PULMONARY FUNCTION IS RELATED TO SUCCESS IN JUNIOR ELITE *KUMITE* KARATEKAS

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Abstract
Spirometry can be considered a method for measuring lung capacity and speed of air-flow through the airways. Due to its simple application, it is commonly used in sport diagnostics. Aims of this research were to determine the values of ventilation function variables in karatekas competing in kumite discipline and their relationship to result. The sample included 51 junior karate athletes (with defined subgroups of more successful [n=31] and less successful [n=20]), competing in kumite discipline, from nine European countries. Their values of some ventilation function variables were measured. Measurement procedures were chosen and used according to acknowledged literature. By univariate analysis of differences, significant differences between more successful and less successful competitors were determined in the following variables: forced vital capacity (more successful 5.24±0.56 l; less successful 4.27±0.61 l; p=0.00), forced expiratory volume in 1 second (more successful 4.13±0.68 l; less successful 3.69±0.57 l; p=0.02), ratio of forced expiratory volume in 1 second/forced vital capacity (more successful 78.98±10.29%; less successful 86.64±8.37%; p=0.01) and maximal voluntary ventilation (more successful 150.46±31.14 l/min; less successful 125.50±29.49 l/min; p=0.01). More successful contestants showed higher values in some relevant variables compared to less successful ones supporting a relationship to result.

Key words: *martial art, spirometry, vital capacity, pulmonary ventilation, analysis of variance, juniors*

Introduction

Karate is a combat sport in which two competitors try to strike each other using punches and kicks (with limited contact). In the basic structural division, according to the rules of sport, karate is divided into *kata* (pre-determined attack and defensive actions), and *kumite* (combat competitive discipline, which can be practised individually and in teams, according to age and weight categories; Chaabène, Hachana, Franchini, Mkaouer & Chamari, 2012). *Kumite* is the activity in which two fighters (contestants) are directly opposed each other. The karate fight differs from other combat sports in the fact that the basic aim, being a symbolic destruction of the opponent, is performed *via* symbolised or strictly controlled hand and leg strikes. The opponents try to direct optimally precise and timed strikes using their arms and legs – fist and foot – directed towards certain body parts, while fighting off or avoiding attacks (Chaabène et al., 2012). In relation to this, the *kumite* competitive karate discipline can be interpreted as a process of dynamic interaction between two opponents (Katic, Jukic & Milić, 2012).

Aerobic metabolism has been considered to be the predominant source of energy in this sport (Beneke, Beyer, Jachner, Erasmus & Hütler, 2004; Doria et al., 2009). The determination of the karateka`s pulmonary ventilation function and the obtained results of this type of research represent a contribution to the methodology building, since high-intensity intermittent sports, such as karate, mainly rely on the aerobic energy sources, although the determinant actions are maintained by the ATP-PCr system (Beneke et al., 2004; Doria et al., 2009). In their study, Beneke et al. (2004) successfully analysed the metabolic profile of karate *kumite* based on the measurement of the blood lactate concentration and oxygen uptake pre, during and post fighting over a simulation with top-class athletes. The results showed that karate *kumite* fighting is made of activities that require a high metabolic rate. The acyclic activity profile including more or less frequent forward, backward and sidesteps, and hopping movements, combined with short bouts of extremely technical actions having high-energy requirements, and subsequent short breaks, causes a metabolic profile, in which aerobic metabolism is the predominant source of energy and where anaerobic supplementation occurs mainly by high-energy phosphates use (Chaabène et al., 2015). The aim of the study by Doria et al. (2009) was to evaluate the metabolic expenditure and the metabolic energy sources of a well-selected group of Italian top-level *kata* and *kumite* athletes, including world champions, together with their physiological characteristic such as the maximal aerobic and anaerobic powers and the explosive strength with the purpose to provide support for athletes training. They found out that world champions of *kata* and *kumite* are featured by approximately the same maximal aerobic and anaerobic powers *per* unit of body mass during conventional laboratory tests. And an oxidative predominance among the energy sources for both *kata* and *kumite* athletes (50%/74%, respectively).

