Journal of Physical Education and Sport ® (JPES), 15(3), Art 67, pp. 446 - 451, 2015
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

The interrelationship between performance parameters and variables of respiratory function of orienteers

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Published online: September 28, 2015
(Accepted for publication september 05, 2015)

DOI:10.7752/jpes.2015.03067;

Abstract:
Our study was undertaken to reveal the adaptive changes in the respiratory function variables of trained orienteers and their possible effect on sport performance. The investigation was carried out on trained orienteers 20–25 years age, both males and females. The respiratory function variables (BTPS) have been measured at rest and during tests of vital capacity (VC), forced vital capacity (FVC) and maximal voluntary ventilation (MVV15). They were compared with mean distance speed on short (2.4 km) and classical (6.2 and 8.4 km) distances. Our study reveals the high levels of tidal volume (0.69–0.98 L) of orienteers at rest. Values of VC (3.69–5.77 L) and FVC (3.64–5.68 L) were closed to predicted normal levels (PNL). The FEV1 were found to be in the range 89.8%–94.8% of FVC in different groups. They significantly exceed the predicted normal levels. The value of MEF50 was found to be between 105–123% of PNL, and MEF75 – 131–144% of PNL. The significant effect of respiration variables on the sport performance of the orienteers is supported by the high values of their MVV15 ¬(129– 199.38 L/min), which lie between 121–139% of PNL. Obtained results can be interpreted as the evidence of adaptive hypertrophy of respiratory muscles and dilatation of respiratory pathways of trained orienteers. The close correlation of performance parameters and respiratory capacity of the orienteers (especially the relative indices, calculated per kg body weight) was found.
Key words: respiratory function variables, trained orienteers, male, female.

Introduction

Many observations have shown the adaptive changes in the respiratory system of the athletes engaged in various sports (Harries, 1994; Mehrotra, Varma, Tiwari, & Kumar, 1998; Mazica et al., 2015). The adaptive changes most commonly results in the increase of some pulmonary function tests (lung volumes and capacities, forced expiratory volume in one second, peak expiratory flow etc.) (Mehrotra et al., 1998; Mazica et al., 2015; Adegoke & Arogundade, 2002; Bilgin, Çetin, & Pulur, 2010). Some studies have suggested the significant positive relationship between aerobic capacity and pulmonary function tests (Harries, 1994; Bilgin et al., 2010; Fatemi & Ghanbarzadeh, 2010; Chaitra, Pandurang, Nagaraja, & Vijay, 2011). The significant improvement in the pulmonary functions have been found in endurance trained athletes: swimmers (Mehrotra et all., 1998; Nilesh et al., 2012), basketball and water polo players, rowers (Mazica et all., 2015), cyclists, middle and long distance runners (Harries, 1994). Some authors have suggested that respiratory system could be an exercise limiting factor in the endurance events (Boutellier, Büchel, Kundert, & Spengler, 1992; McKenzie, 2012). Orienteering is an endurance running event which differs from other running sports both in its cognitive element and in the type of terrain encountered (Creagh & Reilly, 1997). It has been shown that aerobic capacity was among the best predictors of performance in orienteering (Creagh & Reilly, 1997; Larsson, Burlin, Jakobsson, & Henriksson-Larsén, 2002). Thus, it is reasonable to assume the influence of the respiration parameters on the performance parameters in orienteering. However, the adaptive changes in the respiratory system of the orienteers remains poorly investigated. Therefore our study was undertaken to reveal the adaptive changes in the respiration function variables of high skilled orienteers and such adaptive changes effect on orienteers performance.

Method

The investigation has been carried out on orienteers 20–25 years age. They were divided into three groups – MMS (master of sport, males), FMS (master of sport, females) and MCM (candidate master, males), described in table 1.

