

The caloric cost of combat sports and martial arts training in relation to health recommendations – initial research

Authors' Contribution:

- A** Study Design
- B** Data Collection
- C** Statistical Analysis
- D** Manuscript Preparation
- E** Funds Collection

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Abstract

Background

The aim of study was to expand the knowledge about the caloric cost (CC) of trainings in selected combat sports and martial arts, in the context of daily recommended physical activity necessary for health.

Material & Methods:

The study was conducted in a total of 89 men who recreationally trained 3–4 times a week aikido, capoeira, jujutsu, kick boxing, kyokushin karate, traditional karate, vma (various martial arts). For the measurements of training CC, “Caltrac Monitor” accelerometers (Muscle Dynamics, Inc. Torrance, CA, USA) were used. CC of three 60-minute workouts was monitored in each of the seven tested combat sports and martial arts, and the average results were given in kilocalories per hour (kcal/h) (absolute CC of exercises). The intensity of exercises was measured by multiplicity of metabolic equivalent (MET) (index of relative CC of trainings). Absolute and relative values of CC in each martial arts were compared to health-oriented physical activity (PA) recommended by the American College of Sports Medicine.

& Study Aim:

Results:

We have demonstrated that the majority of men taking part in combat sports and martial arts trainings met the criteria of daily physical activity for health.

Conclusions:

In the further studies on CC of combat sports and martial arts practice, measurement devices should be used that allow estimation of the ratio of training exercises with low, moderate, high and very high intensities.

Key words:

physical activity • energy expenditure • Karate • Capoeira • accelerometry • Various Martial Arts

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BACKGROUND

A positive social phenomenon in recent years is the growing awareness of the crucial role of physical activity in the prevention of health. For the present generations it becomes not only a form of pleasant leisure activities (recreation), but rather a duty and a necessity of life [1–4]. It has been repeatedly demonstrated that regular physical activity at the appropriate load and form

can effectively prevent negative consequences of a progressing hypokinesia in following generations, reducing the risk of a number of so-called diseases of civilization (lifestyle diseases), the etiology of which is closely associated with hypokinesia. The most common among these disorders are cardiovascular diseases (heart attack, stroke, and high blood pressure), type 2 diabetes, obesity and osteoporosis. A rational recreational physical activity reduces mortality rate caused by these diseases [5,6].

Energy expenditure – amount of energy (calories), that a person uses to breathe, circulate blood, digest food, and be physically active.

MET (metabolic equivalent of tasks) – is a physiological measure expressing the energy cost of physical activities and is defined as the ratio of metabolic rate during a specific physical activity to a reference metabolic rate, set by convention to 3.5 ml O₂/kg/min.

Hypokinesia – refers to decreased bodily movement. It is associated with basal ganglia diseases, mental health disorders and prolonged inactivity due to illness, amongst other diseases.

Accelerometer – device that measures proper acceleration. Accelerometers are used to measure the motion and vibration of a structure that is exposed to dynamic loads. <http://en.wikipedia.org/wiki/Accelerometry> - cite_note-23 Dynamic loads originate from a variety of sources including f.e. Human activities – walking, running, dancing or skipping; Working machines – inside a building or in the surrounding area; Construction work – driving piles, demolition, drilling and excavating; Moving loads on bridges and others.

Caltrac Monitor – Caltrac is a 1-dimensional accelerometer, which uses subjects physiological data to calculate the number of calories burned by a person in any given period of time Caltrac uses a piezoceramic cantilevered beam to produce a voltage in response to vertical accelerations and decelerations.

Among physical activities, one of the more popular in recent years, especially in males, are martial arts (combat sports). Diverse aspects of martial arts training, including health, for years have been the subject of scientific investigations. Many published studies focused on the possible use of combat sports for weight loss programs [7–9]. Physiological reactions of the organism to selected exercises from the martial arts training regimens have been observed, thus their intensity have been evaluated [10–14]. Absolute and relative energy expenditure – EE (kcal, kJ, MET) have been frequently assessed during different combat sport trainings. This parameter is considered the best measure of the level of physical activity [15, 16]. Studies included estimations of EE (caloric cost – CC) of executing a combination of fighting techniques – strikes, blocks, kicks, etc. [12,17–20]. CC was also measured in simulated fights (sparring matches) [8,10,21]. Those studies were conducted among people in different age groups in both the beginner and advanced athletes, and usually focused on one of the many forms of martial arts [7,9,12].