This study focuses on pulmonary ventilation function, which refers to the mechanics of inhalation and exhalation, i.e., the air-flow between the atmosphere and the lung *alveoli*. This can be examined by means of the spirometry method, which measures lung static volumes and dynamic capacities. Two variables, most commonly used to describe the pulmonary ventilation function in athletes and general population, are forced vital capacity and maximal voluntary ventilation. Pulmonary ventilation represents a measure of athlete's health *status*, witnessing the capability of the athlete to perform high-quality and successful training activities. Generally, lung volumes and capacities are only slightly influenced by training. After training, vital capacity results mildly increased, but the overall lung capacity does not change (Wilmore & Costill, 1999). Nevertheless, the breathing function is differently influenced by different sports practice. In people, who are used to physical strain due to repeated exercise, more efficient ventilation is highlighted (Prakash, Meshram & Ramtekkar, 2007). The increase of vital capacity is mostly influenced by aerobic *stimuli*, whereas the increase of air-flow speed is mostly influenced by anaerobic *stimuli* (Attene et al., 2014; Jelicic, 2000). The examination of pulmonary function is one of the most important diagnostic sport procedures. Karate is no exception, because its activity duration and intensity demand a high level of functional abilities (Buchheit et al., 2008), which can be limited by the *deficit* of lung volume or capacities (Goic-Barisic, Bradaric & Erceg, 2006; Holmen, Barrett-Connor, & Clausen, 2002).

According to the *criterion* of energetic mechanisms preponderance, karate belongs to the group of high-intensity aerobic sports, even if featured by fast and short-lasting actions. Special metabolic demands, from the aerobic point of view, are required by the competitors due to the need of 1) replenishing the high-energy phosphates used for fast and short-lasting actions (Wilmore & Costill, 1999), and 2) competing in several fights in one single day. Regarding the different metabolic needs, the training process is designed with the aim of strengthening all the energetic mechanisms. The diagnostics area of pulmonary ventilation function in karatekas is almost unexplored. Only one paper using a sample of karatekas was found. Dordevic-Saranovic and Jakovljevic (2009) compared some variables featuring pulmonary function in karate athletes and orienteers, and investigated the differences in variables within each sport group and between the two groups. The following variables were investigated: forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1) and maximal voluntary ventilation (MVV). The study included 48 athletes, members of national teams. The examined sample consisted of equal numbers of karatekas and orienteering athletes. The condition for the entrance into the study was that the athletes were at the beginning of their general athletic training. The ventilation function variables were examined before and after high-intensity-exercise in both groups. After an overall analysis of the listed respiratory function variables for both sports at rest phase and after exercise, the conclusion was that there was not any significant difference between the two sports. These results show that at level of respiratory system the management of high-intensity exercise is performed in a way very similar, if not completely the same, regarding the analysed variables.

Problem and aim

The aim of the present research was to determine the values of pulmonary ventilation function variables in *kumite* karate competitive discipline in a junior age group and their relationships to result.

Methods

Participants

The study included 51 karatekas of junior age group competing in *kumite* discipline, from 9 European countries (Albania, Bosnia and Herzegovina, Bulgaria, Croatia, FYR Macedonia, Hungary, Israel, Montenegro, and Serbia). Their age was 16.9±0.9 (mean [M]±standard deviation [SD]) yrs, body height 177.0±6.8 cm, body mass (BM) 69.6±9.4 kg, and body mass index (BMI) 22.3±3.1 kg/m^2. The athletes were divided into two groups according to the success *criterion*: more successful (n=31) and less successful (n=20). The *criterion* variable was represented by the junior *kumite* karatekas result defined by taking into account the competitor's rank at the International Karate Federation World and European ranking list, the number of medals won at World, European and National level, and rankings at other relevant competitions. The group of more successful karatekas was represented by the medal winners, whereas the less successful group included competitors without a medal at the mentioned competitions. All the athletes participated in the international two-week karate camp held in Budva (Montenegro) in August 2013. Written informed consent was obtained from each of the participants and guardians (i.e., for underage players) after receiving an oral explanation of the potential risks and benefits resulting from the study participation. The protocol was approved by the local university ethical committee in the spirit of the Helsinki Declaration.

