THE EFFECTS OF INTERMITTENT HYPOXIC TRAINING ON AEROBIC CAPACITY AND BLOOD COMPONENTS OF ENDURANCE ATHLETES

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Abstract

Aim: The aim of this paper was to evaluate the influence of a three-week intermittent hypoxic training (IHT) on endurance athletes´ organism from the point of haematological parameters, aerobic capacity and aerobic efficiency of the organism. Methods: 7 athletes (4 ♀, 3♂) aged 23 – 32 years who practice on a daily basis participated on the research. These athletes completed a 21 – 25-day IHT with three days (every seventh day) without hypoxia. They performed the IHT at rest, which means 90 min before and after the IHT they were not exposed to load. Within the IHT training days the monitored athletes were exposed to hypoxia during the first 6 days for 60 min and every day another 5 min were added up until the 90 min exposure duration was achieved at the end, for the interval of 6 min of hypoxia + 3 min of normoxia (10 repeats at the end altogether). During the IHT the athletes were exposed to a hypoxia on the level of 14 – 8 % O_2 concentration in the air (corresponding to the altitude of 3500 – 7000 a.s.l.). The oxygen saturation of the blood (SpO_2) during the first week was in a diapason of 90 – 85% and from the second week on decreased down to the level of 75%. Results: Due to the IHT the increase of reticulocytes was observed, the increase was from 5,86 ‰ to 8,14 ‰, which in the absolute expression means the increase of 28,1%. Increase from 3,5 to 4,7 % was also measured in the case of erythrocytes, haemoglobin, and hematocrit. In the case of VO_2max, $VO_2max.kg^{-1}$, VO_2max at ANT, and $VO_2max.kg^{-1}$ at ANT the increase dispersal was between 7,3 – 9,8%. In all observed parameters there was a significant increase (P<0,05, resp. P<0,01).

***Key words**: endurance, intermittent hypoxic training, aerobic capacity, blood*

Introduction

The use of hypoxic training, training in conditions with a lowered oxygen concentration, gained the attention of sport experts in the second half of the 20th century, influenced mainly due to organizing rights for the OG assigned to the Mexican capital in 1968. It is known that the endurance and strength-endurance training in a hypobaric-hypoxic environment, while keeping the velocity from regular heights, increases the load from 5 – 10% (Korčok & Pupiš, 2006), therefore in such conditions it is necessary to reduce the load intensity. Through a correct load indication, though, the positive changes in the organism should be achieved. Špringlová (1999) reckons the contribution of the high altitude (=hypoxic) stay and practice, which is recognizable in an oxidative energetic metabolism improvement. As a consequence there is an improvement of performance and aerobic capacity which more researches such as Levine Stray & Gundersen (1997), Kompán & Görner (2001), Meeuwes et al. (2001), Broďáni & Tóth (2005), and Pupiš & Čillík (2008) confirmed. Researchers all over the world try to implement hypoxic training using various methods. Based on their experience, back in 1993 in Finland and 1994 in Sweden, scientists created rooms where they simulated normobaric hypoxia. In these rooms the oxygen level is artificially lowered, but without sideway effects caused by the pressure change. Norwegians constructed a house where they were able to simulate a hypobaric hypoxia equivalent to the altitude of 2500 m a.s.l.

The principle of these halls, houses, rooms and today even tents is that the level of nitrogen is artificially increased while the level of oxygen remains on the level of 15,3%, and the partial pressure is 116 mmHg. This way of using hypoxia is close to a method of "live high train low". A similar principle is used in the method of intermittent hypoxic training (IHT), started by Russian flyers (Hamlin & Hellemans, 2003). This method is based on exposing the organism to an extreme hypoxia, equivalent to high altitudes, even more than 6500 m a.s.l. A special device – hypoxic generator, is used in it. Stukeet al. (2004) confirmed positive changes caused by IHT on the athletes organisms, in some cases describing up to a 20% improvement. Many studies (Terrados et al., 1988; Desplancheset al., 1993; Fulcoet al., 2000; Meeuwsen et al., 2001) show as well the possibility to use the IHT in endurance development. Further studies show the facts that even a short-time hypoxia (1 – 2 hours) stimulate erythropoietin increase (Abbrecht et al., 1972; Eckardt et al, 1989). Rodriguez et al. (2000) recorded in their IHT experiments that the mean plasma concentration of EPO increased from 8,7 to 13,5 $mU.ml^{-1}$ (55.2%; P < 0.01) after 90 min of acute expos urein a simulated altitude of up to 5000 m a.s.l., and continued to rise until a peak was attained 3 hours after the termination of hypoxia. In their second experiment, in which subjects were exposed to a simulated altitude of up to 5500 m a.s.l. for 90 min, three times a week for 3 weeks, all haematological indicators of red cell mass increased significantly, reaching the highest estimated mean values at the end of the programme or during the subsequent 2 weeks, including the increase in packed cell volume (from 42,5 to 45,1%; P < 0.01), red blood cell count (from 4,55 x 10(6) to 4,86 x 10(6).l^{-1}; P< 0.01), reticulocytes (from 0,5 to 1,4%; P < 0.01), and haemoglobin concentration (from 14.3 to 16.2 g.dl^{-1}; P < 0.01), without an increase in blood viscosity. Arterial blood oxygen saturation during hypoxia was improved (from 60% to 78%; P < 0.05).The IHT thus can create preconditions for a similar organism response as in training in higher altitudes, but while keeping the training intensity. These facts made some authors think whether the IHT is not a doping and more of them (i.e. Böning (2010), Lippi & Franchini (2010)) could not find a univocal answer. As there is no univocally confirmed IHT influence on organism, we decided to deal with this topic within the UGA and VEGA 1/0322/10 grants tasks.

