# VARIOUS ALTERNATIVES OF HYPOXIC TRAINING

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*Abstract*

*The aim of the paper was to compare the influence of three different alternatives of hypoxic training (a training in higher altitude – HA, an intermittent hypoxic training – IHT, and a hypoxic tent – HT). The research was executed on 10 athletes who all took part in higher altitude training and an intermittent hypoxic training. Four of the athletes from this sample took part in a training (a sleep) in a hypoxic tent. All the three alternatives lasted for approximately three weeks. In haematological indicators the number of erythrocytes, haemoglobin and hematocrit in HA and IHT increased from 3% to 4.9%. A more significant increase (25.3%, resp. 26.2%) was measured in reticulocytes. In HT we measured the increase of reticulocytes in 17.9%; however in the remaining indicators we observed even smaller increase, namely 0.7 – 2.3%. From the point of spiroergometric indicators we observed the most significant increase in the $VO_2max.kg^{-1}$ at ANT where we measured an increase of 8.7%, resp. 9.9%. Obviously, this indicator is directly influenced by the decrease of body weight, but also in absolute rate of $VO_2max$ at ANT we measured an increase (7%, resp. 7.7%), which indicates the increase of oxygen usability at ANT, thus the intensity corresponding to the competition load. In HT we also measured the increase in these parameters as well as a moderate decrease of body weight (0.3%), however only from 0.3 – 1.5%. From the point of effectiveness we confirmed a positive influence of hypoxic training in all the three methods (HA, IHT, HT), but according to our findings the influence of HA and IHT was significantly higher than in HT.*

***Key words:*** *training in higher altitude, intermittent hypoxic training and hypoxic tent.*

## INTRODUCTION

Exposing the organism to a higher altitude is a very frequent way of athletic training not only in endurance sports. In connection with this form of a training we meet the problem that some authors (e.g. Görner - Kompán, 2001; Štulrajter et al., 2001; Paugschová – Kobela - Štulrajter, 2006; Kobela, 2007) use for the training in higher altitude a term mid-highland training, the other authors (e.g. Špringlová, 1999; Suchý – Dovalil, 2005) use the term high altitude training, where they most probably draw from the English terminology (e.g. Bigardet al., 1991; Suslov, 1994; Friedmann – Burtsch, 1997 and others) that uses „high–altitude training". Nowadays we see various variations of higher altitude training as well as various possibilities of simulating such an environment and therefore we consider (in concordance with Broďáni - Tóth, 2005; Korčok - Pupiš, 2006; Suchý, 2011) the most appropriate term for various alternatives of exposing the organism to such an environment the term HYPOXIA. This term can be seen as the most appropriate mainly from the point that in all cases there is a targeted reduction of the oxygen level in the inspired air, thus it is a hypoxia, whether caused by the increase of the altitude or by the influence of the oxygen reduction in the inspired air by using instruments. The origin of the hypoxic training goes the most often back to the stays in higher altitudes where this problematic has been investigated by the authors for many centuries. In 1644 Toricelli invented the mercury barometer that was relatively exactly able to measure the atmospheric pressure. This invention enabled further research of the decreased atmospheric pressure (Pb) and $PO_2$. In 1648 Pascal proved a lower barometric pressure in higher altitude in comparison to lowland (e.g. Espe, 1965). In 1777 Lavoiser described oxygen and other gases that are a part of the atmospheric pressure (Wilber, 2004; Wilmore et al., 2008). As it was mentioned above the hypoxic training does not necessarily mean only a stay in higher altitude. The aim of the hypoxic training is always the same, though. One of the main mechanisms of adaptation to a stay in a hypoxic environment is the reproduction of erythrocytes and an increase of haemoglobin level by the cause of which the hematocrit rate and blood viscosity increases. Hypererythrocytosis is a permanent phenomenon during the whole stay in a high altitude environment and according to Trojan et al. (1992) it can reach even a double of the normal rate. It originates as a consequence of kidney incretion of erythropoietin that stimulates the production of the red blood cells in the bone marrow. Špringlová (1999) points to the asset of the high altitude stay and training which is globally recognizable in the improvement of oxidative energetic metabolism. Physiologically the number of red blood cells and haemoglobin in the organism increases. Altitude affects the changes in cell functions and metabolism that have a positive influence on athletes' performance. In a longer lasting stay it influences the capillary density and the content of myoglobine in the muscles. The increase of the blood cells number can be seen already on the third day of a high altitude stay. In the peripheral blood, though, a higher number of macrocytes with a lower level of haemoglobin can be seen, which causes the deterioration of oxygen transport (Gurský, 1994).