Procedures

This experimental study was approached through an observational research design (Padulo et al., 2013). The measures set regarded six ventilation variables. The ventilation variables were: FVC, FEV_1, and FEV_1/FVC [%]), MVV, and, from the flow *vs.* volume curve, maximal expiratory flow at 50% FVC (MEF_{50}), and maximal expiratory flow at 25% FVC (MEF_{25}). Measurement procedures were chosen and used according to the known standards (Knudson, Lebowitz, Holberg, & Burrows, 1983; Knudson, Saltin, Lebowitz, & Burrows, 1976; Miller et al., 2005). Standardisation of spirometry has been achieved through several stages.

The first American Thoracic Society (ATS) statement on the standardisation of spirometry was issued in 1979 (Snowbird workshop) and updated in 1987, and again in 1994. The European Community for Steel and Coal issued the first European standardisation document in 1983, which was updated in 1993 as the official statement of the European Respiratory Society (ERS). There are generally only minor differences between the two most recent ATS (American Thoracic Society, 1987; 1995) and ERS statements (Quanjer & Tammeling, 1983; Quanjer et al., 1993), except that the ERS statement includes absolute lung volumes and the ATS does not (Miller et al., 2005). Spirometry can be done by means of many different types of equipment, it requires cooperation between the participant and the examiner, and the results depend on both technical and human factors. In the present study, spirometry was performed by means of a portable and fully automated spirometer microQuark PC Based Spirometer (COSMED, Rome, Italy). Computer software included programs for lung function tests: spirometry, flow-volume curves, and maximum voluntary ventilation. The programs fulfilled CECA and ATS standards about all the technical factors, and mathematical algorithms. Karatekas performed a forced expiratory maneuver connected to a mouthpiece with nose closed in standing position to avoid any influence by the body position (Padulo, Di Capua & Viggiano, 2012). Air temperature was 11 to 15 °C and relative humidity ranged from 91% to 86% (http://m.meteo-info.hr/grad/budva). The room where the measurement was performed as well as the conditions of measurement met the recommendations of the manufacturer regarding placement and handling the instrument. Measurements were always carried out by the same person, a qualified nurse especially instructed to operate the instrument. Before the measurement, the instrument was calibrated following the manufacturer's instructions, with the aim of minimizing its errors.

Statistical Analysis

According to the aim of the research, data analysis was performed as follows. Basic descriptive indicators of pulmonary ventilation function variables included mean (M) and standard deviation (SD). To determine the differences in terms of success prediction power between ventilation variables values between the two groups competing in the karate *kumite* discipline, the univariate analysis of variance (ANOVA) was used, as well as the calculation of the *F*-test (Fisher test) values and p level of significance. All data were checked for univariate and multivariate outliers and no significant outliers were detected. Cohen´s d effect size (ES) between more successful and less successful *kumite* competitors was also calculated. The obtained ESs were shown and interpreted as proposed by Hopkins (http://www.sportsci.org/resource/stats/), with ES<0.2 considered as trivial, 0.2-0.5 small, 0.6-1.1 moderate, 1.2-1.9 large, and >2 very large. In all cases, statistical significance was set at $p<0.05$.

Data analysis was performed using the *Statistica ver. 11.00* software.

Results

Differences in values of pulmonary ventilation function variables between the groups divided according to their competitive success are shown in Table 1. More successful *kumite* competitors showed higher values in five out of the total six spirometry variables in comparison with the less successful junior competitors, who showed higher values only in FEV_1/FVC. It can be seen that there was a significant difference between more successful and less successful *kumite* competitors in FVC, FEV_1, FEV_1/FVC, and MVV. From moderate to large values of ES were noticed in the aforementioned pulmonary ventilation function variables, which were significantly determined by the groups divided according to the competitive success *criterion*.

