Respiratory Parameters in Elite Finn-Class Sailors

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ABSTRACT Spirometry is an essential test for assessing the state of the respiratory system. It provides the measurement of the ventilation volumes and flows expressed in absolute and relative values. Among elite athletes, the values of ventilation parameters are usually higher than the norm; therefore the interpretation of individual results of elite athletes in relation to the general healthy population is not advisable. This study aimed to determine the respiratory characteristics of elite sailors in the Olympic Finn class, and the differences between more successful and less successful sailors according to the criterion of sport efficacy. The study included 33 sailors of the Olympic Finn class who participated at the 2015 Finn European Championship. Absolute values of spirometry parameters of elite Finn sailors (FVC-Forced-vital-capacity 5.96±0.79; FEV1-Forced-expiratory-volume-in-1-second 5.10±0.63; FEV1/FVC%-Forced-expiratory-volume-in-1-second/Forced-vital-capacity 86.10±6.38; MVV-Maximum-voluntary-ventilation 190.94±32.64) are higher than the spirometry values of most other athletes. Relative values of spirometry parameters of elite Finn sailors (FVC% 101.24±14.21; FEV1% 102.53±12.09; FEV1/FVC%% 102.00±7.94; MVV% 96.77±18.59) are within the ranges of most elite athletes. Elite sailors can be considered healthy in terms of ventilation, and sailing as a sports activity can be considered beneficial for the ventilatory function of the lungs. More successful sailors had higher mean values of absolute and relative ventilation parameters of FVC, FEV1, and MVV, whereas significant differences were determined in the variables of MVV. The differences between more successful and less successful sailors in the MVV and MVV% variables could be interpreted precisely by the state of respiratory muscles.

KEY WORDS lung volumes, spirometry, Olympic, dinghy, performance, sailing

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Introduction

Sailing is a very broad term that includes various competitive formats in different sailing classes – from the Optimist, which is intended for children aged 14 years, to the world-renowned events of America's Cup or Volvo Ocean Race. Among the vast variety of competitive sailing forms, sailing in the Olympic classes may be considered the most competitive. Among many other parameters, sailors' aerobic and anaerobic capacity contributes to sailing performance in Olympic sailing (Bojsen-Moller, Larsson & Aagaard, 2014). The main function of the respiratory system is the respiratory gas exchange. By ensuring a sufficient supply of oxygen during exercise, the respiratory system plays a key role in regulating the acid-base homeostasis (McConnell, 2007). Spirometry is an irreplaceable test for assessing the state of the respiratory system. It provides measurements of the ventilation volumes and flows expressed in absolute and relative values (Miller et al., 2005). Relative values of the person's ventilation parameters are calculated as the ratio of the obtained results and the reference value for the general healthy population (Laszlo, 2006). Whether it be the product of the selection process or the effect of the training process, in the population of elite athletes the values of ventilation parameters are usually higher than the norm; consequently, the interpretation of individual results of elite athletes in relation to the general healthy population is not advisable (Cotes, Chinn, & Miller, 2006). Therefore, it is essential to determine the respiratory characteristics of groups of elite athletes in each sport. Numerous studies have been conducted with the aim of comparing the ventilation parameters of athletes and the sedentary healthy population (Doherty & Dimitriou, 1997; Durmic et al., 2017; Jelicic, Uljevic & Zenic, 2017; Lazovic-Popovic et al., 2016; Mazic et al., 2015), to compare groups of athletes involved in different sports (Durmic et al., 2015; Lazovic et al., 2015), to compare different age groups of athletes within the same sport (Foretic, Uljevic, Rogulj, & Marinovic, 2013; Hraste, Lozovina, & Lozovina, 2008), and to compare athletes regarding

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their position within the same sport (Ostojic, Mazic & Dikic, 2006). The effect of athletes' respiratory characteristics on their athletic performance was studied by Cular, Milic, Franchini, Ardigo, & Padulo, (2017). In their study, the authors determined that more successful *kumite karateka* in the junior age group had higher absolute values of the ventilation parameters FVC, FEV1, and MVV.