According to Suchý and Dovalil (2005) the decrease of the oxygen pressure in the arterial blood leads to the growth of the absolute number of red blood cells, a so called polycythemia or polyglobulia. The process is stimulated by the increased formation of the erythropoietin, a hormone that is created in kidneys. Elevation of erythropoietin level can be seen already after 3 hours in the higher altitude (the maximum of secretion is given between 24 - 48 hours). There starts the stimulation of red blood cells, in the blood stream the reticulocytes are released and the absorption of iron is increased. The difference between those acclimatized individuals and the persons with normal hematologic parameters (at the sea level) reach over 28% of the increased transport capacity of blood. The increase can be significantly helped by the iron supplementation.

Zrubák – Štulrajter et al. (1999), Štulrajter et al. (2001) and Kobela (2007) explain this finding when mentioning that by staying in higher altitudes there is achieved not only the increase of the erythrocytes number, but especially their rejuvenation. In the blood stream the over aged blood cells are employed, with the life cycle up to 180 days, which were stored in so called capacity vessels. When they are employed in the stream they pass through the bone marrow, spleen and they demise (in so called blood cemeteries). Instead of them younger and functionally fitter red blood cells originate, which secures a much better oxygen transfer.

The load itself causes changes in the blood structure. In sports where there is a short intensive load we see a myogenic erythrocytosis which Brozmanová (1990) explains as a thickening of blood plasma that causes a relative increase of the red blood cells. The decline of the blood plasma occurs by the transfer of the liquid from the blood into the intercellular space. The other situation occurs in an endurance load where in the long lasting load there comes to a decrease of red blood cells number, a so called myogenic erythrocytopenia, that is being justified (Brozmanová, 1990) especially by an increased disintegration of erythrocytes in an exhaustive physical load. This fact needs to be taken into consideration so in the hypoxic environment stays as in its effectiveness evaluation by the means of the rate and the content of red blood cells. Even the effect of hypoxic training is mostly positive there occurred a couple of opinions arguing the fact whether the hypoxic training is not a doping. Lippi et. al. (2006) identify the hypoxia clearly as a doping method. They divided the techniques of the blood doping as follows:

a) Blood transfusions.
b) Erythropoiesis stimulating substances.
c) Hypoxic training.
d) Blood substances.
e) Supplements.
f) Genetic doping.

However, the prevailing opinions clearly exclude the hypoxic training from this category. The basic division of hypoxic training was in the past based on a single criterion which was the altitude. The actual division would be clearly different. From our point of view it could be as follows:

a) Staying and training in a high altitude.
b) Staying in a high altitude, training in lowland.
c) Staying in lowland, training in a high altitude.
d) Sleeping in hypoxic houses, tents, training in natural conditions.
e) Sleeping and training in hypoxic houses, tents.
f) Sleeping in natural conditions, training in hypoxic houses, tents.
g) Intermittent hypoxic training.

To the most frequent methods that we are using in our conditions belongs the method "staying and training in a high altitude" as well as "staying in a high altitude, training in lowland" and in the last time we use the method of "intermittent hypoxic training". As a part of a VEGA 1/1158/12 grant project (Adaptation effect of a training load in individual sports) we compared these three methods of hypoxic training.