Martial arts are a discontinuous type of exercises, therefore, EE monitoring of parts of the practice (e.g. sequences of movements) does not allow to evaluate the effectiveness of activities in the context of fulfilling the standards of daily health-related physical activities [22–24]. A condition that would allow such an evaluation is CC monitoring of the full-length training practice of various combat sports. This type of studies are so far scarce [8,12], hence the potential health effects of the training unit of martial arts, treated as recreation, are not yet sufficiently recognized from the scientific standpoint.

The aim of our study was to increase the knowledge about energy expenditure (EE) during trainings of selected martial arts, practiced by adult males. We sought answers to the following questions:

1. What is the average total caloric cost of recreational workout in aikido, capoeira, jujutsu, kick boxing, kyokushin karate, traditional karate, vma (various martial arts) in men who practice martial arts?
2. What is the average exercise intensity during one-hour training in the aforementioned varieties of martial arts?
3. To what extent the practice of martial arts has allowed the subjects to fulfil health-oriented physical activity guidelines recommended by renowned global institutions?

We hypothesize that training most of the combat sports studied here allow for the implementation of a daily dose of physical activity recommended for health.

MATERIAL AND METHODS

The study was approved by the Ethics Committee of the Opole Medical Council (Nr 165 2009) and was conducted in 2011 in the province of Opole on 89 men, aged 18–46, that trained recreationally 3-4 times a week following sports: aikido, capoeira, jujutsu, kick boxing, kyokushin karate, traditional karate, vma. All tested groups consisted of 13 subjects with the exception of jujutsu group that counted 12 men. The selection for the study was targeted as only persons with at least one year training experience were qualified for the study.

To measure the CC of the training in kilocalories (kcal), Caltrac Monitor accelerometers (Muscle Dynamics, Inc., Torrance, CA, USA) were used, which subjects wore on the bands fastened on hips under sportswear. Prior to trainings, members of the research team entered the data on age, height and weight of the subjects to the measuring devices, and the results of the monitoring of the CC (kcal) of the exercises were recorded in a specially prepared observation sheet after the trainings. The CC of three 60-minutes trainings in each of the seven studied combat sports was monitored. It was ensured that their structure consisted of three main parts, i.e. warm-up, improvement of specific elements of fighting techniques, and sparring, stretching and calming exercises.

Average results of the CC monitoring of the three trainings are given in kilocalories per hour of exercise (kcal/h), treated as an absolute indicator of EE. The intensity (strength) of the exercises was defined by multiplicity of the metabolic equivalent of task (MET), which was used as an indicator of the relative EE [23]. This allowed us to compare our results with other studies, as these are the most commonly used parameters.

The mean absolute and relative EE values obtained in the current study during trainings were compared to the recommendations for health-oriented physical activity, recommended by the American College of Sports Medicine (ACSM), the American Heart Association (AHA) and the World Health Organization (WHO) [23,24]. These guidelines assume two equivalent criteria of physical activity recommended for health for adults. The first criterion assumes that the exercise should be undertaken five times a week for not less than thirty minutes and should have at least moderate intensity (3–6 METs).

According to the second criterion, the physical exercises of high intensity (>6 METs) should be performed at least three times a week for not less than twenty minutes.

Taking into account the factors of time and intensity of physical activity from the first criterion and the body

Table 1. Biometric properties of tested men practicing selected martial arts.