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Table 1. The description of the orienteers' groups

Group	n	Age, years	Weight, kg	Height, cm	Classical distance		Short distance	
					length, km	MDS m/s	length, km	MDS m/s
MMS	14	23.69 ±0.98	68.57 ±1.24	180.64 ±1.30	8.6	2.07 ±0.08	2.4	3.29 ±0.07
MCM	13	20.45 ±0.97	66.54 ±2.29	180.08 ±1.82	8.6	1.75 ±0.06	2.4	2.98 ±0.09
FMS	8	23.14 ±1.06	51.50 ±1.73	162.00 ±2.24	6.2	1.66 ±0.06	2.4	2.82 ±0.06

Footnotes: MMS – master of sport, males; MCM – candidate master, males; FMS – master of sport, females; MDS – mean distance speed.

All the participants were informed about the aim and methodology of the study and they volunteered to participate in this study. Informed consent was obtained. This study was approved by ethics committee of the Lviv State University of Physical Culture. All procedures accorded with the principles of the Code of Ethics of the World Medical Association (Declaration of Helsinki).

The pulmonary function tests were recorded with the help of SpiroComStandard computerized pulmonary function test machine and analyzed by SpiroCom 3.1.122.10041 software. The respiratory function variables were determined at rest and during the respiratory function tests of vital capacity (VC), forced vital capacity (FVC) and maximum voluntary ventilation during 15 s (MVV_{15}). Obtained respiration variables (BTPS) were compared with predicted normal values (%norm, calculated by built-in functions based on F.Pistelli, M.Bottai, G.Viegi, et al. equations).

The values of mean distance speed (MDS in meters per second) were used as the parameter of orienteers performance. The statistical analysis was carried out by SPSS 11.5 package software. All values are given as mean σM (standard error of the mean). They were compared using the t-test. Changes with $P \leq 0,05$ were considered to be significant.

Results

The highest values of MDS on the classical and short distances were found for the male orienteers of the highest qualification – in MMS group (table 1). The MDS values in MCM and FMS groups on short distance were 9.63% ($P < 0,05$) and 14.31% lower ($P < 0,05$). There was no statistical difference in MDS between MCM and FMS groups. The difference in MDS between MMS and MCM groups reached 15.51% ($P < 0,05$) and between MMS and FMS groups – 19.72% ($P < 0,05$) on classical distance. There was still no statistical difference in MDS between MCM and FMS groups on this distance.

Thus, we can suppose that MDS of male orienteers with lower qualification and female orienteers with high qualification were similar. By the investigation of the pulmonary functions of the orienteers of different qualification and sex the possible effect of respiration capacities on the performance of the orienteers could be revealed.

Table 2. Respiratory function variables of orienteers at rest

Group	n	TV, L	TV, %norm	RR, per min.	VV, L/min.	VV, %norm
MMS	14	0.98±012	102.43	19.93±1.86	18.08±2.97	121.21
MCM	13	0.97±0.08	115.92	19.08±1.10	18.22±1.62	129.54
FMS	8	0.69±0.07	119.14	21.50±2.90	14.88±2.78	146.86

Footnotes: MMS – master of sport, males; MCM – candidate master, males; FMS – master of sport, females; TV – tidal volume; RR – respiratory rate; VV – ventilation volume.

During the analysis of orienteers respiration at rest, the high levels of tidal volume (TV) in all groups have been found (table 2). The TV value in FMS group reached up to 70% from the male orienteers level. However, TV in FMS group was 19.1% higher than predicted normal value, suggested the adaptive increase of the respiration volumes variables. The TV value was 2.4 and 15.9% higher than predicted norms also in MMS and MCM groups. Relatively high respiratory rate (RR) was found in all groups (table 2).

The ventilation volume (VV) was higher (21–46%) than predicted normal value in all groups. The possible explanation for this increase of ventilation in the rest is incomplete recovery of orienteers in the training camp. From this point of view the highest recovery level was found in MMS group. This confirms the high level of their adaptation to training loadings.

