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Original Article

Effect of interval hypoxic and hypercapnic exercises on the respiratory function of orienteers

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Abstract.
The objective of our investigation is the effect of the interval hypercapnic and hypoxic exercises with the supplementary respiration resistance on the respiration variables of the orienteers. 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 (MVV_{15}). They were compared with average speed of running on short (2.4 km) and classical (6–8 km) distances. We have revealed a close positive connection between sports result of the orienteers of different qualifications and several variables of respiratory function (RRmax, FEV_1, FVC and VC). The increase of sportsmen's qualification is accompanied by the improvement of the MVV_{15}, MVV% and Tiffeneau index. We study the effect of 30 days of the interval hypercapnic and hypoxic exercises (IHHE) on the important respiration variables. The "Carbonic-01" device with additional volume of dead space from 800 to 1000 ml has been used. We found that IHHE with the supplementary expiration resistance allows improving of RRm, FVC, MVV and Tiffeneau index of the trained orienteers (candidate master). There has been also discovered the up trend of VC and FEV_1 after IHHE. Due to the close correlation of the respiration variables and a competitive result, the established effect of IHHE on these variables will contribute to the improvement of orienteers sport achievements.
Key words: orienteering, respiration, hypoxia, hypercapnia, supplementary respiration resistance.

Introduction

Many authors have proved the correlation between the possibilities of the respiratory system and aerobic capacities of the sportsmen (Bilgin et al., 2010; Fatemi & Ghanbarzadeh, 2010; Chaitra, Pandurang, Nagaraja, & Vijay, 2011; Harries, 1994). Many observations have shown that in some sports the result is to the great extent determined by aerobic capacities of the sportsmen. That is why respiratory system could be an exercise limiting factor in some sport events (Boutellier, Büchel, Kundert, & Spengler, 1992; McKenzie, 2012). It is confirmed by the expressed adaptive changes of pulmonary functions in swimmers (Nilesh, 2012; Chhabra, Julka, & Mehta, 2013), water polo players (Mazic et al., 2015), rowers (Mazic et al., 2015), long and middle distance runners (Harries, 1994), basketball players (Mazic et al., 2015) and athletes engaged in team sports (Amandeep, 2014). It has been determined that the aerobic capacities are very important for orienteering, namely for the achievement of top score (Larsson, Burlin, Jakobsson, & Henriksson-Larsén, 2002; Creagh & Reilly, 1997).

In our previous investigations (Vovkanych & Penchuk, 2015) there was determined a strong interrelation between the results of sprint and classical distance running and the range of variables of respiratory function of high qualified orienteers. Some authors revealed that the respiratory muscles training (Downey et al. 2007) and hypoxic trainings (Czuba et al., 2011) improve respiratory function of sportsmen. One of the perspective kinds of hypoxic trainings is the interval hypoxic training. (Kolchinskaya, 2008), which can be combined with the regular training session. Therefore our study was undertaken to reveal the effect of the interval hypoxic and hypercapnic exercises with supplementary respiration resistance on the variables of respiratory function of the orienteers.

Materials and Methods

The pulmonary function tests were recorded with the help of SpiroComStandard open type lung-tester 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).

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The investigation has been carried out on male orienteers 18–25 years age. They were divided into three groups according to their level of qualification and result on classical (6–8 km) and short (2.4 km) distance running. Groups are described in table 1.

Table 1. The average speed of running (ASR) of sportsmen of different groups (M ± m)

Group	Qualification	n	ASR, m/s	
			classical distance	short distance
MSG	II–III category (mass sport)	14	1.23 ± 0.20	1.52 ± 0.07
CM	I– candidate master	28	1.86 ± 0.06	2.53 ± 0.09
MS	master of sport	16	2.15 ± 0.09	3.25 ± 0.09

All the participants were informed about the aim and methodology of the study and they volunteered to participate in it. 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 interval hypoxic and hypercapnic exercises (IHHE) were accomplished through the use of respiratory training device "Carbonic-01". The normobaric hypoxic-hypercapnic gas mixture in it is formed by means of additional “dead space” volume (ADSV) formation. This respiratory training device creates additional respiration resistance. The value of ADSV has been changed from 800 ml (6–7% CO_2; 13–15% O_2) to 1000 ml (7–8% CO_2; 11–13% O_2). The IHHE lasted 30 days (27 training sessions and 3 days of rest). During the workout session, the person under investigation fulfilled a certain number of respiratory cycles (RC) with normoxic (NOx) and hypoxic (HOx) gas mixture. The duration of NOx and HOx respiratory periods, as well as the amount of cycles, are indicated in table 2.