Variables	Martial arts	$\bar{x} \pm SD$	Min.–Max	Kruskal-Wallis test	Variables	Martial arts	$\bar{x} \pm SD$	Min.–Max	Kruskal-Wallis test
Age [year]	Aikido	24.3±4.4	19–33	H=23.9 p<0.001	Body mass [kg]	Aikido	80.8±7.3	71–96	H=15.0 p=0.020
	Capoeira	23.2±2.1	21–27			Capoeira	70.5±10.2	54–91	
	Jujutsu	32.2±4.5	22–36			Jujutsu	82.9±10.8	72–110	
	Karate	24.3±9.1	18–46			Karate	75.5±10.4	60–93	
	Kyokushin karate	26.8±7.1	20–41			Kyokushin karate	79.1±12.6	69–108	
	Kick boxing	22.1±2.9	18–28			Kick boxing	75.0±8.4	63–91	
	VMA	24.3±4.4	19–33			VMA	80.8±7.3	71–96	
Height [cm]	Aikido	179.7±5.5	172–193	H=10.0 p=0.123	BMI [kg/m ²]	Aikido	25.0±1.6	23–28	H=27.9 p<0.001
	Capoeira	176.9±5.9	165–187			Capoeira	22.5±2.6	18–29	
	Jujutsu	174.7±4.7	170–185			Jujutsu	27.1±2.6	24–34	
	Karate	178.3±4.5	170–185			Karate	23.7±3.1	20–30	
	Kyokushin karate	176.5±6.2	170–188			Kyokushin karate	25.3±3.1	21–33	
	Kick boxing	180.0±6.4	170–193			Kick boxing	23.1±1.6	20–26	
	VMA	179.7±5.5	172–193			VMA	25.0±1.6	23–28	

Actigraphy – is a non-invasive method of monitoring human rest/activity cycles. A small actigraph unit, also called an actimetry sensor, is worn by a patient to measure gross motor activity. Motor activity often under test is that of the wrist, measured by an actigraph in a wrist-watch-like package. The unit continually records the movements it undergoes.

Calorie – The energy needed to increase the temperature of a given mass of water by 1 °C depends on the atmospheric pressure and the starting temperature, and is difficult to measure precisely. Accordingly, there have been several definitions of the calorie that attempt to make the definition more precise.

VMA (Various Martial Arts) – mix of various martial arts which are practiced for a variety of reasons: self-defense, physical health and fitness.

weight of the tested athletes, each of them was assigned an absolute daily range of EE on physical activity recommended for health (RDEE). The formula used for this purpose was:

$$RDEE [kcal] = 0.017 [kcal/kg/min] \times I \times 30 [min] \times BM [kg]$$

where:

RDEE – recommended daily energy expenditure on physical activity,

I – the recommended intensity of an exercise – 3 and 6 METs (lower and upper limit of the range),

BM – body mass of the subject, for which RDEE is determined.

Arithmetic means were calculated for all indices considered (\bar{x}), standard deviations (SD), and minimal (Min) and maximal (Max) results. The Kruskal-Wallis test was used to determine significance differences between groups of athletes training different martial arts. The statistical analysis was performed using STATISTICA 9.1 software.

RESULTS

The average values of biometric parameters of tested men who practiced various combat sports were similar. The exception were the practitioners of jujutsu, who were the oldest, mean age: 32.2±4.5 years, (all

subjects mean: 25.2±6.0 years), had the lowest average body height (mean 174.7±4.7 cm), and possessed the highest average weight (mean 82.9±10.8 kg). As a result, they had the highest body mass index (BMI mean: 27.1±2.6 kg/m²), while the average in all subjects was 25.2±6.0 kg/m² (Table 1).

Energy expenditure (EE) during one-hour training for all of the researched combat sports in the individual subjects fell in the range of 130.0 to 439.0 kcal (mean: 265.7±57.3 kcal), and the intensity of effort fluctuated in a wide range of 2.0 to 6.0 METs (mean: 3.5±0.8 MET) (Table 2).

On average, most calories were expended by kyokushin karate participants (333.3±55.0 kcal/h), the lowest absolute CC was measured in jujutsu trainings (195.1±33.0 kcal/h).

In other martial arts workouts CC values were similar, slightly exceeding 270.0 kcal/h, an exception was capoeira (233.8±24.2 kcal/h) (Table 2).

