Journal of Physical Education and Sport ® (JPES), 16(1), Art 25, pp. 156 - 161, 2016
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Self-adapting effect of physiological parameters on a hypoxic environment by a triathlon Slovak representative

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Published online: March 25, 2016
(Accepted for publication February 26, 2016)
DOI:10.7752/jpes.2016.01025

Abstract:

Nowadays is hypoxic preparation in different kinds of sports essential. It has a big importance mainly in endurance disciplines, where the blood creation is one of the basic success indicators.

We were observing in our contribution two forms of hypoxic preparation by professional triathlon athlete. One of the hypoxic forms was artificial hypoxy, with the help of hypoxic gadget in a laboratory of Department of Physical Education and Sports Metej Bell University in Slovakia. The second, natural hypoxy, was the movement in highlands, Livigno (ITA). Both hypoxic preparations lasted for 18 days.

We were observing not only the reaction on the achievement, physiologic changes (VO_2max) but also changes within the blood tests (athlete is a bit anemic).

In both cases was the physiologic and also the biochemical effect of hypoxic exercise positive, the anaerobic energetical metabolism was better, the heart-vascular system noticed higher work capacity, and also the level of erythropoetin got higher wherewith it relates the increasing level of red blood cells and consequently better oxidation of the system, finally the upgrade of sport achievement.

By the artificial hypoxy were striking changes noticed after threee weeks after finishing hypoxy. On the other hand by the natural hypoxy was the increase observed considerably earlier, it was after the 4th day from the return from highlands.

Keywords: hypoxic training, triatlon, haemoglobin, VO_2max

Introduction

Top athletes as a part of their long-term preparation include in the training process visits in uplands and highlands, which have already become an integral part of their annual training cycle.

Best elaborated system of upland and highland preparation training between athletes have ski runners, cyclists, runners, walkers, swimmers and triathletes. After completing the training in altitudes from 1600 m above sea level to 2400 m above sea level by most observed athletes has their performance improved in the comparison with the preparation training in uplands.

In 1951, scientists L. Wasserman and T. Hennessy for the first time showed public the scientific research results where was noted how the altitude affects the hematopoiesis.

In 1970 J. Daniels and N. Oldridge describe the positive effect of higher altitude in the preparation of athletes - midfielder, effects of altitude to increase the production of red blood cells.

Wilber (2001) as well as Dívald (2010) shows threee basic models of hypoxic training:

- "live high + train high" (LHTH), proponents of this thesis claim that our body needs both impulses for quality adaptation chamges and not everything is measurable through higher number of red blood cells.
- "live high + train low" (LHTL) = „sleep high, train low“ (SHTL). The aim of this option is to make real the positive changes in our body, that means to live in hypoxy and do the exercise in lower altitude. According to this theory the sessions in higher altitudes is pointlesly hard and the speed is disappearing.
- "live low + train high" (LLTH). Proponents of this option claim that after a training session in hypoxic environment is good to have regeneration.

The fourth option is the option of interupted hypoxic training with the help of hypoxic gadget. Hypoxic gadget, according to our needs, in regular periods pauperizes oxygen - it enables us to simulate altitude.

Interupted hypoxic training method has more advantages compared to mentioned methods of hypoxy. The gradual control of altitude has as a results better adaptation of the athlete as well as oxygen saturation. This can avoid unpleasant reactions, such as headache, insomnia, dizziness and many others. The advantage is the possibility of adapting the impoverishment of oxygen and the length of hypoxy to complexity, volume and intensity of training.

Bonetti & Hopkins (2009) show further models and options for hypoxic training but they had been proved to be impractical.

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Millet et al. (2001) and Robertson et al. (2010) also describe combinations and joining of hypoxic training. This includes "live high a train alternately "high and low" or "live low and train high and low".

Various methods of hypoxic training and training in the hypoxic environment - tent, intermitted method, mountains - have a positive effect on the human beeing. To most significant changes in the body comes while using the interruption method and in the mountains (Pupiš, 2014).

Hamlin (2014) was observing by intermittent hypoxic training well-trained athletes. He created two groups. One underwent intermittent hypoxic training and the second one placebo effect. Research has shown that by intermitted hypoxic method will the training capacity increase in the anaerobic training zone.

According to Suchý et al. (2009), Martin (2003) and Mauro (2003) the capacity reaches its top after hypoxic training from the third to the fourth week of reacclimation.

Friedmann (2005) claims that according to German coaches is sufficient 10 days to reach the best performance.

Positive results in hypoxic preparation last for 5-6 weeks (Suchý & Dovalil, 2005). Hellemans (1993) and Mauro (2003) state that it is only 1-3 weeks.

Brugniaux et al. (2006) found out fading of positive effect of hypoxic preparation after 13-15 days. However Brugniaux et al. (2006), Rusko et al. (1999), Matilla & Rusko (1996) and Levin (2002) document the positive impact of hypoxic training for cyclists and runners, even after three weeks of reacclimation.

Brocherie et al. (2012) found out that the method "live high-train low" has a positive effect on repetitive sprinting power for three weeks period. Players have completed 14 days.