Table 3. Results of vital capacity and forced vital capacity tests of orienteers

Group	n	VC, L	VC, %norm	FVC, L	FVC, %norm	PEF, L/s
MMS	14	5.77±0.10	99.46±2.18	5.68±0.13	99.85±1.84	9.48±0.45
MCM	13	4.94±0.23	88.92±3.66	4.76±0.25	85.09±2.00	7.69±0.40
FMS	8	3.69±0.19	100.86±3.49	3.64±0.17	99.71±3.59	6.18±0.37

Footnotes: MMS – master of sport, males; MCM – candidate master, males; FMS – master of sport, females; VC – vital capacity, FVC – forced vital capacity; PEF – peak expiration flow.

The detailed analysis of the variables, obtained in tests of vital capacity (VC) and forced vital capacity (FVC), will help in the understanding of the mechanisms of the adaptive changes in the respiratory system of orienteers. Although the absolute values of VC and FVC in MCM and FMS groups were 14–16% (P < 0,05) and 36% smaller (P < 0,05) than in MMS group, but their comparison with the predicted normal values showed other possible interpretation of the test data (table 3). In the groups of elite orienteers (MMS and FMS) the VC and FVC values were found to lie between 99–100% of their predicted normal levels, while in the less skilled male orienteers they were smaller – 85–88% from norms.

The detailed analysis of the time course of the FVC test revealed some special features of its performance by the orienteers (Figure 1). First of all, the values of forced expiration volumes (FEV) in all points of FVC expiration

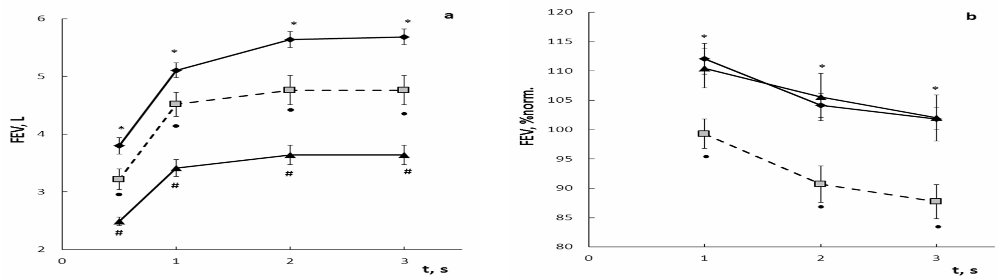

Fig. 1. The time course of the expiration volumes during the forced vital capacity (FVC) test in the different orienteers groups. a – the FEV values (L); b – the FEV comparison to predicted normal values (F.Pistelli, M.Bottai, G.Viegi, et al.). Black rhombuses, solid line – MMS group; grey squares, dotted line – MCM group; black triangles, solid lines – FMS group. The significant difference (P < 0.05) markers: * – between MMS and MMC groups, # – MMS and FMS groups, • – MMC and FMS groups.

Curve decreased in the same sequence: MMS–MCM–FMS group (P < 0,05). It is clearly observed during the first 0.5 s of forced expiration ($FEV_{0,5}$). The value of force velocity expiration remained high up to the 1 s of expiration ($FEV_{0,5}$–FEV_1) in the MCM and FMS groups, while in FMS group the slight decrease could be observed. The FEV_1 value is 89.8%, 94.8% and 93.8% from FVC in MMS, MCM and FMS groups, respectively. The additional increase of FEV_2 (in comparison with FEV_1) has been found only in the MMS group, results in the high final values of FVC in it. In summary, the obtained values of FVC indicate the high velocity and short duration of the forced expiration of orienteers. Secondly, the obtained values comparison with the predicted normal values revealed a clear relation between FEV and sport performance. Thus, in the groups of elite orienteers (MMS and FMS) all the volumes of forced expiration exceeded predicted normal values by 2–12%. The highest exceeding was found for FEV_1 value. The FEV values in the MCM group were found to lie between 99–87% of predicted normal values.