Most of the monitored combat sports activities were characterized by a moderate intensity of exercises, at a level closer to the lower limit of the activity intensity in this interval (mean 3.4-3.7 MET). Intensity of kyokushin karate training was placed in the middle of the interval (4.2 MET). Low intensity of exercises was found only in the jujutsu practice (2.4 MET) (Table 2).

Table 2. Numerical characteristics of EE associated with selected martial arts.

Variables	Martial arts	$\bar{x} \pm SD$	Min.–Max	Kruskal-Wallis test	Variables	Martial arts	$\bar{x} \pm SD$	Min.–Max	Kruskal-Wallis test
EE [kcal]	Aikido	274.3±53.1	210–420	H=41.8 p<0.001	EE [MET]	Aikido	3.4±0.8	3–6	H=45.9 p<0.001
	Capoeira	233.8±24.2	196–279			Capoeira	3.4±0.5	3–4	
	Jujutsu	195.1±33.1	130–248			Jujutsu	2.4±0.4	2–3	
	Karate	277.2±34.4	211–330			Karate	3.7±0.4	3–4	
	Kyokushin karate	333.3±55.0	269–439			Kyokushin karate	4.2±0.4	4–5	
	Kick boxing	273.2±42.2	208–349			Kick boxing	3.7±0.6	3–5	
	VMA	272.8±53.9	210–420			VMA	3.4±0.8	3–6	

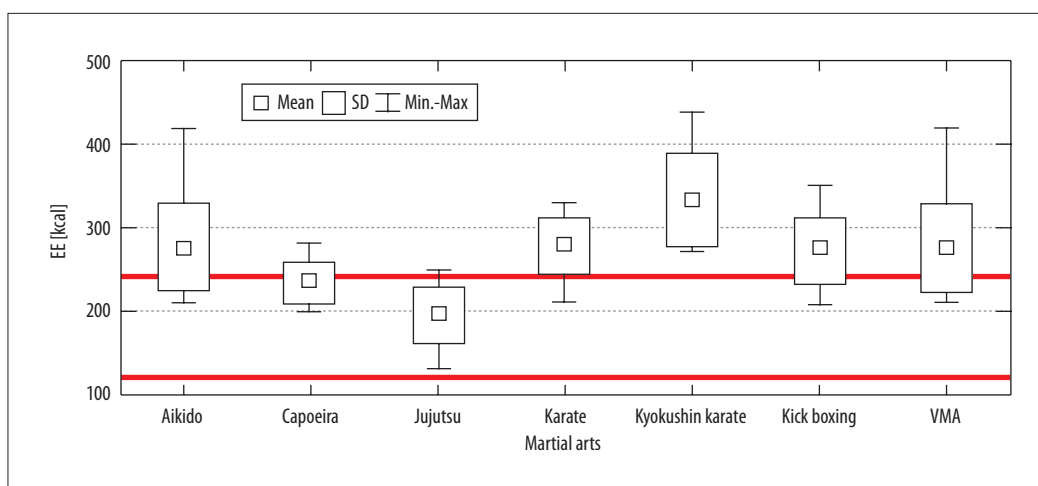


Figure 1. Energyexpenditure (kcal) of recreational training of martial arts against the daily EE recommended for health prevention.

The main part of the results analysis was to compare the estimated EE parameters of subjects training martial arts with values recommended by ACSM, AHA and WHO as sufficient to obtain health benefits. Assessment of the health-oriented effects of recreational training of the combat sports was made in the light of the first criterion of above-described recommendations.

The range of recommended CC of daily physical activity that is beneficial to health (3–6 METs) was estimated for all (89) examined men at 119–238 calories, using the formula described in the methodology section of this study. These values are indicated in Figure 1 by solid lines.

The average caloric cost of one hour of practice of all martial arts studied here was sufficient to preserve health. For most of them, with the exception of capoeira and jujutsu, the average absolute EE of one-hour practice exceeded the upper value of the range recommended to achieve health benefits. The data illustrated in Figure 1

(maximum performance) indicate that most of the combat sports monitored here significantly exceeded the upper values of recommended daily EE for health-oriented physical activity (Figure 1).