## METHODS

### *Participants*

The research group consisted of 10 long distance runners (6 men, 4 women – in the age range 23 – 32 years, average body weight at the beginning of the research 62.2 kg, and an average body height 172.5 cm). All the examined athletes took part in a hypoxic training in higher altitude (mountain training – HA) and an intermittent hypoxic training (IHT). Four of the research group members completed a stay in a hypoxic tent (HT). The research lasted for 3 years and the athletes completed a hypoxic stay from the 6$^{th}$ to the 3$^{rd}$ week before participating in a peak event. Thus we ensured almost identical content of the training load as well as the supplementation.

*Training in a high altitude*
The observed athletes carried out training in a high altitude in an altitude higher than 1800 m (Livigno – ITA, St. Moritz – SUI, Melago – ITA, Creer - Mexico). The length of the stay was approximately 20-24 days.

*Intermittent hypoxic training*
For IHT we used a hypoxic generator Summit 3in1 from Altitude tech that can create the air with the oxygen content around 8% which is comparable with the altitude of 6500 metres above the sea level. The athlete is exposed to hypoxia in the out-of-the-training mode. The observed athletes carried out a 21 – 25-days long intermittent hypoxic training with three days (every 7$^{th}$ day) without hypoxia. During the intermittent hypoxic training the athletes were exposed to hypoxia in the first six days for 60 min. and 5 minutes were then added every day up to the final 90 min. in an interval of 6 min. of hypoxia + 3 min. of normoxia (thus at the end 10 reps altogether). During the IHT the athletes were exposed to hypoxia on the level of 14 – 8 % of the oxygen content in the air (corresponding to the altitude 3500 – 7000 m), where the blood saturation with the oxygen ($SpO_2$) was in the first week in a range of 90 – 85% and from the second week onwards decreased down to the level of 75%.

*Hypoxic tent*
Technical conditions allowed us to use the hypoxic tent in athletic training only with four athletes. Every day they spent in the tent at least 12 hours. At the beginning the oxygen concentration in the inspired air ranged between 2000 – 2200 m of altitude and during the next days gradually increased to the level of around 3000 m. All the four athletes completed 21 – 24 days of sleeping in a hypoxic tent.

In the assessment of the effect of the hypoxic training we used two tests:

1. Spiroergometry – athletes carried out the entrance test immediately before the beginning of the hypoxic training, the output test 17 – 21days after the completing of the hypoxic training. We observed the level of $VO_2$max, $VO_2$max. kg$^{-1}$, $VO_2$max at ANT and $VO_2$max. kg$^{-1}$ at ANT.
2. Blood tests – entrance test maximum of 3 days before the hypoxic training, output test between the 11$^{th}$ – 14$^{th}$ day after the hypoxic training. We observed the changes in the red blood cell count, namely reticulocytes, erythrocytes, hematocrit, and haemoglobin.

## RESULTS AND DISCUSSION

Training in higher attitudes is a problem that authors have been dealing with for almost four centuries making it thus a considerably well researched issue which, though, despite many years of research leaves many unanswered questions resulting in countless polemic about the effects of this type of training. Our probands carried out their training in altitudes above 1800 m what was positively reflected in the hematologic and spiroergometric indicators. As we see in the table 1, in erythrocytes, haemoglobin and hematocrit we measured an increase from 3 to 3.7 %. Important, though, is the rejuvenation of the blood which demonstrates the reticulocytes indicator where there was an increase up to 25.3 %.