The aim of this study was to determine the respiratory characteristics of elite sailors in the Olympic Finn class, and the differences between more successful and less successful sailors according to the criterion of sport efficacy.

Methods

This study included sailors of the Olympic Finn class who participated at the 2015 Finn European Championship (FEC), in Split. FEC is an "open" competition, and it allows participation of sailors from non-European countries. This FEC included over 60 competitors from almost every continent. Participation in the study was voluntary, and 33 sailors, including the winners of world, continental and national medals, underwent measurement. The sailors were divided into two groups (more successful and less successful) according to their ranking at the World Sailing Rankings (WSR). The WSR is formed by collecting the points from the six most successful competitions for each sailor in the 12 months from the publishing of the table. The WSR is usually published nine times per year. For this study, the authors used the WSR table for the Finn class published on 27th April 2015. The group of more successful sailors included the subjects who were ranked among the first 50 sailors according to the WSR, and the group of less successful sailors included the subjects who were ranked from the 50th to the 329th place of the WSR.

The testing of respiratory characteristics was done using a portable and fully automated microQuark PC-based Spirometer (COSMED, Rome, Italy). The measurement was performed by following the test protocol of Miller et al. (2005). The room where the measurements were taken and the environmental conditions were in accordance with the recommendations from the manufacturer. The following ventilation parameters were measured: FVC (1) – Forced vital capacity, FEV1 (l) - Forced expiratory volume in 1 second, FEV/FVC1% – Forced expiratory volume in 1 second / Forced vital capacity and MVV (l/min) – Maximum voluntary ventilation. No exclusion criteria were applied. In addition to the ventilation parameters, basic morphological variables were also measured: Body height (cm) and Body mass (kg), from which the Body mass index (kg/m^2) was calculated.

All the measurements were taken by the same measurer in the week prior to the competition, in the morning hours before the first training session.

Methods of data analysis included the calculation of basic statistical indicators: Mean, Min - minimum result, Max - maximum result, SD - standard deviation and determination of measures of sensitivity of result distribution: Skew - Skewness, Kurt - Kurtosis, MaxD - maximum distance between relative cumulative theoretical frequency (normal) and relative cumulative empirical frequency (obtained by measuring). Differences between more and less successful sailors were determined using a Student's t-test for independent samples. Data analysis was performed using the Statistica software (ver. 11.00).

The study was approved by the Ethical Board of the Faculty of Kinesiology in Split and conducted with the support of the Executive Committee of the International Finn Association.

Results

The normality of distribution was tested by the Kolmogorov-Smirnov test with the limit value of 0.24, which represents the maximum allowed size of the maximum difference between cumulative and theoretical relative

TABLE 1 Descriptive statistics of age, anthropometric, and respiratory variables of Finn sailors (N=33)

Variables	Mean±SD	Min	Max	Skew	Kurt	maxD
Age (yrs)	25.40±4.26	17.95	33.72	0.35	-0.72	0.09
Body height (cm)	186.51±4.56	176.10	195.80	0.01	0.31	0.09
Body mass (kg)	95.79±7.21	76.30	119.00	0.41	3.62	0.15
Body mass index (kg/m^2)	27.57±2.31	23.66	36.24	1.67	5.35	0.15
FVC (l)	5.96±0.79	4.26	8.10	0.34	0.33	0.09
FVC% (%)	101.24±14.21	78.00	142.00	0.77	0.60	0.12
FEV1 (l)	5.10±0.63	3.60	6.64	0.26	0.63	0.10
FEV1% (%)	102.53±12.09	79.00	141.00	0.85	2.31	0.12
FEV1/FVC%	86.10±6.38	73.70	99.00	-0.06	-0.57	0.12
FEV1/FVC% (%)	102.00±7.94	86.00	116.00	-0.15	-0.68	0.09
MVV (l/min)	190.94±32.64	126.90	257.10	-0.08	0.44	0.15
MVV% (%)	96.77±18.59	63.00	160.00	1.01	3.41	0.13

Note. SD: standard deviation; Min: minimum result; Max: maximum result; Skew: Skewness; Kurt: Kurtosis; maxD: maximum distance between relative cumulative theoretical frequency (normal) and relative cumulative empirical frequency (obtained by measuring). Limit value of KS test for N=33 is 0.24.

