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FUNCTIONAL PARAMETERS IN BOXERS AND KICKBOXERS

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(Original scientific paper)

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Abstract

Introduction: The metabolic needs of boxers and kickboxers are supplied by mixed sources—both aerobic and anaerobic. In both combat disciplines, aerobic capacity plays a significant role, particularly during rest periods when anaerobic sources must be regenerated. Aim: To determine and compare the functional parameters of cardiorespiratory function in boxers and kickboxers. Materials and Methods: A total of 40 athletes, divided into 2 groups—twenty boxers and twenty kickboxers—were tested with ergometric and spirometric assessments. The ergometric test was conducted on a treadmill using the Bruce protocol. Pulmonary volumes were determined using a Spirocom device. Results: The average age of the boxers and kickboxers was the same, about 19.1 years. Their average training history was also identical at about 3.3 years, while weekly training volume was 7.6 hours in boxers and 8.4 hours in kickboxers. The average height of the boxers was 180.3 ± 6.6 cm, and of the kickboxers 177.7 ± 8.3 cm, while the weight of the boxers and kickboxers was 78.75 ± 11.4 kg vs. 74.9 ± 10.9 kg, respectively. The maximum oxygen consumption obtained from the submaximal test was 43.65 ± 4.2 ml/kg/min in boxers and 46.1 ± 3.8 ml/kg/min in kickboxers. All analyzed anthropometric and cardio-physiological parameters showed no statistically significant difference between the two groups. Kickboxers demonstrated significantly higher spirometric parameter values for FVC% (102.5% vs. 113.6%) and FEV1% (104.7 ± 2.9% vs. 113.56 ± 29.39%). Conclusion: The spirometric parameters showed higher values in the kickboxers, while the cardio-physiological parameters of aerobic capacity did not differ between athletes in the two combat disciplines.

Key words: *boxers, kickboxers, maximal oxygen consumption, heart rate, vital capacity.*

Introduction

Athletes who train and compete in martial arts must possess a very high level of physical fitness. For effective physical conditioning, training should include those components that will develop and fulfill the metabolic pathways necessary during performance. From sports physiology, it is well known that short-term and explosive activities, such as punches, derive energy from the phosphagen system, which has energy reserves for about 8–10 seconds. The next source of energy is anaerobic glycolysis for high-intensity activities lasting 80 to 100 seconds (Guyton, 2012). Longer activities of lower intensity are supplied by aerobic pathways. Metabolic demands depend on the intensity and duration of activities: during attacks, anaerobic processes predominate, while during rest periods, aerobic pathways take over (Slimani et al., 2017). Most research on the metabolic needs of boxers indicates that, during boxing, about 70% of activity is aerobic, while the remaining portion is divided between anaerobic alactic and anaerobic glycolytic activities (Bruzas et al., 2023). Some researchers assert that in boxing, with an activity-to-rest ratio of about 2:1, energy consumption is 70–80% anaerobic and 20–30% aerobic (Yamak et al., 2023). In kickboxing, strikes are executed using both upper and lower limbs, which increases the demand on anaerobic pathways. According to some authors, in a kickboxing match, 70–80% of the energy is derived anaerobically and 20–30% aerobically (Gosh et al., 2003). Cappai and colleagues report that during a Muay Thai fight, 60% of the round is spent on offensive actions, while 40% is spent on defensive reactions (Cappai et al., 2012). It is recommended to develop these energy systems using various training methods—for example, submaximal loads for aerobic capacity, 3–8-second maximal loads for the alactic anaerobic system, and 30–90-second loads for the lactic anaerobic system (Akgul et al., 2016). The aerobic capacity of boxers and kickboxers depends on (is connected to) their level of skill (Bruzas et al., 2014). Previous research shows variations in the maximal oxygen uptake of kickboxers and boxers, with moderate to high cardiorespiratory levels reported for these athletes (Rydzik et al., 2021). The aerobic capacity of boxers and kickboxers depends on (is linked to) their level of athletic skill. Previous research indicates that there are certain variations in the maximal oxygen consumption among kickboxers and boxers, with moderate to high cardiorespiratory levels reported for these athletes.

The aim of this research is to examine the physiological variables that serve as indicators of athletes' aerobic capacity and to compare them between two groups of athletes practicing different martial arts: boxing and kickboxing.