**Table 1**. Comparison of the observed indicators before and after the HT

| Proband | | RTC | Ery | Hgb | Htc | $VO_2$max | $VO_2$max.kg | $VO_2$max kg at ANT | $VO_2$max.kg at ANT | kg | Cm |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Before HT | 1 | 7 | 4,68 | 131 | 42,5 | 60,3 | 3425 | 52,5 | 2985 | 56,8 | 169 |
| | 2 | 6 | 5,41 | 155 | 48,3 | 65,9 | 4478 | 60,5 | 4116 | 68 | 178 |
| | 3 | 4 | 4,91 | 151 | 43,8 | 67,8 | 4921 | 55,4 | 4019 | 72,6 | 182 |
| | 4 | 8 | 4,67 | 137 | 41,8 | 54 | 3502 | 49 | 3187 | 64,8 | 169 |
| | 5 | 5 | 5,01 | 146 | 45,7 | 64,8 | 4008 | 59,7 | 3694 | 61,9 | 176 |
| | 6 | 6 | 4,97 | 151 | 47,1 | 55,2 | 3312 | 47,9 | 2874 | 60 | 164 |
| | 7 | 6 | 4,44 | 139 | 39,7 | 56,3 | 3367 | 52,4 | 3135 | 59,8 | 169 |
| | 8 | 5 | 4,32 | 132 | 37,7 | 61,1 | 3589 | 55,2 | 3243 | 58,7 | 170 |
| | 9 | 9 | 5,22 | 147 | 44,3 | 69,9 | 4405 | 67,2 | 4236 | 63 | 177 |
| | 10 | 6 | 4,93 | 149 | 41,2 | 72,7 | 4123 | 66,9 | 3795 | 56,7 | 171 |
| After HT | 1 | 8 | 4,93 | 136 | 43,2 | 68,2 | 3752 | 61 | 3356 | 55 | 169 |
| | 2 | 9 | 5,56 | 167 | 49,9 | 72,8 | 4897 | 66,9 | 4509 | 67,3 | 178 |
| | 3 | 7 | 5,11 | 153 | 46,2 | 76 | 5417 | 71,2 | 4541 | 71,2 | 182 |
| | 4 | 8 | 4,8 | 143 | 40,9 | 58,1 | 3721 | 52,9 | 3391 | 64 | 169 |
| | 5 | 7 | 5,12 | 155 | 46,3 | 69,2 | 4279 | 63,5 | 3926 | 61,8 | 176 |
| | 6 | 8 | 5,12 | 154 | 48,2 | 60,5 | 3526 | 51,2 | 2986 | 58,3 | 164 |
| | 7 | 10 | 4,83 | 138 | 39,6 | 60,4 | 3527 | 56,1 | 3277 | 58,4 | 169 |
| | 8 | 9 | 4,71 | 137 | 38,7 | 67,5 | 3837 | 64,6 | 3669 | 56,8 | 170 |
| | 9 | 8 | 5,26 | 148 | 46,9 | 74,7 | 4536 | 71,5 | 4345 | 60,7 | 177 |
| | 10 | 9 | 4,97 | 156 | 45,7 | 75,4 | 4235 | 70 | 3927 | 56,1 | 171 |

| Proband | RTC | Ery | Hgb | Htc | $VO_2$max | $VO_2$max.kg | $VO_2$max kg at ANT | $VO_2$max.kg at ANT | kg | Cm |
|---|---|---|---|---|---|---|---|---|---|---|
| $\bar{x}$ before HT | 6,2 | 4,9 | 143,8 | 43,2 | 62,8 | 3 913,0 | 56,7 | 3 528,4 | 62,2 | 172,5 |
| $\bar{x}$ after HT | 8,3 | 5,0 | 148,7 | 44,6 | 68,3 | 4 172,7 | 62,9 | 3 792,7 | 61,0 | 172,5 |
| % diff. before-after | 25,3% | 3,7% | 3,3% | 3,0% | 8,0% | 6,2% | 9,9% | 7,0% | -2,1% | 0,0% |
| SD before HT | 1,4 | 0,32 | 8,02 | 3,13 | 6,11 | 529,32 | 6,44 | 475,55 | 4,81 | 27,05 |
| SD after HT | 0,9 | 0,24 | 9,59 | 3,58 | 6,32 | 595,73 | 7,07 | 519,42 | 4,95 | 27,05 |

Similarly, as well as in the blood parameters also in the indicators describing the use of the oxygen we measured an increase. In the parameters $VO_2$max, $VO_2$max.kg$^{-1}$, $VO_2$max at ANT and $VO_2$max.kg$^{-1}$ at ANT there was an improvement in a range from 6.2 – 9.9%. The lowest increase was measured in the absolute range of maximum oxygen consumption (6.3 %). A more significant increase in this indicator occurred at ANT where there was an increase of 7.0%. So the usability of oxygen consumption at ANT increased from the 90.17% of the absolute range to the 90.89% of the absolute range of maximum oxygen consumption. The most significant increase was observed in the relative indicators (converted to a kilogram of body weight) as the accompanying feature was that in the observed group there was an average decrease of the body weight in 2.1%. Maximum oxygen consumption, converted to a kilogram of body weight, increased in 8.0% and $VO_2$max at ANT in 9.9%. In these indicators its usability at ANT also increased, from 90.28% to 92.09%.