Table 2. Characteristics of the orienteers’ interval hypoxic and hypercapnic exercises (IHHE)

Day of IHHE	ADSV, ml	NOx, s	HOx, s	RC, number
1–2	800	60	60	20
3–7	900	60	60	20
9–15	1000	60	90	25
17–23	1000	90	90	20
25–30	900	60	60	20

Footnotes: ADSV – additional dead space volume, NOx – duration of breathing with normoxic gas mixture, HOx – duration of breathing with hypoxic gas mixture, RC – number of respiratory cycles.

A statistical analysis of the results was carried out by means of SPSS 11.0. All values are given as mean M±m (standard error of the mean). Difference between groups was analyzed by t–test and ANOVA analysis. Changes with $P \leq 0.05$ were considered to be significant.

Results

The interrelation of the variables of respiratory function and the sport result (ASR) has been analyzed by means of correlation (r) and the ANOVA analysis (F), as well as by comparing CMS and MS groups variables (by means of t-test). It has been determined that several variables of respiratory function (in particular RRmax, FEV_1, FVC and VC) are closely correlated with the competitive result of sportsmen of all groups (table 3).

Table 3. Important variables of respiratory function of the orienteers

Variables of respiratory function	Correlation with ASR, r	Difference between the groups, P (according to F)	Difference between the CMS and MS groups, P (according to t)
RRmax, per min	0.55	0.08	0.05
FEV_1, l	0.54	–	0.05
FVC, l/s	0.52	–	0.05
VC, l	0.51	–	–
MVV, %norm	0.43	0.02	0.03
MVV, l/min	0.42	<0.001	<0.001
TI, %norm	–	0.06	0.02
TI	–	0.09	0.03

Footnotes: ASR – average speed of running, RRmax – maximal respiratory rate, FEV_1 – forced expiratory volume (1 s), FVC – forced vital capacity, VC – vital capacity, MVV – maximal voluntary ventilation, TI – Tiffeneau index, "–" – a correlation coefficient is statistically uncertain or $P > 0.05$.

A comparison of the variables of respiratory function between the groups by means of ANOVA analysis confirms the improvement of many of them (RRmax, MVV, MVV%, and tendency for TI and TI%) with increase of the sportsmen’s qualification. These positive changes are also maintained in high qualification groups of sportsmen, as indicated by the difference between MS and CMS groups (based on t-test). Hence, we have determined the important variables of respiratory function, which are closely associated with the competitive result in all the groups (RRmax, FEV_1, FVC, VC , MVV, MVV%, TI and TI%). The results of the first stage of investigation show that it is reasonable to improve the variables of respiratory function of the orienteers in order to enhance their sport performance. For this purpose at the second stage of the investigation the possibility of improvement of the variables of respiratory function of the orienteers by means of IHHE has been examined. The male sportsmen of CM group were divided into two groups – the experimental (EG, n=12) and the control group (CG, n=12). At the beginning of the experiment, the groups did not differ by age, height, weight and the informative variables of respiratory function (table 4).

Table 4. Main characteristics of sportsmen representing the experimental (EG) and the control (CG) groups before the beginning of the experiment (M ± m)

Index	EG	CG	P
Number of the participants	12	12	–
Age, years	18.36±1.25	18.10±0.87	0.86
Weight, kg	65.75±1.93	63.75±3.66	0.64
Height, cm	175.17±1.37	170.25±4.64	0.33
RRmax, per min	62.84±4.98	58.85±3.92	0.54
FEV_1, l	4.27±0.25	4.29±0.26	0.95
FVC, l	4.28±0.25	4.34±0.26	0.87
VC, l	4.45±0.24	4.51±0.25	0.88
MVV, %norm	122.27±9.19	120.78±8.94	0.39
MVV, l/min	159.27±9.75	153.11±13.00	0.71
TI, %norm	110.99±3.02	109.77±2.67	0.77
TI, units	92.85±2.75	89.99±2.70	0.47

Footnotes: RRmax – maximal respiratory rate, FEV_1 – forced expiratory volume (1 s), FVC – forced vital capacity, VC – vital capacity, MVV – maximal voluntary ventilation, TI – Tiffeneau index.