Table 1. Values and differences of pulmonary ventilation function variables in more successful (n=31) and less successful (n=20) junior *kumite* competitors

Variables	More successful n=31	Less successful n=20			
	M±SD	M±SD	*F*-test	p	ES
Forced vital capacity - FVC (l)	5.24±0.56	4.27±0.61	34.16	0.00	2.07
Forced expiratory volume in 1 second - FEV_1 (l)	4.13±0.68	3.69±0.57	5.79	0.02	0.70
Forced expiratory volume in 1 second / Forced vital capacity - FEV_1/FVC (%)	78.98±10.29	86.64±8.37	7.75	0.01	0.82
Maximal expiratory flow at 50% FVC - MEF_{50} (l/min)	4.57±1.32	4.34±1.11	0.42	0.52	0.19
Maximal expiratory flow at 25% FVC - MEF_{25} (l/min)	2.93±1.04	2.74±0.89	0.42	0.52	0.20
Maximal voluntary ventilation - MVV (l/min)	150.46±31.14	125.50±29.49	8.14	0.01	0.82

M –mean, SD – standard deviation, *F*-test – value of statistical significance coefficient, p – level of statistical significance, ES – Cohen's d.

Discussion

We found that more successful *kumite* competitors had higher values of FVC, FEV_1, MEF_{50}, MEF_{25}, and MVV (Table 1). Less successful karatekas had higher FEV_1/FVC. This was caused by different differences in the primary variables FVC and FEV_1. Tiffeneau-Pinelli index is the percent ratio of FEV_1 to FVC (Swanney et al., 2008). Normal values of this index exceed 80%. Lower values indicate obstructive ventilation disturbances (Sahebjami & Gartside, 1996). Forced expiratory volume is the volume of air exhaled after the deepest inhalation. It is usually measured in the first second (FEV_1) and the end of the curve expresses the changes in capacity.

Therefore, it is considered one of the most important tests for detecting obstructive changes in large airways, but it also reflects the changes in small airways. As said, it is normally around 80% of FVC in reference participants. All children, when starting the training process in karate, first practice the *kata* discipline and then during puberty they are oriented towards the combat discipline *kumite*. Some young athletes partially practice both disciplines (most frequently between the ages of 8 and 13). As *kata* discipline requires special technique of inhaling and exhaling during demonstration of each *kata* (Vando et al., 2012), it is possible that among the examinees who are less successful in the combat discipline *kumite* there are also those who have more regular (recent) maximal inhalation practice and thus also the exhalation.

The aim of future research will be to analyze FEV_1/FVC more in depth. Regarding MVV, it refers to the training level of breathing musculature, which favors the more successful athletes, but can be related to different training processes. When spirometry results accuracy and precision are good enough, the range of normal values for populations can be defined and abnormalities more easily detected (Miller et al., 2005). The procedure of spirometry standardisation and determination of reference values for normal population and population of athletes is based on body height and mass, age and sex. Such a procedure provides not only absolute reference values but also the percent values of the ventilation pulmonary function variables. This is compulsory given the fact that this procedure allows the use of absolute values only when there are no significant differences in the anthropometric variables, small results variability, and large participants sample (Pavlov, 2003; Quanjer et al., 1993; Wrangler, 1992). In this study, comparison between actual athletes and their reference results was not feasible, because karatekas BM and BMI variation coefficients (CV) were higher than 10% (Cohen, 1988), results' CVs far exceeded such value, and participants sample was not large (Altman, 1991).

Previous research compared the variables of pulmonary ventilation between the athletes participating in different organized exercise activities, as well as between athletes and control groups of non-athletes. Therefore, results from literature cannot be compared with our results on the basis of the success *criterion* variable, but only as values of pulmonary ventilation function variables in karatekas with respect to other athletes. Different trainings should be considered as well. The lack of papers about the relationship between pulmonary ventilation function and success in sport can be explained by the common opinion that the analysis of ventilation in sports would not be that important, since athletes are acknowledged to have rather large capacities, and ventilation would have little influence on the oxygen consumption (Jelicic, 2000).