The observed athletes showed during the IHT the blood saturation of $O_2$ in the first days on the level of 90 – 85%, at the $O_2$ concentration in the inspired air from 12 – 14%. During the next days there was an increase of hypoxia up to the level corresponding to the altitude over 6000 m (thus the concentration of $O_2$ in the air decreased down to the 10% and $SpO_2$ was coming close to 75%). Hypoxia was relatively well tolerated without any significant negative reflections that are frequent accompanying phenomena of hypobaric hypoxia. The only negative subjective feeling was measured as a general feeling of malaise during the IHT training which is in a contrary to the claims of Hamlina – Hellemans (2004) who did not observe in the athletes any negative experience during the IHT. After the IHT these feelings had a wavy course. The changes of hematologic parameters and spiroergometric examinations made the results significantly more objective. From the point of hematologic parameters we consider the most significant indicator the number of reticulocytes where there was an average increase from 6.2‰ to 8.4‰ which in the absolute expression meant an increase of 26.2%. There was an increase from 3.3 to 4.9% also in the case of erythrocytes, haemoglobin, and hematocrit. This lower increase in percentage (in all the three alternatives of hypoxic training) can be justified by the fact that by the influence of an endurance load there occurs a hemodillution as a result of the increase of the blood plasma volume (hypervolemia) (Neumann et al., 2005) which causes the decrease of relative levels of blood components (so the actual increase of hematocrit, haemoglobin and erythrocytes was probably even higher).

**Table 2.** Comparison of the observed indicators before and after IHT

| Proband | | RTC | Ery | Hgb | Htc | $VO_2$max | $VO_2$max.kg | $VO_2$max kg at ANT | $VO_2$max.kg at ANT | kg | cm |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Before HT | 1 | 8 | 4,07 | 124 | 37,5 | 61,4 | 3499 | 54,7 | 3118 | 57 | 169 |
| | 2 | 6 | 5,64 | 161 | 48,1 | 66,6 | 4529 | 61,4 | 4175 | 68 | 178 |
| | 3 | 5 | 5,02 | 149 | 44 | 66,9 | 4837 | 54,7 | 3955 | 72,3 | 182 |
| | 4 | 6 | 4,67 | 134 | 42 | 56 | 3696 | 49,1 | 3241 | 66 | 169 |
| | 5 | 5 | 5,07 | 166 | 48 | 65,4 | 4105 | 60,1 | 3768 | 62,7 | 176 |
| | 6 | 6 | 4,89 | 156 | 42,4 | 51,1 | 3173 | 45,6 | 2832 | 62,1 | 164 |
| | 7 | 5 | 4,01 | 129 | 38,1 | 55,6 | 3280 | 51,2 | 3021 | 59 | 169 |
| | 8 | 8 | 3,87 | 117 | 34,7 | 61,4 | 3499 | 54,7 | 3221 | 59 | 170 |
| | 9 | 5 | 5,13 | 142 | 47,8 | 68,9 | 4389 | 64,5 | 4109 | 63,7 | 177 |
| | 10 | 8 | 4,77 | 159 | 43 | 72,6 | 4095 | 69,1 | 3895 | 56,4 | 171 |