Aim

The aim of this paper is to assess the impact of a three-week intermittent hypoxic training on the organism of endurance athletes from the point of hematologic parameters, aerobic capacity and aerobic performance of organism.

Methods

For the hypoxic training realization we used a hypoxic generator Summit 3in1 from Altitude tech that can create air containing 8% of oxygen and which thus can be compared to the altitude of 7000 metres a.s.l. The principle of hypoxia is that the athlete is exposed to hypoxia in an out-of-training mode. The observed athletes completed the 21 – 25-day intermittent hypoxic training with three days (every seventh day) without hypoxia. They performed the IHT at rest, which means 90 min before and after the IHT they were not exposed to load. Within the IHT training days the monitored athletes were exposed to hypoxia during the first 6 days for 60 min and every day another 5 min were added up until the 90 min exposure duration was achieved at the end, for the interval of 6 min of hypoxia + 3 min of normoxia (10 repeats at the end altogether). During the IHT the athletes were exposed to a hypoxia on the level of 14 – 8 % O_2 concentration in the air (corresponding to the altitude of 3500 – 7000 a.s.l.). The oxygen saturation of the blood (SpO_2) during the first week was in a diapason of 90 – 85% and from the second week on decreased down to the level of 75%.

The group was built of seven endurance athletes (4 women, 3 men) aged 23 – 32 years that practice on a daily basis (2 ski touring, 2 triathlon, 3 athletics – long distances runs). Our assessment of the IHT influence was based on two tests:

1. Spiroergometry – the athletes underwent the entrance examination right before the beginning of the IHT, the final examination 17 - 21 days after the conclusion of the IHT. We observed the level of VO_2max, VO_2max. kg^{-1}, VO_2max at ANT and VO_2max. kg^{-1}at ANT.
2. Blood tests – entrance examination maximum 3 days before the initiation of the IHT, final examination on the 11th – 14thday after the conclusion of the IHT. We observed the changes in the red blood count (reticulocytes, erythrocytes, hematocrit and haemoglobin).

For data processing and analysis we used Microsoft Excel 2007. The results of the mean observed values achieved before and after the IHT, differences of results before and after the IHT were measured by Student´s paired T-test (P<0,05).

Results and discussion

All the observed athletes during the IHT had the blood saturation with oxygen during the first days on the level of 90 – 85 %, and the oxygen concentration in the inhaled air was12 – 14 %. During the next days the hypoxia increased up to the level equivalent to the altitude more than 7000 m a.s.l. (i.e. the concentration of the O_2 in the air decreased fewer than10 % and SpO_2approached to 75%). They coped with hypoxia relatively well without considerable negative utterances that are a frequent accompaniment of hypobaric hypoxia. The single negative subjective feeling noticed was a feeling of lassitude during the IHT training days, which is in contradiction to the statement of Hamlin & Hellemans (2004) who did not notice in tested athletes negative experiencing during the IHT. After the conclusion of the IHT these feelings had a sine curve.

As we can see in Table 1 all the observed athletes had an increased level of all parameters influencing the aerobic performance of the organism. Likewise, we see in the Table 2 that in all observed hematologic as well as functional parameters a statistically significant improvement (P<0,05, P<0,01) was achieved. From the point of hematologic parameters we consider the most significant indicator the number of reticulocytes where there was an increase from 5,86 ‰ to 8,14 ‰ which in an absolute expression means an increase of 28,1%. An increase from 3,5to 4,7 % was observed also in the case of erythrocytes, haemoglobin and hematocrit. This proportionally lower increase can be explained by the fact that by the influence of endurance load a haemodilution can occur due to an increase of blood serum volume (hypervolemia) (Neumann et al., 2005), which causes the decrease of relative values of blood components (i.e. the real growth of hematocrit, haemoglobin and erythrocytes could have been even more noticeable). There are several studies showing the facts that even a short-term hypoxia (on the level of 1-2 hours) cause the increase of erythropoietin (Abbrecht et al., 1972; Eckardt et al., 1989). Rodriguez et al. (2000) supports these findings with their research where they observed a similar growth of the studied parameters as in our research and showed a significant increase of EPO influenced by the IHT.