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frequencies. Therefore, none of the measured variables deviated significantly from normal distribution, and they were suitable for further analysis by parametric statistical methods.

Significant differences in arithmetic means between more successful and less successful participants were determined in the Age, MVV, and MVV% variables.

TABLE 2 Differences between more and less successful Finn sailors

Variables	Mean±SD more successful FS (N=18)	Mean±SD less successful FS (N=15)	t-value	p
Age (yrs)	26.85±4.32	23.65±3.57	2.29	0.03
Body height (cm)	187.11±3.72	185.79±5.44	0.83	0.41
Body mass (kg)	97.13±4.18	94.19±9.63	1.17	0.25
Body mass index (kg/m^2)	27.76±1.26	27.34±3.19	0.51	0.61
FVC (l)	6.20±0.75	5.67±0.75	1.99	0.06
FVC% (%)	104.06±15.10	97.87±12.74	1.26	0.22
FEV1 (l)	5.25±0.59	4.89±0.64	1.65	0.11
FEV1% (%)	104.67±12.76	99.79±11.02	1.14	0.26
FEV1/FVC%	85.29±5.77	87.15±7.17	-0.81	0.42
FEV1/FVC% (%)	101.50±7.59	102.64±8.63	-0.40	0.69
MVV (l/min)	204.92±29.20	176.02±30.12	2.71	0.01
MVV% (%)	103.63±18.89	89.47±15.74	2.26	0.03

Note. SD: standard deviation; t-value: ratio between the differences of two arithmetic means; p: level of statistical significance.

Discussion

The more successful sailors were significantly older, which was expected given that the WSR ranking was selected as the criterion of efficacy. The WSR is a ranking system that sums up the rankings of a minimum of six regattas during a season. To achieve the best possible ranking at WSR, a sailor must achieve top results over an extended period, and more experienced sailors will be better at this. Furthermore, younger sailors who have not yet fully asserted themselves in the Finn class, often do not even participate in sufficient numbers of regattas, which are scored for the WSR and are thus further penalized in the final WSR.

In their study, Maisetti, Guevel, Iachkine, Lergos, and Briswalter (2002) presented values of body height and body mass of the participants at the 2000 Olympic Games. The values of body height and body mass recorded for Finn sailors (N=24) in this study were 187±6.00 cm and 97.5±7.5 kg, respectively, which is almost identical to the values of the observed sample.

Ventilation parameters of sailors have not previously been a subject of scientific research; thus, there is no possibility to draw comparisons within the sailing population. However, many other authors have dealt with the problem of ventilation parameters in elite athletes (Durmic et al., 2017; Jelicic et al., 2017; Lazovic-Popovic et al., 2016; Mazic et al., 2015). Mazic et al. (2015) presented absolute and relative values of ventilation parameters for athletes from 15 sports and a control group. Finn sailors showed higher mean absolute values of FVC, FEV1, and MVV than athletes involved in athletics, cycling, cross-country running, soccer, kayak, kickboxing, volleyball, rugby, handball, wrestling, taekwondo, tennis, and the control group. Higher values of FVC, FEV1, and MVV in relation to sailors were recorded in water polo players and rowers. Higher mean values of FVC and FEV1 in relation to Finn sailors were also recorded in the elite junior, sub-elite senior and an elite senior group of rowers (Mikulic, 2008). Lazovic et al. (2015) compared the respiratory characteristics of athletes in different types of sport. In relation to the presented results of absolute values of FVC, FEV1, and MVV, Finn sailors had higher values of FVC and MVV in comparison to athletes in the Skill, Power, Mixed, and Endurance groups of sports, whereas their FEV1 values were almost identical. Given that body height and body mass affect the absolute values of spirometric parameters (Cotes, Chinn, & Miller, 2006), higher absolute values of sailors' ventilation parameters in relation to most other athletes were expected. In contrast, rowers categorized as sub-elite seniors (N=21), aged 22.16±2.8 years, in a study conducted by Mikulic (2008), showed higher values of FVC (7.2±0.7l) and FEV1 (5.6±0.6l), despite the relatively similar values of body height (188.6±5.4cm) and body mass (92.9±5.4kg).