Materials and Methods of the Research

Sample of Participants

This study presents the results of an analysis of the functional parameters of the cardiovascular and respiratory systems in 40 athletes, divided into two groups of 20 participants each: boxers and kickboxers, aged between 16 and 25 years. The average age of the participants in the boxing group was 19.1 ± 2.8 years, and for the kickboxing group, 19.1 ± 4.3 years.

Informed consent was obtained from all participants, confirming that they were informed about the nature of the research and how the collected data would be used. The testing was conducted at the Institute of Physiology, Medical Faculty, in Skopje.

Methods

Functional testing of the cardiovascular system was performed using the Bruce test on a treadmill. Functional testing of the respiratory system was conducted using spirometry.

Ergometric Testing According to the Bruce Protocol. This submaximal, progressively increasing, stepwise ergometric test of aerobic capacity is performed on a treadmill. The workload consists of 7 consecutive, progressively increasing stages, each lasting 3 minutes. Each stage involves changes (increases) in both the incline and speed of the treadmill. Using the Bruce test, cardiorespiratory fitness and relative maximal oxygen consumption (VO^2 max, in ml/kg/min) are indirectly determined with the help of tables and nomograms.

The Bruce ergometric test analyzes the following variables: ET: Exercise time, test duration in minutes, which is a key parameter as it is used to calculate oxygen consumption.VO_2 max: Estimated maximal oxygen consumption, expressed as milliliters of oxygen per kilogram of body weight consumed per minute. HRR: Resting heart rate, measured before the test. HR1–HR10: Heart rates recorded during each of the ten consecutive minutes of the test. HRrec: Recovery heart rate, measured during the recovery phase.

All heart rate values before the test, during the test, and in the recovery phase—form the heart rate curve. This curve serves as an indicator of the cardiovascular system's ability to adapt during ergometric testing.

Spirometry. A standard spirometry procedure is conducted to measure the lung volumes and capacities of participants, typically athletes (professional or recreational). The technical aspect of this procedure is performed by experienced medical technicians.

The analyzed spirometric variables include:Forced Vital Capacity (FVC): Measured as both an absolute value (in liters) and a relative value (as a percentage).Forced Expiratory Volume in the First Second (FEV_1): Also expressed as an absolute value (in liters) and a relative value (as a percentage).PEF - Flow volume

Statistical Analysis

The statistical analysis was performed using the SPSS program. The characteristics of the two groups of participants, boxers and kickboxers, were presented as mean values and standard deviations (±). Differences between the groups were determined using an independent t-test. The significance level was set at 0.05.

Results

The results present the central descriptive statistics for demographic, anthropometric, and functional parameters, separately for each group of participants: boxers and kickboxers.

Table 1 displays the age, years of sports experience, weekly training volume, and certain anthropometric parameters of the boxers. The results indicate that the boxers have a high level of lean body mass (FFM), a normal nutritional status (BMI), and normal values for adiposity-related parameters, such as the waist-to-hip ratio, body fat percentage (BF%), and fat distribution (FD). The average body fat percentage was 14.01 ± 3.3%.

Table 1. Demographic Data and Anthropometric Parameters of Boxers

		age	years of training	hours per week	height	weigth	FFM(kg)	BMI	BF %	WHR	Obesity degree
Mean		19.10	3.303	7.158	180.30	78.75	66.910	23.955	14.010	0.854	108.20
Median		18.00	2.000	6.000	181.00	77.95	66.750	23.950	14.450	0.845	108.50
Std. Dev.		3.919	3.670	2.572	6.622	11.457	8.277	2.421	3.309	0.038	11.228
Skewness		2.453	2.206	1.749	0.162	1.121	0.362	-0.068	-0.418	0.824	-0.073
Kurtosis		8.228	5.481	3.817	-0.230	2.014	0.306	-0.524	-0.582	0.045	-0.419
Minimum		14	0.17	4.0	169.0	61.05	51.1	19.8	7.7	0.80	88
Maximum		33	15.00	15.0	195.0	110.7	85.2	28.5	19.3	0.93	129
Percen-tiles	25	17.00	0.50	6.00	174.63	70.85	22.13	10.63		0.82	99.75
	50	18.00	2.00	6.00	181.00	77.95	23.95	14.45		0.85	108.50
	75	21.00	4.00	8.00	186.00	83.55	25.76	16.00		0.87	115.75