Table 1. Comparison of observed indicators before and after the IHT of particular athletes

		RTC (‰)	Ery (10^12.l^{-1})	HGB (g.l^{-1})	Htc (%)	VO_2max.kg-^{1} (ml.kg^{-1}.min-^{1})	VO_2max (ml.min-^{1})	VO_2max.kg-^{1} at ANT (ml.kg^{-1}.min-^{1})	VO_2max at ANT (ml.min-^{1})	Body weight (kg)	Body height (cm)
S.L.♀	p	8	4,07	124	37,5	61,4	3499	54,7	3118	57	169
J.P.♂	r	6	5,64	161	48,1	66,6	4529	61,4	4175	68	178
M.G.♂	e	5	5,02	149	44	66,9	4837	54,7	3955	72,3	182
S.T.♀	d	6	4,67	134	42	56	3696	49,1	3241	66	169
M.P.♂	I	5	5,07	166	48	65,4	4105	60,1	3768	62,7	176
M.Cz.♀	H	6	4,89	156	42,4	51,1	3173	45,6	2832	62,1	164
B.S.♀	T	5	4,01	129	38,1	55,6	3280	51,2	3021	59	169
S.L.♀	p	9	4,23	130	40,2	73,5	3896	64,1	3397	53	169
J.P.♂	o	9	5,77	162	50,5	75,3	4970	63,4	4184	66	178
M.G.♂		7	5,42	156	48	72,3	5213	64,1	4622	72,1	182
S.T.♀	I	8	4,9	143	44	59,8	3947	55,9	3689	66	169
M.P.♂	H	7	5,08	165	49	69,9	4364	66,7	4162	62,4	176
M.Cz.♀	T	9	5,02	164	44	55,3	3434	49,9	3099	62,1	164
B.S.♀		8	4,15	138	39,2	58,2	3434	53,6	3162	59	169

Table 2. Statistic summary of the IHT influence on organism of the observed athletes

	RTC (‰)	Ery (10^12.l^{-1})	HGB (g.l^{-1})	Htc (%)	VO_2max.kg-^{1} (ml.kg^{-1}.min-^{1})	VO_2max (ml.min-^{1})	VO_2max.kg-^{1} at ANT (ml.kg^{-1}.min-^{1})	VO_2max at ANT (ml.min-^{1})	Body weight (kg)	Body height (cm)
$\bar{x}$ before	5,86	4,77	145,6	42,87	60,43	3 874,1	53,83	3 444,3	63,87	172,4
$\bar{x}$ after	8,14	4,94	151,1	44,99	66,33	4 179,7	59,67	3 759,3	62,94	172,4
difference	28,1%	3,5%	3,7%	4,7%	8,9%	7,3%	9,8%	8,4%	-1,5%	0%
SD before	0,99	0,53	15,35	3,92	5,80	588,74	5,28	478,30	4,90	5,88
SD after	0,83	0,54	13,01	4,03	7,66	651,70	5,97	536,62	5,58	-
T test	0,000203	0,009157	0,010201	0,001724	0,003387	0,000208	0,002290	0,008073	0,160067	-

Legend:RTC – reticulocytes (‰ in blood); Ery – red blood cells (10^12.l^{-1}); HGB – hemoglobin (g.l^{-1}); Htc – hematocrit (%); ANT – anaerobic threshold

Similarly to the blood components, also in the case of VO_2max, VO_2max.kg^{-1}, VO_2max at ANT and VO_2max.kg^{-1} at ANT we observed a statistically significant improvement ($P<0,05$, $P<0,01$). As stated in the Table2, in these parameters a similar increase, at a dispersal of 7,3 – 9,8 %, was observed. The lowest increase was observed in the absolute value of the maximum oxygen consumption and so the organism potential for the oxygen utilization increased by 7,3 %. A considerable increase observed by this indicator was at ANT where the increase was 8,4 %. So the usability of the oxygen consumption at ANT increased from 88,9 % of the absolute expression to 89,95 % of the absolute expression of the maximum oxygen consumption. The most significant growth was measured in relative indicators (counted on the kilogram of the body weight) as the accompaniment was that in the observed group an average weight loss was 1,5 %. Maximum oxygen consumption increased by 8,9 % and VO_2 max at ANT by 9,8 %. The observed results show a positive influence of the IHT on the organism of endurance athletes and the current sport shows that the hypoxic training can find its space not only in the endurance sport disciplines. The results of our research correspond to the statement of Meeuwes et al. (2001) who executed a similar research on the group of elite triathlonists, but in a hypobaric natural hypoxia, and observed a 7% VO_2max.kg^{-1} increase, a 7,4 % maximum performance increase and a 5% sub maximum performance increase (per kg/weight). In a natural hypobaric hypoxia several authors measured similar results (Levine Stray & Gundersen, 1997, Pupiš & Čillík, 2008). These authors, in connection to hypoxia, describe an increase of blood components influenced by hypoxia which was also confirmed in our case as well as the case of Rodriguez et al. (2000), Katayamo et al. (2003) and Hamlin & Hellemans (2003, 2004) who also describe this increase by IHT, so at anormobaric hypoxia.