The recommended moderate intensity of exercises (3–6 METs) during recreational training of studied combat sports was reached by the majority of subjects, with the exception of individuals training jujutsu (solid lines in Figure 2). Kyokushin karate practitioners came closest to the upper limit of the interval of the effort intensity. Subjects training traditional karate, kick boxing, aikido, vma and capoeira, exercised with an average intensity closer to the lower limit. The highest individual variability of exercise intensity was found in the group of men practicing aikido and vma, the lowest variability was reported in men who trained two varieties of karate. Individual members of the groups training aikido and vma exercised with the intensity approaching the high level. At the same time, only three men from jujutsu group exceeded the lower limit of moderate-intensity effort (Figure 2).

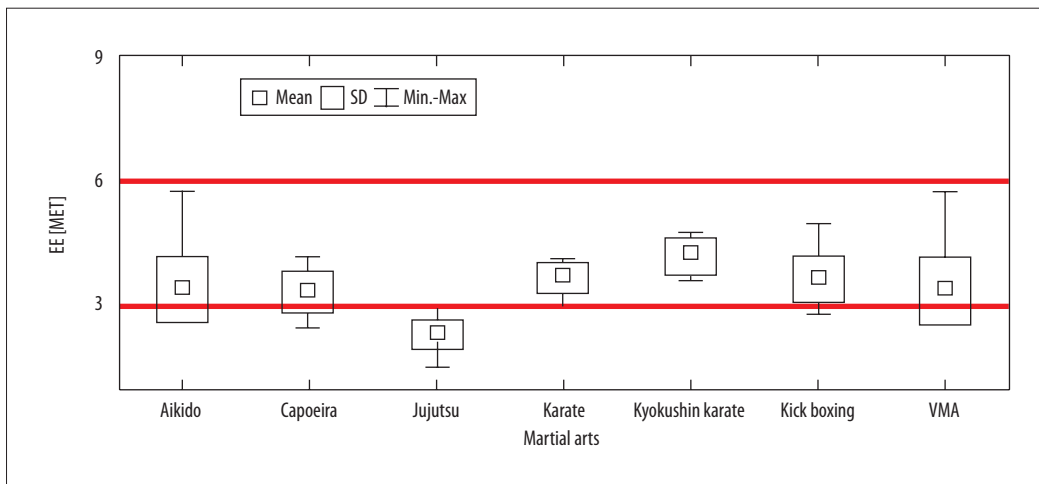


Figure 2. Energy expenditure (MET) of recreational training of martial arts against the daily EE recommended for health prevention.

DISCUSSION

In recent compendia of the intensity of various forms of physical activity, the exercise intensity during martial arts training (such as judo, jujutsu, karate, kick boxing and tea-kwan-do) are estimated at the level of 5.3 METs in novice participants to 10.3 METs in advanced participants. These estimations are based on the results of many observations and experiments conducted over the last decades [25–28].

In martial arts studies, usually the absolute and relative EE of the combination of movements such as throws, kicks, strikes and blocks were evaluated. These sequences are repeated during exercises, on average lasting from 2 to 10 minutes, more frequently in men than women. Caloric cost of such exercises varied, depending on the type of combat sport (karate, tea-kwan-do) and the duration of the repeated exercises from 5 to 14 kcal/min [9,12–14,18].

EE was also frequently estimated during simulation matches (sparring matches). Imamura et al. [21] estimated CC of karate sparring to be about 8 kcal/min. Bellinger et al. [29] calculated that during non-contact boxing, participants expended about 11 kcal/min. Further, energy expenditure during simulation matches of Muay Thai was estimated to be 10.7 kcal/min [10].