Table 2. Cardio-physiological and Respiratory Parameters of Boxers

Variables		HRrest	HRrec	ET	VO_2 max	VO_2%	FVC (L)	FVC%	FEV1 (L)	FEV1%	FEV1 FVC%	PEF %
Mean		84.40	115.00	12.150	43.65	99.63	4.835	102.59	3.886	104.078	101.476	82.986
Median		83.00	116.00	12.70	45.00	103.50	4.480	102.10	3.910	105.000	102.330	82.000
Std. Dev.		13.272	15.145	1.504	4.209	9.680	0.919	3.804	0.559	2.926	5.622	6.225
Skewness		0.292	-1.054	-0.711	-0.904	-0.984	1.862	0.566	0.899	-1.324	-1.252	1.080
Kurtosis		0.035	2.754	-0.742	0.139	0.174	3.096	-0.017	3.007	0.930	0.764	1.202
Minimum		60	77	9.33	34	77	4.06	97.8	3.04	98.00	91.00	76.64
Maximum		114	146	14.17	49	112	7.08	110.0	5.20	107.00	108.33	97.00
Perc en tiles	25	87.25	10.85	10.85	41.2	93.50	4.25	98.98	3.79	102.85	100.00	77.30
	50	98.50	12.70	12.70	45.0	103.5	4.48	102.1	3.91	105.00	102.33	82.00
	75	105.7	13.18	13.18	46.7	105.7	4.89	105.2	3.95	106.04	105.18	87.00

Table 2 presents the functional parameters for the group of boxers. The average resting heart rate was slightly above the normal physiological range, measured at 84.4 ± 13.3 beats per minute (bpm). During the first minute of the test, despite the low intensity of effort, the heart rate increased to 99.9 bpm. The average test duration was 12.15 ± 1.5 minutes, resulting in an average maximal oxygen consumption of 43.65 ± 4.2 ml/kg/min.

Spirometric parameters showed average vital capacity values of 4.83 ± 0.9 L, or 102.3% of the predicted values for vital capacity.

Table 3. Demographic Data and Anthropometric Parameters of Kickboxers

Variables		age	years of training	hours per week	height	weight	FFM (kg)	BMI	BF %	WHR	OD%
Mean		19.10	3.306	8.389	177.025	74.950	65.432	23.950	12.495	0.833	108.35
Median		18.50	3.000	9.000	175.500	72.700	64.000	23.550	12.850	0.810	106.50
Std. Dev.		2.751	1.564	2.993	8.358	10.964	9.113	2.689	4.821	0.518	12.132
Skewness		0.356	0.277	-0.453	0.288	0.740	0.471	0.940	0.047	0.954	0.969
Kurtosis		-1.586	-1.130	-0.865	-0.628	0.665	0.670	0.221	-0.624	-0.153	0.368
Minimum		16	1.00	3.00	162.00	56.0	46.8	20.7	3.4	0.76	93
Maximum		23	6.00	12.00	192.00	102.0	84.9	30.0	21.5	0.94	136
Percen-tiles	25	17.00	2.00	6.00	171.25	68.45	21.53	8.58	0.80	98.75	98.75
	50	18.50	3.00	9.00	175.50	72.70	23.55	12.85	0.81	106.50	106.50
	75	22.00	5.00	10.50	184.38	82.95	25.53	16.00	0.86	116.00	116.00

Table 3 displays descriptive statistics for the age, years of training, weekly training hours, and certain anthropometric parameters of the kickboxers. The kickboxers demonstrated a high level of lean body mass (FFM), a normal nutritional status (BMI), and a normal waist-to-hip ratio. The average body fat percentage was 12.495 ± 4.8%.

Table 4 presents the functional parameters for the group of kickboxers. The average resting heart rate was within the normal physiological range, measured at 79.45 ± 1.3 beats per minute (bpm). During the first minute of the test, despite the low intensity of effort, the heart rate increased to 97.85 bpm. The average test duration was 13.05 ± 0.7 minutes, with a maximal oxygen consumption of 46.1 ± 3.8 ml/kg/min.Spirometric parameters showed high vital capacity values of 6.5 ± 1.4 L, or 113.5% of the predicted values for vital capacity.