| Proband | | RTC | Ery | Hgb | Htc | $VO_2$max | $VO_2$max.kg | $VO_2$max kg at ANT | $VO_2$max.kg at ANT | kg | cm |
|---|---|---|---|---|---|---|---|---|---|---|---|
| After HT | 1 | 9 | 4,23 | 130 | 40,2 | 73,5 | 3896 | 64,1 | 3397 | 53 | 169 |
| | 2 | 9 | 5,77 | 162 | 50,5 | 75,3 | 4970 | 63,4 | 4184 | 66 | 178 |
| | 3 | 7 | 5,42 | 156 | 48 | 72,3 | 5213 | 64,1 | 4622 | 72,1 | 182 |
| | 4 | 8 | 4,9 | 143 | 44 | 59,8 | 3947 | 55,9 | 3689 | 66 | 169 |
| | 5 | 7 | 5,08 | 165 | 49 | 69,9 | 4364 | 66,7 | 4162 | 62,4 | 176 |
| | 6 | 9 | 5,02 | 164 | 44 | 55,3 | 3434 | 49,9 | 3099 | 62,1 | 164 |
| | 7 | 8 | 4,15 | 138 | 39,2 | 58,2 | 3434 | 53,6 | 3162 | 59 | 169 |
| | 8 | 10 | 4,11 | 127 | 38 | 73,5 | 3896 | 64,1 | 3782 | 59 | 170 |
| | 9 | 8 | 5,14 | 148 | 47,9 | 70,5 | 4453 | 66,8 | 4217 | 63,1 | 177 |
| | 10 | 9 | 4,92 | 163 | 46,7 | 73,5 | 4127 | 70,46 | 3953 | 56,1 | 171 |
| $\bar{x}$ before IHT | | 6,2 | 4,7 | 143,7 | 42,6 | 62,6 | 3 910,2 | 56,5 | 3 533,5 | 62,6 | 172,5 |
| $\bar{x}$ after IHT | | 8,4 | 4,9 | 149,6 | 44,8 | 68,2 | 4 173,4 | 61,9 | 3 826,7 | 61,9 | 172,5 |
| % diff. before-after | | 26,2% | 3,3% | 3,9% | 4,9% | 8,2% | 6,3% | 8,7% | 7,7% | 1,2% | 0,0% |
| SD before IHT | | 1,25 | 0,54 | 16,20 | 4,45 | 6,40 | 535,50 | 6,86 | 470,82 | 4,82 | 27,05 |
| SD after IHT | | 0,92 | 0,53 | 13,76 | 4,17 | 7,05 | 559,20 | 6,21 | 470,94 | 5,19 | 27,05 |

Similarly, as in the blood parameters also in the $VO_2$max, $VO_2$max.kg$^{-1}$, $VO_2$max at ANT and $VO_2$max.kg$^{-1}$ at ANT there was an improvement, ranging from 6.3 – 8.7%. The lowest increase was measured in the absolute range of maximum oxygen consumption and so the potential of the organism for using the oxygen increase in 6.3%. A more significant increase of this indicator occurred in ANT where there was an increase of 7.7%. So the usability of oxygen consumption at ANT increased from the 90.36% of the absolute range to the 91.69% of the absolute range of maximum oxygen consumption. The most significant increase was observed in the relative indicators (converted to a kilogram of body weight) as the accompanying feature was that in the observed group there was an average decrease of the body weight in 1.2%. Maximum oxygen consumption, converted to a kilogram of body weight, increased in 8.2% and $VO_2$max at ANT in 8.7%.

The use of hypoxic tents is a method that finds its application among the athletes much harder as it significantly limits the existence of a partnership. Such a form of a training 4 observed athletes carried out. From the point of hematologic indicators we observed the highest increase (similarly as in HA and IHT) in reticulocytes, namely in 17.9%. The increase from 0.7 to 2.7% was measured also in the case of erythrocytes, haemoglobin, and hematocrit.