Precisely due to the influence of body height and body mass on the absolute values of ventilation parameters, the relative values of ventilation parameters are more suitable for the comparison (Pellegrino et al., 2005) of different groups of athletes. According to the American Thoracic Society (ATS), a normal spirometry result is considered one with relative values of ventilation parameters that are within 80% of the reference value. Given that sailors' relative ventilation parameters range from 96.77% to 102.53%, sailors can be considered healthy in terms of ventilation, and sailing as a sports activity can be considered beneficial for the ventilatory function of the lungs, which was also confirmed in a study conducted by Jelicic et al., (2017). The aforementioned is also characteristic for athletes who compete in other sports. However, sailors have lower values of relative ventilation parameters (FVC%, FEV1%, FEV1/FVC%, and MVV) in relation to swimmers (Lazovic-Popovic et al., 2016) and water polo players (Mazic et al., 2015). In these studies, the relative values of FVC, FEV1, FEV1/FVC%, and MVV recorded for swimmers (N=38) aged 20.9±2.4 years were 115.1±12, 112.1±10.2, 96.3±9.4, and 114.9±18.1, respectively, whereas relative values of FVC, FEV1, and MVV recorded for water polo players (N=14) aged 19±4 years were 116.79±16.43, 113.36±15.97, and 143.03±53.36, respectively. As presented in Table 2, more successful sailors had higher mean values of absolute and relative ventilation parameters FVC, FEV1, and MVV, and the morphological parameters BH and BM, whereas significant differences were determined in the variables MVV and age. MVV is defined as the maximum volume of air that can be inhaled and exhaled over a period, usually 12 seconds (Miller et al., 2005), which was set as the time interval in this study. Due to the high correlation between the MVV and FEV1 parameters (Pellegrino et al., 2005), it is thought that MVV does not have to be discretely measured when FEV1 is present (Miller et al., 2005). However, despite the high correlation of FEV1 and MVV, significant differences between more successful and less successful sailors were not determined in the variable FEV1.

As the results of MVV are influenced, among other things, by the weakness and sensitivity of respiratory muscles to fatigue (McConell, 2007), the differences between more successful and less successful sailors in the MVV and MVV% variables could be interpreted precisely by the state of the respiratory muscles of more successful and less successful sailors.

Conclusion

To the authors' knowledge, this is the first paper in which the respiratory characteristics of elite sailors in the Olympic Finn class or any other sailing class, in general, are published. Determining the respiratory characteristics of elite sailors has a role of setting reference values for future research and comparison of sailors' individual results with the results of elite Finn sailors. In this context, the contribution of this paper is significant, but to obtain a more comprehensive picture of the respiratory abilities of elite sailors, spirometric measurements should be performed on sailors competing in other Olympic classes, such as Laser or RSX. The differences between more successful and less successful Finn sailors in the criterion variable of WSR ranking were determined in the MVV and MVV% parameters, whereas in other respiratory parameters, the differences were not found. This also justifies future application of the MVV spirometric test, which, along with FVC, FEV1, and FEV1/FVC, can provide a clearer image of athletes' respiratory abilities. The obtained differences in the MVV variable between more successful and less successful sailors may indicate that there are differences in the states of respiratory muscles. Thus, it would be advisable for future studies to include the tests assessing the functions of respiratory muscles, in addition to spirometric tests. Although useful, the WSR ranking is not a sufficient measure for assessing competitive efficacy. The authors believe that a repeated measurement, with placement at elite sports competition as the criterion variable, would additionally contribute to understanding the importance of respiratory parameters on success in sailing.

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