Table 4. Cardiophysiological and Respiratory Parameters of Kickboxers

Variables →		HRrest	HRrec	ET	vo2max	vo2%	FVC	FVC%	FEV1%	FEV1 FVC%	PEF %
Mean		79.45	112.50	13.048	46.10	104.27	6.524	113.556	103.789	102.667	98.444
Median		77.50	113.50	12.835	45.50	103.00	6.480	106.000	97.000	109.000	92.000
Std. Dev.		12.137	8.787	1.635	3.810	8.747	1.428	33.080	29.392	12.675	24.130
Skewness		1.053	-0.117	0.763	0.752	0.728	0.577	2.420	1.471	-0.914	1.362
Kurtosis		1.276	-0.809	0.589	0.492	0.602	0.349	6.469	1.516	-1.738	2.445
Minimum		64	97	10.50	40	90	4.52	86.0	81.40	85.00	67.00
Maximum		112	128	16.92	55	125	9.15	197.0	166.00	113.00	151.00
Percen-tiles		70.00	112.50	13.048	44.00	100.00	5.47	94.50	81.80	87.25	86.50
		77.50	113.50	12.835	45.50	103.00	6.48	106.00	97.00	109.00	92.00
		79.45	8.787	1.635	48.50	109.25	7.37	116.50	122.50	112.25	109.00

Table 5. Comparison of Tested Variables Between Boxers and Kickboxers (t-test)

Variables	t	df	p
Age	0.000	38	0.762
Years of training	-0.003	35	0.104
Hours per week	-1.134	35	0.234
Height	1.374	38	0.346
Weight	1.072	38	0.938
FFM	0.531	37	0.909
SMM	0.487	38	0.974
BFM kg	1.239	38	0.421
BMI	0.006	38	0.639
BF %	1.159	38	0.072
BMR	0.633	38	1.000
WHR	1.438	37	0.168
Obes. Deg. %	-0.041	38	0.762
SF Мирување	1.231	38	0.745
SF3	0.639	38	0.412
ET	-1.783	37	0.887
vo2max	-1.930	38	0.501
vo2%	-1.594	38	0.410
FVC	-3.205	18	0.369
FVC% *	-1.044	17	0.038
FEV1% *	-0.031	17	0.002
FEV1 FVC% *	-0.272	15	0.005
PEF% *	-1.872	18	0.037

Table 5 displays the results of the comparison of all examined variables using the t-test. The results clearly indicate that there is a statistically significant difference between the two groups—boxers and kickboxers—in the following variables: FVC%: ($t = -1.044$; $p < 0.05$); FEV_1%: ($t = -0.031$; $p < 0.01$); FEV_1/FVC%: ($t = -0.272$; $p < 0.01$); PEF%: ($t = -1.872$; $p < 0.05$). For all other variables, no statistically significant differences were found.

Discussion

This study analyzed several functional parameters in boxers and kickboxers, which serve as indicators of aerobic capacity. The examined functional parameters pertain to the cardiovascular system and were derived from the results of the Bruce protocol ergometric test. The functional capacity of the respiratory system was analyzed through spirometric parameters.

In the selected sample of athletes from two martial arts disciplines, it was determined that participants in both groups had similar ages, anthropometric characteristics (height, weight, and body composition). It should be emphasized that anthropometric parameters, especially height, weight, and body surface area, influence functional parameters, particularly respiratory ones. In terms of body composition, both groups exhibited high levels of lean body mass, normal values for BMI, and adiposity parameters (waist-to-hip ratio and fat distribution percentage, FD%). The body fat percentage was lower in kickboxers (12.49% vs. 14.01%).

The results of the ergometric test showed that kickboxers performed better, with the average test duration being one minute longer. Both relative and absolute maximal oxygen consumption values were higher in kickboxers, although these differences were not statistically significant. An analysis of the heart rate curves during ergometric testing revealed a continuous rise in heart rate in both groups, which is a normal cardiac response to physical exertion. At rest and during recovery, the heart rate was slightly lower in kickboxers, but the difference was not statistically significant.