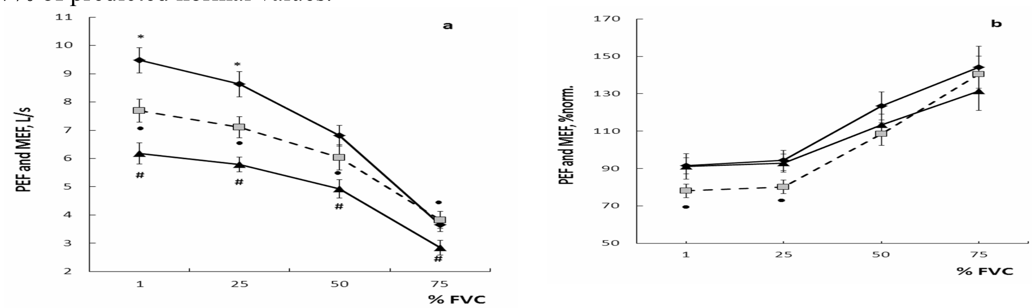

Fig. 2. The time course of the flow indices during the forced vital capacity (FVC) test in the different orienteers groups. a – the absolute values (L/s); b – the values comparison to predicted normal values (F.Pistelli, M.Bottai, G.Viegi, et al.). Black rhombuses, solid line – MMS group; grey squares, dotted line – MCM group; black triangles, solid lines – FMS group. The significant difference (P < 0.05) markers: * – between MMS and MMC groups, # – MMS and FMS groups, • – MMC and FMS groups.

The FEV curve analysis show that the maximal expiration flow indices (PEF, MEF_{25}, MEF_{50}, MEF_{75}) in most cases decreased in the MMS–MCM–FMS ($P < 0,05$) sequence (Figure 2). There were no significant differences ($P > 0,05$) in MEF_{50} and MEF_{75} only between MMS and MCM groups. The absolute values of expiration flow indices in the FMS group were smaller in comparison to male orienteers in all points of expiration curve. However, the comparison of the data with the predicted normal levels revealed another dependence. First of all, the PEF and MEF_{25} values in all groups changed between 78–94% of predicted normal level. This indicates that resistance of big bronchial tubes (upper parts of respiratory pathways) of orienteers was close to those of untrained subjects. The comparative (%norm) PEF and MEF_{25} were substantially lower in MCM than in MMS group ($P < 0,05$). There were no significant differences in MEF_{50} and MEF_{75} between groups. The value of MEF_{50} was found to lie between 105–123% of predicted normal levels, and MEF_{75} – 131–144% of predicted normal levels. This could be the evidence of adaptive changes in the respiratory system of orienteers, which leads to the decrease of the resistance of middle and small bronchial tubes.

Table 4. Results of maximal volume ventilation test of orienteers

Group	n	TVmax, L	RRmax, per min.	MVV_{15}, L/min
MMS	14	2.03±0.16	98.57±9.82	199.38±7.78
MCM	13	1.79±0.23	103.33±6.71	169.08±13.72
FMS	8	1.51±0.12	88.13±5.95	129.50±6.74

Footnotes: MMS – master of sport, males; MCM – candidate master, males; FMS – master of sport, females; TVmax – maximal tidal volume; RRmax – maximal respiratory rate; MVV_{15} – maximum voluntary ventilation during 15 s.

The highest values of the MVV_{15} have been found for the male orienteers of the highest qualification – in MMS group (table 4). In the MCM group the tendency of 15% smaller values of MVV_{15} ($P > 0,05$) was found. The MVV_{15} of female orienteers was lower than in the MMS (by 35%, $P < 0,05$) and MCM (by 23%, $P < 0,05$) groups. The ratio between maximal respiration rate (RRmax) and tidal volume (TVmax) during the MVV_{15} test was lowest in the MMS group. It could be interpreted as evidence of the highest respiration efficiency in this group. In the other groups the RRmax/TVmax ratio was 18–19% higher without significant difference between MCM and FMS groups.