In the course of the experiment sportsmen of the EG accomplished IHHE according to the description specified in table 1. The application of IHHE in EG led to the significantly bigger changes of the important variables of respiratory function in comparison with the CG (table 5). After the completion of the experiment a significant increase of RRm, VC, FVC, FEV_1 and MVV has been observed in EG. A positive trend was revealed for FVC (%norm), TI and MVV (%norm). There were no statistically significant changes of the variables of respiratory function among the sportsmen of the CG (without IHHE). So, under the influence of IHHE the changes, that indicate the increase in strength and endurance of respiratory muscles (RRm, VC, FVC, MVV) and the reduction of the airways resistance (FEV_1, TI), have been revealed. After the experiment completion (table 5) the RRm, VC, FVC, MVV and TI values in EG were significantly higher ($P < 0,05$) than in CG. The tendency of higher values of and FEV_1 ($P < 0,10$) in EG has been revealed. At the same time, for several variables (MVV%, TI%) the difference between the groups was not statistically confirmed.

Table 5.The variables of respiratory function in EG and CG after the completion of IHHE

Variables	EG	CG	P
RRm., per min	77.97±4.36	60.84±3.76	0.01
FEV_1, l	4.97±0.26	4.36±0.26	0.10
FVC, l	5.06±0.27	4.33±0.21	0.05
VC, l	5.23±0.25	4.67±0.19	0.05
MVV%, %	133.55±9.85	124.80±7.65	0.49
MVV, l/min	191.09±8.64	161.28±10.21	0.04
TI%, %	113.19±4.84	108.27±1.64	0.35
TI	95.22±0.76	91.03±1.79	0.05

Footnotes: RRmax – maximal respiratory rate, FEV_1 – forced expiratory volume (1 s), FVC – forced vital capacity, VC – vital capacity, MVV – maximal voluntary ventilation, TI – Tiffeneau index.

Consequently, our results could be interpreted as evidence for the positive effect of IHHE on the functional capacities of the respiratory system of the orienteers. It is reasonable to assume that such effect will contribute to the improvement of their sport performance.

Discussion

The results of the correlation analysis clearly suggest the increase of many variables of respiratory function of sportsmen along with the improvement of their performance and average speed of running on distance. The obtained data confirm that orienteering can be placed in the list of sports (Vovkanych &. Penchuk, 2015, Adegoke & Arogundade, 2002; Mazic et al., 2015; Chaitra, Pandurang, Nagaraja, & Vijay, 2011; Harries, 1994) where respiratory capacity plays the important role in achieving the high competitive result. It is also agreed with the important role of aerobic capacities in the orienteering, revealed by other authors (Larsson, Burlin, Jakobsson, & Henriksson-Larsén, 2002; Creagh & Reilly, 1997). The obtained results are correlated with the investigations (Downey et al. 2007), in which a positive effect of respiratory muscles training on the external respiration indices have been established. The revealed effect of IHHE is consistent with the positive changes of the respiratory function under the influence of hypoxic and hypercapnic exercises in the mountains (Wilber, 2001) and demonstrated by other authors the advantageous influence of devices, which provide hypoxic conditions (Bernardi et al., 2001; Hamlin & Hellemans, 2007). That is why in the present study we evaluated the effect of the IHHE, which combine the conditions of normobaric hypercapnic hypoxia with increased breathing resistance. It makes them closer to the real conditions of the competitive activity, stimulates the respiratory muscle training and allows the precise determination of the IHHE influence. Our results provided strong evidence that proposed methods of IHHE significantly improved the range of variables of respiratory function of the orienteers, which are of great importance for the sport performance. It has been suggested that the application of IHHE is promising in different sports, in which the high functional capabilities of respiratory system are of great importance.

Conclusions

The close correlation between the sports result of the orienteers of different qualification and several variables of respiratory function (RRmax, FEV_1, FVC and VC) has been revealed. Increase of sportsmen's qualification is also accompanied by the improvement of MVV, MVV% and TI. It has been established that interval hypercapnic and hypoxic exercises (IHHE) with additional airway resistance leads to the improving of RRmax, FVC, MVV and TI of the orienteers. The tendency of VC and FEV_1improvement has also been revealed. We can suppose that such changes will improve the sport performance of the orienteers.

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