In this study, the results of the ergometric test indicated that kickboxers had higher oxygen consumption compared to boxers—both relative (46.6 ml/kg/min vs. 43.65 ml/kg/min) and percentage-based (104.3% vs. 99.6%). However, these differences were not statistically significant. The heart rate curves, derived from heart rate measurements at rest, at each minute during 10 consecutive minutes of testing, and during recovery, showed that kickboxers had a lower initial heart rate. The trend of heart rate increase was similar between groups, and the recovery heart rate was also lower in kickboxers, but again, the difference was not statistically significant.

Dynamic lung parameters obtained via spirometry demonstrated that kickboxers had higher forced vital capacity, both absolute and relative, higher forced expiratory volume, and greater airflow speed through the respiratory tract. Spirometric parameters, which measure vital capacity, the volume of air exhaled in the first second, and the speed of air exhalation, showed statistically significantly higher results in kickboxers.

Oxygen Consumption in Boxers and Kickboxers

The effective functioning of the cardiovascular system is fundamental to the physical fitness of kickboxers and boxers, as it allows them to sustain repeated intense attacks during fights and ensures proper recovery afterward (Cisafulli et al., 2009). Both anaerobic and aerobic systems are engaged in combat sports like boxing and kickboxing, making it essential for training programs to optimize the performance of both systems (Zabukovec et l., 1995).

The average VO_2 max values reported in scientific literature for elite male kickboxers range between 54 and 69 ml/kg/min (Rydzik et al., 2021). Zabukovec et al. tested 4 elite Canadian kickboxers using a cycle ergometer and reported a result of 61.5 ± 7.5 ml/kg/min (10). Portuguese kickboxers (n=13) tested with a maximal treadmill test achieved 57.99 ml/kg/min (Silva et al., 2011). Among amateur kickboxers from Tunisia (n=30), a maximal cycle ergometer test recorded a VO_2 max of 51.9 ml/kg/min. A study of 40 Serbian kickboxers reported values of 57.99 vs. 47.6 ml/kg/min for elite and sub-elite athletes, respectively (Ljubisavljevic et al., 2014). In Turkish kickboxers, a field test measured maximal oxygen consumption at 48.5 ml/kg/min (Salci., 2015). Comparisons of elite and sub-elite kickboxers from the UAE and Tunisia yielded VO_2 max values of 54.6 ml/kg/min and 49.1 ml/kg/min, respectively (Slimani et al., 2016).

These values are consistent with those observed in other combat sports disciplines, such as amateur boxers (ranging from 49 to 65 ml/kg/min for men (20)), elite karate athletes (ranging from 47 to 61 ml/kg/min for men), and elite taekwondo athletes (ranging from 44 to 63 ml/kg/min for men and 40 to 51 ml/kg/min for women) (Chaabene et al., 2015). These findings highlight that, like other combat sports, kickboxing places significant demands on the cardiovascular and respiratory systems and their functions. A study of the physiological profiles of Indian boxers found VO_2 max values of 54.6 (±4.7) ml/kg/min for junior boxers and 61.7 (±9) ml/kg/min for senior boxers (Khanna et al., 2006). Balci et al. measured a maximal VO_2 max of 53.93 (±8.69) ml/kg/min in 13 young boxers in Turkey (Balci et al., 2020). Results for VO_2 max among boxers vary widely: a group of boxers of different nationalities recorded 49.9 ± 2.6 ml/kg/min (Di Prampero et al., 1999); French boxers showed a high average of 62.2 ± 3.1 ml/kg/min; Polish boxers recorded 52.2 ± 7.2 ml/kg/min (Krawitz et al., 2003), while Brazilian boxers displayed lower values of 41.0 ± 6.5 ml/kg/min (de Lira et al., 2013).

Compared to these previously mentioned VO_2 max results for boxers and kickboxers, the values obtained in our study are lower. This may be attributed to the type of ergometric testing (submaximal workload) and the lower level of athletic skill (performance level) of our athletes.

Spirometric Parameters in Boxers and Kickboxers

The role of the respiratory system during physical activity is undeniable, as it works in conjunction with the cardiovascular system to deliver sufficient oxygen to active muscles for energy production and the regeneration of anaerobic energy systems (Guyton, 2012). Despite this awareness, respiratory function parameters are rarely examined in athletes. Pulmonary ventilation demonstrates a linear relationship with oxygen consumption, and higher levels of exercise result in higher ventilation parameters (Chaabene et al., 2015). Pulmonary volumes depend not only on individual characteristics, such as sex, age, height, and weight, but also on health status and physical fitness (Degens e al, 2013). Studies show that individuals with higher levels of physical activity have greater vital capacity compared to sedentary individuals with similar physical characteristics (Wasserman, 1994). Physical activity enhances vital capacity, forced vital capacity (FVC), and maximum voluntary ventilation (Bakthar et al., 2019).