Other studies also noticed that the diverse intensity of exercises is a characteristic feature for this type of physical activities. For instance, exercise intensity at the low and moderate level (3.0–3.6 METs) was found in subjects with low functional capacities that participated in a modified form of Tai chi exercises [11]. Whereas, the relative EE when executing a sequence of exercises from the area of combat sports by novice participants

was determined at 6.6 METs in men and 6.0 METs in women [12]. High intensity effort (>7 METs) was characteristic of sparring matches [21], for athletes training Muay Thai (9.4 METs) [10] as well as boxing (>10 METs) [29].

High intensity of exercises can be sustained only in the short time intervals, therefore martial arts are considered a discontinuous type of exercises. This means that the practitioner must often engage in fairly intense levels of exercise, followed by periods of reduced activity or rest. The work intervals are typically brief (i.e. 30–60 s exercise followed by 30–60 s of reduced activity), so that a reasonably consistent level of metabolic intensity can be maintained [12]. For this reason, MET expenditure for the martial arts activity is equivalent to activities such as wrestling, fencing, boxing, aerobics and selected walk/job intensities.

Energy cost of full training session and its intensity are proportionally lower than in the mainly studied dynamic parts of the training. As a result, the average EE of complete martial arts training session in our study (270 kcal/h) was lower than in the previously referenced studies. The same held true for the exercise intensity (3.6 METs). Similar results to our study were obtained by Imamura and others [8] who studied EE in karate training sessions. In 70 min long training session, mean EE was 1120 kJ, which translates to 240 calories per hour. Toskovic and colleagues [9] studied the 20 min long dynamic classes of Tea-Kwan-Do and found that the total caloric cost exceeded 200 kcal in women and 300 in men. According to these authors, such intense exercises can be continued for no longer than 20 minutes.

Many studies available in the literature refer to standards of health-related physical activity developed by

Paffenbarger group at the turn of '80s and '90s. These standards assumed, among others, that a healthy adult, weighing 70 kg, should be spending on a habitual and free time physical activity a total of about 300 calories a day. Our findings indicate that 60 minutes of combat sports training, bring men engaged in these types of activities significantly closer to fulfil Paffenbarger standards. However, recreational workouts usually last about 90 minutes, which allows to assume that the standards are fulfilled with a surplus. At the same time, however, they take place only 3–4 times a week, and the ASSM recommends physical activities at least 5 times a week. Thus, the recommendations pertaining to the frequency of practice per week were not fulfilled by a majority of subjects in our study.

It should also be noted that the average intensity of the exercise training session of the most martial arts studied here balanced on the border of the low and moderate intensity efforts. In previously cited recommendations concerning physical activity that benefit one's health, it is emphasized that only moderate and high exercise intensities guarantee the desired results in this regard [22–24]. The reasons for the relatively low intensity of trainings of the studied martial arts were probably the recreational nature of these activities and great diversity in functional capacity, commitment of athletes and their training experience, which is characteristic of these disciplines. Moreover, level of qualifications of the coaches was most likely not without significance as indicated by work of Kalina and colleagues [30]. The lowest intensity of jujutsu trainings was probably also conditioned by athletes age, their relatively high body

mass, and most of all, specific character of the movements accompanying this variety of martial arts (movement in a small space).

In summary we state that the Caltrac Monitor accelerometer was able to record only the total CC of motion exercises within a certain time frame, without giving the possibility to assess the proportion of the efforts of varying intensity. Such information would more accurately describe the health effects of martial arts training, which are characterized by a continuous variation of exercise intensity.

New generation of measuring devices such as ActiGraph, activPAL, and BodyMedia SenseWear Armband allow registration of the intensity of different forms of physical activity in short intervals [31–33]. We believe that the research progress on EE during combat sports practice will be possible using such modern measurement devices.

CONCLUSIONS

Empirical data collected in this study are a sufficient proof to confirm the assumed hypothesis, i.e. recreational martial arts training met the criteria of the daily health-oriented physical activity in the majority of the studied individuals. Our results refer more to the absolute EE during exercises and to a lesser extend to their intensity. Therefore, we can conclude that in the future studies on EE during combat sports practice, measurement devices should be used that allow the assessment of the ratio of training exercises with low, moderate, high and very high intensities.

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