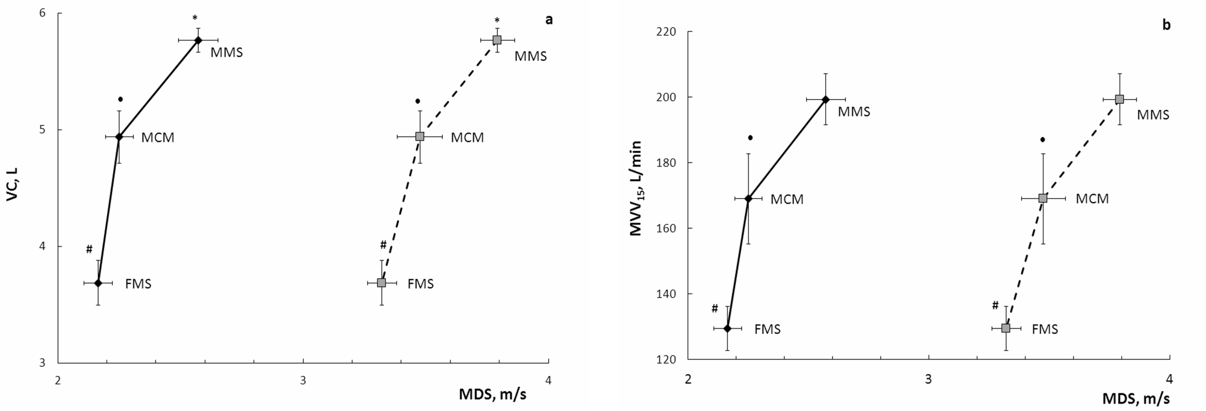

Fig. 3. The dependence between mean distance speed (MDS, m/s) and vital capacity (VC, L) (a) or maximal voluntary ventilation (MVV_{15}, L/min) (b) values in different orienteers groups. Black rhombuses, solid line – classical distance; black squares, dotted line – short distance. The significant difference ($P < 0.05$) markers: * – between MMS and MMC groups, # – MMS and FMS groups, ● – MMC and FMS groups.

Data showed at the Figure 3 may indicate that dependence between MDS improvement and both the VC and MVV_{15} increase in the groups of male and female orienteers is different. In the case of male orienteers the VC values (the same as FVC, data not shown) increase proportionally to the MDS, while in the female group the large decrease in VC (compared to MCM group) is not accompanied with the MDS deceleration. During comparison of the MVV_{15} and MDS values in the different groups of orienteers it have found the very small difference in the MDS between the MCM and FMS groups along with the large difference in MVV_{15} (Figure. 3). The MDS changes were not proportional to changes in MVV_{15}, as it was found in the MMS and MCM groups. There may be several explanations for these data. For example, the higher MDS in the orienteers of FMS group can be explained by their advantage in the other components, which determine the performance parameters. But most plausible is suggestion that relative values of respiration variables (VC or MVV_{15} per kilogram of body weight) are the better predictors of sport performance (MDS).

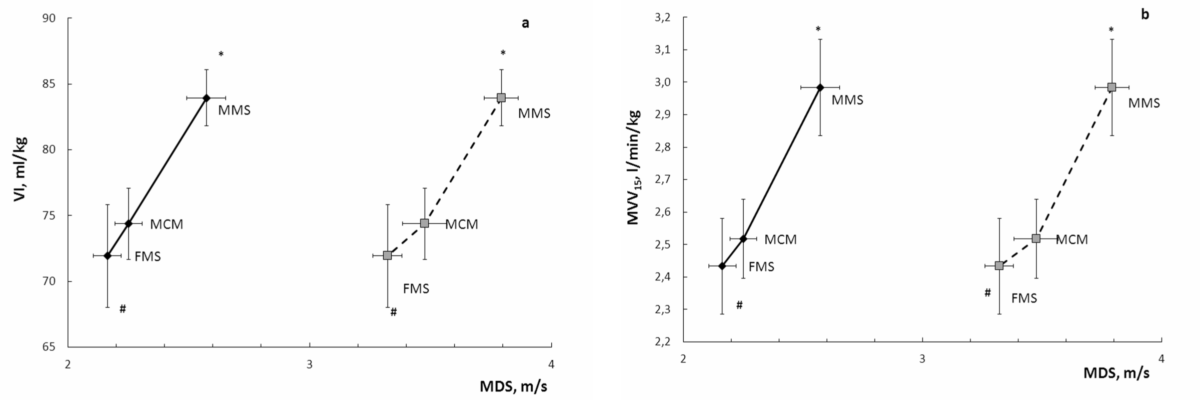

Fig. 4. The dependence between the vital index (VI, ml/kg), relative maximal voluntary ventilation MVV_{15} (L/min/kg) and mean distance speed (MDS, m/s) in the different orienteers groups. Black rhombuses, solid line – classical distance; black squares, dotted line – short distance. The significant difference ($P < 0.05$) markers: * – between MMS and MMC groups, # – MMS and FMS groups, • – MMC and FMS groups.