Table 3. Comparison of the observed indicators before and after HT

| Proband | | RTC | Ery | Hgb | Htc | $VO_2$max | $VO_2$max.kg | $VO_2$max kg at ANT | $VO_2$max.kg at ANT | kg | cm |
|---|---|---|---|---|---|---|---|---|---|---|---|
| before HS | 2 | 7 | 5,62 | 166 | 48,4 | 64,9 | 4426 | 60,3 | 4110 | 68,2 | 178 |
| | 3 | 5 | 5,47 | 147 | 45,6 | 66,4 | 4785 | 54 | 3896 | 72,1 | 182 |
| | 5 | 5 | 5,12 | 162 | 47,7 | 66,3 | 4183 | 58,7 | 3701 | 63,1 | 176 |
| | 9 | 6 | 5,09 | 149 | 46,9 | 67 | 4217 | 63,04 | 3988 | 62,9 | 177 |
| after HS | 2 | 8 | 5,87 | 168 | 49,1 | 66,4 | 4522 | 60,5 | 4121 | 68,1 | 178 |
| | 3 | 7 | 5,42 | 143 | 45,2 | 64,9 | 4678 | 53 | 3819 | 72,1 | 182 |
| | 5 | 7 | 5,17 | 169 | 48,1 | 66,9 | 4197 | 59,3 | 3716 | 62,7 | 176 |
| | 9 | 6 | 5,34 | 152 | 47,6 | 70,3 | 4399 | 65,2 | 4082 | 62,6 | 177 |
| $\bar{x}$ before HS | | 5,8 | 5,3 | 156,0 | 47,2 | 66,2 | 4 402,8 | 59,0 | 3 923,8 | 66,6 | 178,3 |
| $\bar{x}$ after HS | | 7,0 | 5,5 | 158,0 | 47,5 | 67,1 | 4 449,0 | 59,5 | 3 934,5 | 66,4 | 178,3 |
| % diff. before-after | | 17,9% | 2,3% | 1,3% | 0,7% | 1,5% | 1,0% | 0,8% | 0,3% | -0,3% | 0,0% |
| SD before HS | | 0,83 | 0,23 | 8,15 | 1,04 | 0,77 | 239,5 | 3,28 | 149,34 | 3,83 | 2,28 |
| SD after HS | | 0,71 | 0,26 | 10,98 | 1,43 | 1,98 | 175,9 | 4,35 | 171,48 | 3,98 | 2,28 |

Even lower increase than in hematologic parameters was measured at $VO_2max$, $VO_2max.kg^{-1}$, $VO_2max$ at ANT and $VO_2max.kg^{-1}$ at ANP, namely in a diffusion 0.3 – 1.5%. The lowest increase was observed in the absolute rate of the maximum oxygen consumption at ANT, namely in 0.3%. A more significant increase was measured in the $VO_2max.kg^{-1}$ where there was an increase of 1%.

A paradox is a decrease of the usability of maximum oxygen consumption where there was a decrease from 89.12% to 88.4% (similarly also when converted to a kilogram per weight from 89.12% to 88.6%).
For the objectification of the results we realized an independent comparison of all the three hypoxic methods in the 4 athletes who went through all the methods of hypoxic training (table 4).

**Table 4**. Comparison of changes in the measured indicators of four probands who went through all the four methods of hypoxic training

| Method | RTC | Ery | Hgb | Htc | $VO_2max$ | $VO_2max.kg$ | $VO_2max$ kg at ANT | $VO_2max.kg$ at ANT | kg | cm |
|---|---|---|---|---|---|---|---|---|---|---|
| %diff. before-after HA | 22,6% | 2,4% | 3,9% | 3,8% | 8,3% | 6,9% | 11,1% | 7,3% | -1,7% | 0,0% |
| % diff. before-after IHT | 32,3% | 2,6% | 2,1% | 3,8% | 7,0% | 6,0% | 7,8% | 6,9% | -1,2% | 0,0% |
| % diff. before-after HT | 17,9% | 2,3% | 1,3% | 0,7% | 1,5% | 1,0% | 0,8% | 0,3% | -0,3% | 0,0% |

In processing of the results we found out that the influence of HA and IHT from the point of hematologic parameters and spiroergometry was comparable, what we can also see in the figure 1. On the contrary, the changes in the HT were from the point percentage significantly higher.