Conclusion

On the basis of our findings we consider a three-week IHT as an appropriate means of endurance development (development of aerobic capacity, efficiency and improvement of blood quality from the point of transport capacity of O_2) of athletes. From the point of the IHT realization an effective way seems the exposure to hypoxia on the level of 14 – 8 % of the oxygen content in the air (equivalent to the altitude of 3500 – 7000 m a.s.l), and the blood saturation with the oxygen (SpO_2) during the first week should be in a diapason of 90 – 85% and from the second week on decreased down to the level of 75%. Due to such an IHT the raise of reticulocytes was observed, the increase was from 5,86 ‰ to 8,14 ‰, which in the absolute expression means the increase of 28,1%. Increase from 3,5 to 4,7 % was also measured in the case of erythrocytes (3,5%), haemoglobin (3,7 %), and hematocrit (4,7 %). In the case of VO_2max, VO_2max.kg^{-1}, VO_2max at ANT, and VO_2max.kg^{-1} at ANT the increase dispersal was between 7,3 – 9,8%.

From the point of endurance performance for the most important we consider the VO_2max at ANT indicator where we measured the increase from 88,9 % of the absolute expression to 89,95 % of the absolute expression of the maximum oxygen consumption. The maximum oxygen consumption increased by 8,9 %, VO_2max at ANT for 8,4 % and $VO_2max.kg^{-1}$at ANT for 9,8%.

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EFEKTI INTERMITENTNOG HIPOKSIČNOG TRENINGA NA AEROBNI KAPACITET I KOMPONENTE KRVI KOD SPORTAŠA U SPORTOVIMA IZDRŽLJIVOSTI

Sažetak

Cilje: CIlj ovog članka je bio evaluirati utjecaj tro-tjednog intermitentnog hipoksičnog treninga (IHT) na tjelesnu izdržljivost sportaša s pozicije hematoloških parametara, aerobnog kapaciteta i aerobne učinkovitosti organizma. Metode: Sedam sportaša (4 ♀, 3♂) uzrasta 23–32 g. koji su vježbali svakodnevno sudjelovalo je u istraživanju. Kompletorali su 21-25 dnevni IHT uz tri dana (svaki sedmi dan) uz hipoksiju. Proveli su IHT na kraju, što znači 90 min prije i nakon IHT nisu bili izloženi opterećenju. Za vrijeme IHT trenažnih dana praćeni sportaši bili su izloženi hipoksiji za vrijeme prvih 6 dana u trajanju od 60 min a također svaki dan dodatnih 5 min dok se ne postigne trajanje od 90 min izlaganja na kraju, u interval od 6 min hipoksije + 3 min normoksije (10 ponavljanja na kraju zajedno). Za vrijeme IHT sportaši su bili izloženi hipoksiji razine 14 – 8 % koncentracije O_2 u zraku (što odgovara visini od 3500-7000 nadmorske visine). Saturacija kisika u krvi (SpO_2) za vrijeme prve sedmice bila je u rasponu od 90-85 % a od druge sedmice je smanjena na 75 %. Rezultati: Zbog IHT zabilježeno je povećanje retikulocita s povećanjem od 5.86 ‰ do 8.14 ‰, što u apsolutnom smislu znači povećanje od 28.1 %. Povećanje od 3.5 do 4.7 % također je izmjereno u slučaju eritrocita, hemoglobina i hematokrita. U slučaju VO_2max, $VO_2max.kg^{-1}$, VO_2max at ANT, and $VO_2max.kg^{-1}$ at ANT povećanje se pojavljivalo u rasponu između 7.3 i 9.8 %. Kod svih promatranih parametara to je bilo značajno povećanje (P<0,05, resp. P<0,01).

Ključne riječi: *izdržljivost, intermitenti hipoksivni trening, aerobni kapacitet, krv*

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