Endurance athletes generally exhibit higher FVC, FEV_1 (Forced Expiratory Volume in 1 second), and VC (Vital Capacity) values compared to athletes in strength-based sports (Durmic et al., 2017; Lazovic et al., 2015). A study measuring respiratory muscle strength in martial artists found that these athletes relied more on abdominal muscles (transverse and oblique abdominal muscles) and the diaphragm for producing respiratory muscle strength compared to a control group. This increased ability to control respiratory pressure was utilized by fighters to generate force and counteract opponents, aiding them during combat (Hulke &Patak, 2011).

An investigation into the impact of inspiratory muscle training (IMT) in two groups of combat athletes showed that, after six weeks, MMA fighters improved their respiratory parameters, while kickboxers showed no changes (Walters et al., 2021).

The accuracy and precision of the normal value ranges for specific population groups are critical for interpreting spirometric results and identifying abnormalities (Alnuman et al., 2022). Spirometry involves standardizing results (considering room temperature and humidity) and determining reference values for the general population and athletes, based on height, weight, age, and sex. Therefore, spirometry results are expressed not only in absolute values but also as percentages of predicted values. In this study, the comparison of spirometric parameters was feasible due to the similar anthropometric characteristics of the participants.

Pulmonary function testing is underrepresented in sports science research. This gap may stem from the general belief that respiratory ventilation is superior in athletes and has little impact on athletic performance (Miller et al.,2005). Jeličić (2000) emphasized the importance of developing "optimal" aerobic systems during the aerobic maturation period, between 15 and 20 years of age, regardless of the type of sport. In elite athletes, aerobic systems should be well-developed and monitored dynamically through functional ventilation values (Jelicic, 2000).

The existing literature shows a lack of research on respiratory function in combat sports. One rare study examined spirometric parameters in karate athletes of varying skill levels, finding that more successful athletes had better pulmonary variables than their less successful peers (Cular et al., 2017). Combat sports are categorized as non-cyclical sports where energy needs are alternately met through aerobic and anaerobic sources. Prolonged training in combat sports can improve respiratory function (Guan & Gao, 2022). A study on respiratory functions in child boxers (aged 11–13) reported FVC values of 85%, VC of 100.16%, and FEV_1% of 107.5% (Gucluover et al., 2019). Another study examining the relationship between balance and respiratory parameters in boxers (aged 16–20) found FVC values of 4.21 ± 0.22 L, FEV_1/FVC ratios of 75.54 ± 3.25%, and FEV_1 values of 3.12 ± 0.18 L (Kayacan et al., 2018).

Mazić et al. investigated the impact of sport type on respiratory parameters across 15 sports and a control group. The study included four combat sports—boxing, kickboxing, wrestling, and taekwondo. Kickboxers showed the highest values for respiratory parameters (VC, FVC, FEV_1, FEV/FVC, PEF, and MVV), while boxers displayed the lowest, even below the control group (Mazic et al., 2015). A study on 17 young kickboxers (average age 17.8 years) showed that 47% of participants had higher-than-normal values, leading the author to conclude that kickboxing stimulates the respiratory system (Volodchenko et al., 2017).

The results of this study contribute to a better understanding of the cardiovascular and respiratory functions in boxers and kickboxers. Knowledge of the cardiorespiratory fitness of athletes in these disciplines can provide sports experts with insights to design and plan training programs that enhance specific functional parameters.

Conclusions

The comparison of the cardio physiological parameters between boxers and kickboxers showed that the heart rate curves had a similar trend of gradual increase in heart rate with increasing effort during the ergometric testing, with slightly lower values observed in kickboxers. The maximal and relative oxygen consumption, as well as the test duration, were slightly higher in kickboxers, though the differences were not statistically significant.

The spirometric parameters were significantly higher in kickboxers which should emphasize the meaning and interpretation of the respiratory parameters in these athletes.

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