Another possibility is that, as maximum oxygen consumption is considered to be centrally determined (i.e., cardiac output is the main variable determining it), differences in pulmonary function would have a small impact on sport performance. Jelicic (2000) points out that it is important to develop "perfect" aerobic systems during the period of aerobic maturation, i.e., between the ages of 15 and 20, regardless of the type of sports activity. In other words, top athletes must have developed aerobic systems, and this can be developed with the help of a dynamic monitoring of functional ventilation values. At a later age in athletes, who are already developed, a dynamic monitoring of the aforementioned ventilation values is not as necessary. It has always been considered that the athletes were ready, in terms of ventilation, for performing any kind of work. Studies about the relationship between pulmonary ventilation function and success in sport have been done on rowers, yacht racers, swimmers, water-polo players, and – partially – basketball, soccer, volleyball and handball players, both in laboratory and field conditions (Foretic, Uljevic, Rogulj, & Marinovic, 2013; Goic-Barisic et al., 2006; Jelicic, 2000), but they could not be compared with the results obtained in this research due to their different approach (i.e., not taking into account the success *criterion*).

Conclusions

The aim of this research was to determine the values of ventilation function variables in karatekas competing in *kumite* discipline and their relations to the result. The values of pulmonary ventilation function variables were measured in a sample of 51 karatekas of junior age group, competing in *kumite* discipline, coming from nine European countries. The univariate ANOVA showed a significant difference between more successful and less successful *kumite* contestants in FVC, FEV_1, FEV_1/FVC, and MVV. Previous research compared the variables of pulmonary ventilation between the athletes participating in different organized exercise activities, as well as between athletes and control groups of non-athletes. Therefore, results from literature cannot be compared with our results on the basis of the specific success *criterion* variable, but only as values of pulmonary ventilation function variables in karateka with respect to other athletes.

Different trainings (e.g., respiratory training; Fischer, Tarperi, George, & Ardigò, 2014; Verges, Boutellier, & Spengler, 2008) should be considered as well. Regarding future research, the measure of the values of pulmonary ventilation function variables for female karate competitors is suggested, as well as the analysis of the difference between different age groups, the difference between *kata* and *kumite* competitive disciplines, and the assessment of eventual relationships between ventilation variables measured at rest and when fatigued.

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PLUĆNA FUNKCIJA JE POVEZANA S USPJEHOM KOD ELITNIH KARATISTA JUNIORA

Sažetak

Spirometrija se može smatrati metodom za mjerenje kapaciteta pluća i brzine protoka zraka kroz dišne putove. Zbog jednostavne primjene, obično se koristi u sportskoj dijagnostici. Cilj ovog istraživanja bio je utvrditi vrijednosti varijabli funkcije ventilacije kod karatista koji se natječu u kumite disciplini i njihov odnos prema rezultatu. Uzorak je uključivao 51 juniora karate sportaša (s definiranim podskupinama uspješnijih [n = 31] i manje uspješnih [n = 20]), koji se natječu u kumite disciplini, iz devet europskih zemalja. Mjerene su njihove vrijednosti nekih varijabli funkcije ventilacije. Mjerni postupci odabrani su i korišteni u skladu s priznatom literaturom. Univarijantnom analizom razlika utvrđene su značajne razlike između uspješnijih i manje uspješnih konkurenata u sljedećim varijablama: forsirani vitalni kapacitet (uspješniji 5,24 ± 0,56 l, manje uspješni 4,27 ± 0,61 l, p = 0,00), forsirani ekspiracijski volumen u 1. sekundi (uspješniji 4,13 ± 0,68 l, manje uspješni 3,69 ± 0,57 l, p = 0,02), omjer forsiranog ekspiracijskog volumena u 1. sekundi / forsirani kapacitet (uspješniji 78,98 ± 10,29%, manje uspješni 86,64 ± 8,37%, p = 0,01) i maksimalna voljna ventilacija (uspješniji 150,46 ± 31,14 l / min, manje uspješno 125,50 ± 29,49 l / min, p = 0,01). Uspješniji natjecatelji pokazali su veće vrijednosti u nekim relevantnim varijablama u usporedbi s manje uspješnim, što podupire odnos prema rezultatu.

Ključne riječi: *borilačke vještine, spirometrija, vitalni kapacitet, plućna ventilacija, analiza varjiance, juniori*

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