We have analyzed the dependence between orienteer's MDS and the relative values of the respiration variables (calculated per kilogram of orienteer's body weight). It was found that values of vital index (VI, the VC per kilogram of body weight) are changed proportionally to the MDS on the classical distance (Figure 4) in all groups. The same dependence was found for relative FVC (data not shown). In the case of short distance this dependence was close to linear.

The same proportional dependences have been observed between the relative values of MVV_{15} (l/min/kg) and MDS of the orienteers of different groups. The suggestion about the significant effect of respiration variables on the sport performance of the orienteers is supported by the significantly higher values of MVV_{15} in the groups of the elite athletes (MMS and FMS groups, 135–139% of predicted normal level) in comparison to the less qualified orienteers (MCM group, 121% of predicted normal level). Hence, our results suggest that relative values of some respiratory function variables are closely correlated with the sport performance (MDS) of orienteers. These dependences look to be the same for the male and female orienteers.

Discussion

Obtained data confirm that orienteers, the same as other athletes, tend to have an increase in some respiratory function variables, especially during the adaptation to endurance exercises (Mazica et al., 2015; Adegoke & Arogundade, 2002; Chaitra et al., 2011). Our data comparison with the results of other authors showed that value of FVC for the elite male orienteers (5.68 L) was close to that obtained for elite squash players (5.13 L) (Chin, Steininger, So, Clark, & Wong, 1995), triathletes (5.38 L) (Bilgin et al., 2010), athletes engaged in the other individual sports (5.53 L) and team sports (5.73 L) (Amandeep, 2014). The PEF value of elite male orienteers (9.48 L/s) was higher than reported by other authors for triathletes (9.30 L/s) (Bilgin et al., 2010) and swimmers (8.27 L/s) (Chhabra, Julka, & Mehta, 2013). The MVV_{15} in the group of elite male orienteers (MMS group, 199.4 L/min) was substantially higher compared to those of triathletes (185.0 L/min) (Bilgin et al., 2010) and athletes engaged in the individual sports (142.0 L/min) and team sports (146.4 L/min) (Amandeep, 2014). These results suggest that in the orienteering, the same as in many others sports (swimmers, rowers, cycling, middle and long distance running) (Harries, 1994), the respiratory capacity play the important role in the high sport achievements. Our results are in agreement with the important role of aerobic capacities in the orienteering, found by other authors (Creagh & Reilly, 1997; Larsson et al., 2002). At the same time our data will aid in the understanding of the mechanisms of the adaptive changes in the respiration system of orienteers. During the data analysis the dependence between the sport performance of orienteers and some respiratory function variables has been described. The most informative variables were found.

Obtained model parameters of the respiratory function variables of high skilled orienteers can form the basis for the sport selection and training process improvement. We might expect the positive effect of the respiratory muscles training and hypoxical training on the orienteers' performance. The effect of these factors on the orienteers' performance will be study in our future research.

Conclusions

Our study reveals the significant adaptive changes in respiratory systems of trained orienteers. Obtained data showed increases in the TV, FEV_1, MEF_{50}, MEF_{75} and MVV_{15} of orienteers in comparison with predicted normal values. Obtained results could be interpreted as the evidence of adaptive hypertrophy of respiratory muscles and dilatation of respiratory pathways of trained orienteers. The close correlation of performance parameters on short (2.4 km) and classical (6.2 and 8.4 km) distances and respiratory capacity of the orienteers was found. For the best prediction of orienteers' performance the respiratory function variables should be used as the relative indices (divided on the body weight).

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