccer (n = 14)	Swimming (n = 10)	Control group (n = 132)
FatP	1.000	**0.002**	1.000	1.000	1.000
RL FatP	1.000	1.000	1.000	1.000	**0.006**
LL FatP	1.000	1.000	0.501	1.000	**0.002**
RA FatP	1.000	1.000	1.000	1.000	**0.024**
LA FatP	1.000	1.000	1.000	1.000	**0.006**
TR FatP	1.000	**0.000**	0.349	1.000	1.000

DISCUSSION

One of the most difficult coaching decisions to make is selecting people predisposed to practice a specific sports discipline. In addition to the assessment of motor skills, so far the Sheldon typology has been used to determine the type of body composition of people who train. However, it requires measurements of body weight and height, the thickness of the skin and fat folds and bone epiphyses. Thanks to the use of population patterns, it enables the determination of body types and subtypes. However, Sheldon's typology has some limitations – it is relatively complicated, time-consuming, and requires the development of patterns for a given sport, age and gender [16-18, 29].

Sterkowicz-Przybycień [16] in her research points out that the body type of karate athletes is related to their level of training. It was observed that international class karate athletes had more experience and more training and because of they had a lower value of BMI and Fat Mass. They frequently developed more endomorphic body type. The comparison between the international and national class athletes used by Strekowicz-Przybycień [16] shows the influence the length of training of those athletes who practiced karate.

Similarly, in the research presented by Rutkowski et al. [4, 30] on a karate children's group, changes in segments of their bodies where observed using the FFF index. In his research, \Rutkowski et al. [4, 30] showed the effect of ten weeks of karate training had on the body composition of children. A decreased the FFF index and improved symmetry of their body composition where both observed.

In these studies, it was observed that the FFF index did not significantly differ statistically among the groups participating in training for karate, basketball and swimming despite the apparently lower number of weekly training sessions. It is important that in the case of swimming, we can determine the intensity of training and even calculate the energy expenditure for a training unit, which we cannot determine in the case of karate training. Thanks to the use of such a comparison and the lack of differences, it can be indirectly determined that the karate training used by the respondents is comparable in terms of intensity to the loads used in competition groups.

In my own research, carried out, among others, on teenagers training swimming, differences were observed between short-distance and long-distance athletes [18]. The use of the FFF indicator at

Table 5. Average values and standard deviation (±) of the FFF index in the all studied groups.

Variable	Kyokushin karate (n = 14)	Basketball (n = 41)	American football (n = 35)	Soccer (n = 14)	Swimming (n = 10)	Control group (n = 132)
FFF	0.189± 0.062	0.178± 0.069	0.293 ±0.101	0.206± 0.076	0.177 ±0.052	0.174± 0.06
RL FFF	0.210± 0.062	0.221± 0.084	0.209± 0.056	0.170± 0.061	0.213± 0.079	0.151 ±0.06
LL FFF	0.229 ±0.075	0.227± 0.085	0.216± 0.063	0.170 ±0.052	0.213± 0.080	0.159 ±0.053
RL FFF vs LL FFF [p]	**0.004**	**0.001**	**0.009**	0.594	0.859	**0.000**
RA FFF	0.219 ±0.063	0.226± 0.086	0.250 ±0.065	0.219± 0.076	0.251 ±0.119	0.169± 0.045
LA FFF	0.234± 0.055	0.258 ±0.108	0.269± 0.072	0.233 ±0.084	0.254± 0.133	0.178± 0.046
RA FFF vs LA FFF [p]	**0.01**	**0.000**	**0.000**	**0.008**	0.866	**0.000**
TR FFF	0.163± 0.083	0.139 ±0.063	0.361 ±0.153	0.227 ±0.095	0.142 ±0.043	0.189 ±0.071

Table 6. Kyokushin karate vs other athletes and men from the control group [p] (the FFF index in the all studied groups).

Variable	Basketball (n = 41)	American football (n = 35)	Soccer (n = 14)	Swimming (n = 10)	Control group (n = 132)
PMM	1.000	**0.002**	1.000	1.000	1.000
RL PMM	1.000	1.000	1.000	1.000	**0.007**
LL PMM	1.000	1.000	0.357	1.000	**0.002**
RA PMM	1.000	1.000	1.000	1.000	**0.024**
LA PMM	1.000	1.000	1.000	1.000	**0.009**
TR PMM	1.000	**0.000**	0.330	1.000	1.000

the stage of swimmers' specialization would allow them to target their training according to their abilities and preferences. Comparing karate practitioners to swimmers, it has been observed that the FFF indexes of karate athletes are higher than that of short-distance swimmers and lower than that of long-distance swimmers. Taking into account older swimmers (training experience over 5 years) without the division into distance specialization and karate athletes, there are no significant differences in terms of fat mass, which, however, is lower in swimmers within the torso, lower right limb and the total value, while the remaining values are they are lower in karate men. Such an ambiguous result confirms the research carried out by Gloc et al. [24] on the group of karate fighters comparing the values for women and men.

The conclusions from the conducted research indicate the lack of unambiguous values determining the body composition characteristic of karate athletes. However, Gloc et al. [24] in their broadcasts they used typical indicators such as BMI, waist circumference or body composition components determined with the use of various measurement methods. Gloc et al. [24] first of all, they tried to determine the level of fat mass and Fat free mass together with total body water, but they did not try to make these values dependent on each other. Similar results were obtained in his research by Zombra [31] comparing karate athletes with non-training people, also in his research project karatecas had statistically significantly lower body fat compared to non-training people. The differences in the results of Zombra in relation to the described studies may be due to the age of the non-athletes tested. Unlike Zombra [31], they compare karate athletes to the control group, there are no statistically significant differences in terms of body weight or the FFF and TRFFF index, but there are significant differences in the values of the peripheral RLFFF, LLFFF, RAFFF or LA FFF indexes.

When assessing an athlete's body composition, the most important thing is to determine the ratio of fat mass to lean body, the main component of which is muscle mass. This ratio, presented as the FFF index, shows no statistically significant differences between players with a much greater body weight, such as American football players, or karate fighters who are 20 kg lighter than them on average. In this case, the FFF index seems to be the most effective method of assessing MM regardless of the total body weight.

In the segmental study, karate trainers show relatively slight but statistically significant differences in the values of the FFF index, which prohibits the lack of symmetry in the body structure. Comparing the obtained results to the research on the younger group starting karate training, it can be noticed that with the extension of the training time, the asymmetry of fat mass distribution deepens. In studies on the younger group, an improvement in symmetry and muscle strengthening of the non-dominant limb was observed over a 10-week training period, therefore it is surprising that asymmetry reappears in older players. This may be the result of focusing the training on the dominant side or a significant influence of the lifestyle on the body structure [32, 4, 28].

Thanks to the use of the FFF index, it can be concluded that the studied groups of athletes (players), regardless of the nature of the training and their intensity, do not differ in terms of the ratio of fat and lean mass. The presented research was carried out on a small research group, however, the results allow us to assume that the fat-free index is a good tool for qualifying people for a specific sports discipline and for monitoring the training process. However, in order for this tool to be fully used, it requires research on a larger group of people training at various stages of ontogenetic development.

CONCLUSIONS

The research shows that the training form used in kyokushin karate gives similar effects in terms of body composition as swimming training, used in basketball, soccer or American football. At the same time, an important element that should be supplemented in long-term training is the improvement of the symmetry of fat mass distribution.

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