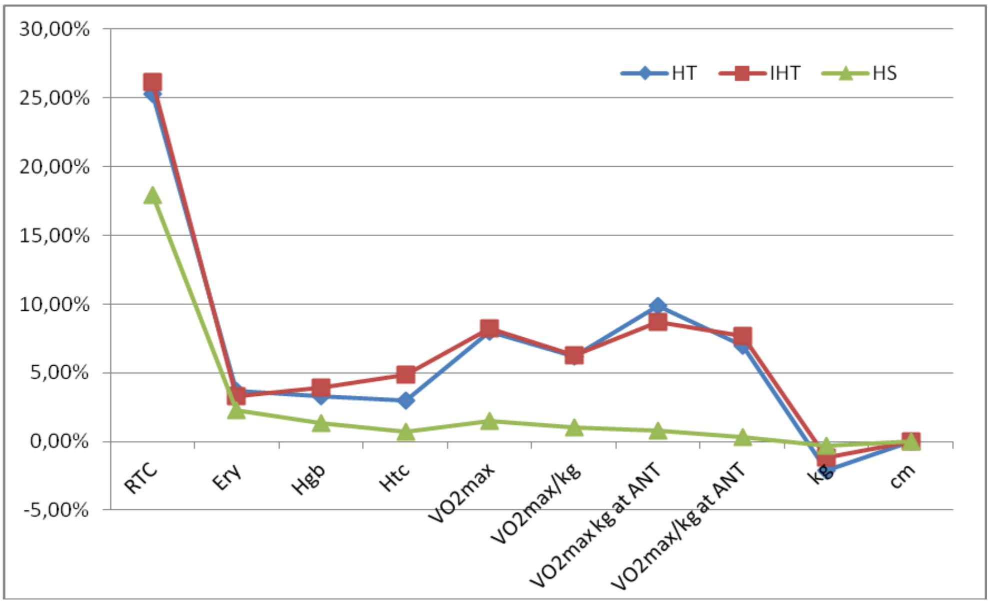


**Figure 1** Comparison of various alternatives of hypoxic training from the point of the influence on the organism

In a natural hypobaric hypoxia other authors found similar results as we did, e.g. Levin – Stray – Gundersen (1997), Pupiš - Korčok (2007). The outcomes of our research correspond to the statements of Meeuwes et al. (2001) who carried out a similar research on the group of elite triathlonists, however in a natural hypobaric hypoxia, where they measured an increase of 7% in $VO_2max.kg^{-1}$, 7,4% increase of the maximum performance and a 5% increase of a sub-maximum performance (on a kilogram of weight). Other authors, such as Komadel (1994), Gurský (1994), Levin - Stray - Gundersen (1997), Pupiš - Korčok (2007) etc. describe in a connection with hypoxia an increase of blood components by the influence of hypoxia what was confirmed in our case as well as in Rodriguez et al. (2000), Katayamo et al. (2003)

and Hamlin – Hellemans (2004) who describe this increase also in IHT, thus in a normobaric hypoxia.

## PRACTICAL ASPECTS

The outcomes of our research confirm a positive influence of a hypoxic training on the athletes´ organism from the point of hematologic and spiroergometric parameters. The results confirm the fact that the intermittent hypoxic training and training in higher altitudes have a very similar influence on the organism as we observed a comparable increase in all indicators. From the point of hematologic indicators in HA and IHT there was an increase of the number of erythrocytes, haemoglobin, and hematocrit from 3% to 4.9%, a more significant increase (25.3%, event. 26.2%) was measured in reticulocytes. In HT we observed an increase of reticulocytes in 17.9%, but in the remaining indicators we measured even smaller increase, namely from 0.7 – 2.3%. From the point of spiroergometric parameters the most significant increase was observed in the indicator $VO_2max.kg^{-1}$ at ANT where we measured an increase of 8.7%, event. 9.9%. Obviously, this parameter is directly influenced by the decrease of body weight, but in the absolute rate of $VO_2max$ at ANT we observed an increase (7%, event. 7.7%), which points to the increase of oxygen usability at ANT, thus the intensity corresponding to the competition load. At HT we also observed an increase in these parameters as well as a slight decrease of body weight, however only 0.3 – 1.5%. From the point of effectiveness a positive influence of hypoxic training in all three methods (HA, IHT a HT) was confirmed, but according to our findings the influence of HA and IHT was higher than of HT.

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