The most striking seems to us the one which is in match with the opinion of Levin Stray-Gundersen (2005), otherwise that any expected positive effects of hypoxic training (increasing erythropoiesis and the maximum oxygen consumption and the improvement of performance endurance) obviously depends mostly on the total dose of hypoxy, that means on the combination of the hypoxy extent (natural altitudes or its simulation) and the exposure of the body to hypoxia (not only the number of days, weeks or months, but the important factor is also the number of hours per day).

All the positive effects of hypoxic training are significantly related to the total dose of hypoxy and also on the possible combination of hypoxy and the exposure of the body to hypoxy (Levin & Stray-Gundersenem, 2005). The researches of Geha et al. (2002) claim the presumptions that there also do exist some individuals who are no table to acclimatize. I exposed a group of athletes to similar conditions of hypoxic environment (2800 m above sea level). Short lasting concentration of erythropoetin in blood was ranging after 24 hours from - 41 to + 400 %. By M.T. was the sport preparation in hypoxic conditions proved from the point of long lasting adaptation in difference in lactate respond on different types of density.

The opinion about the decrease was claimed, let us say the normalization of the lactate level in blood. Long lasting adaptation on similar types of density to 25 km distance led to decrease, let us say the normalization of the lactate level in blood (Broďáni, 2006).

Material and methods

The experimental unit is a representative of a sports club Trian of Metej Bell University in Banská Bystrica. *S.L. woman,* born 12th May 1987, she did triathlon for 8 years (during the research), 4 years before she did athletics, *height*: 169 cm, *wight*: 57 kg, *Physiologic characteristics*: VO_2max 62 ml.min^{-1}.kg^{-1}, Heart rate (HR) max. 195 hr.min^{-1}, HR min (in the morning) 61 hr.min^{-1}, Anaerobic threshold 180 hr.min^{-1}. *Sport achievements:* 3rd place Eropean Championship in cross triathlon, 4th place European Cup in winter triathlon, 13th place Eropean Championship in duathlon 2012, 1st place Slovak Championship in half – ironman 2013, 2nd place Slovak Championship in sprint triathlon 2013, 3rd place Slovak Championship in olympic triathlon 2013.

The observed period of interrupted hypoxic training: the preparation period in annual training cycle 2011. The training sessions took place in Banská Bystrica in an altitude 362 m above sea level. We started the research 14th February 2011 with the blood taking and finised it also with the final blood taking together with spiroergonomic test provided 28th March 2011.

The interruption method of hypoxic training was done via hypoxic gadget: *Altitude tech summit 3 in 1*, lasting 100 minutes in one day of programme, periods of 6 minutes breathing decreased of oxygen from the gadget, with changing of natural breathing of 3 minutes in the room.

The observed period of natural hypoxic training: time before the race in annual training cycle 2012. Training density was in progress from 24th June 2012 – 12th July 2012 in Italy in mountaineous sport centre in Livigno in an altitude 1820 m above sea level. The research started 12th June 2012 with the blood taking from the experimental unit and finished also with blood taking together with spiroergonomic test 30th July 2012.

Blood taking was made in a laboratory of clinical biochemistry, imunology and alergology in a medical centre Alpha medical in Banská Bystrica with the purpose of following blood parametres observation.

The values measurement of heart rate

The research measurements for finding out the values of HR were done by sporttester Garmin 910. The values of the morning HR were measured straight after waking up in back lying position in a period of 4 to 6 minutes.

The evaluation of personal emotions

Experimental unit rated the days by a range of marks:

- Point 1 - great
- Point 2 - very good
- Point 3 - neutral
- Point 4 - worse
- Point 5 - bad

We underwent before the hypoxic testing 14th February 2011 with the experiment unit the first blood taking, after it 16th February 2011 initial medical examination, focused on health condition of experimental unit and her ability to undergo the hypoxic programme, associated with spiroergonomic test at u MUDr. M.S. in the Centre of sport-medical diagnosis in Banská Bystrica.

An day of spiroergonomic examination (16th February 2011) the hypoxic training started in a laboratory on Faculty of Arts in Banská Bystrica, above mentioned process 6+3 minutes in 100 minutes test.

Artificial hypoxic training lasted 24 days (16th February 2011 – 11th March 2011).

On the final day of hypoxic training were done another blood tests and after it there was a period of aclimatisation to normal environment. The third blood taking was done at the 12th day of aclimatisation of our experimental unit. Spiroergometric examination was at 28th March 2011 (17 days after finishing artificial hypoxy).

Natural hypoxic training held in uplands lasted for 20 days (24th June 2012 – 12th July 2012). The first blood taking was done 34 days and the second 2 days before leaving on the testing programme, which was connected with spiroergometric examination. Next blood taking were done 4 days and 18 days after finishing the testing programme in uplands. The last mentioned blood taking was connected with spiroergometric examination.

Results and discusion

In both cases occured better results in VO_2max and blood tests.

Table 1. Values of blood components and VO_2max by the observed person S.L. in preparation of artificial hypoxic period from 14th February 2011 to 28th March 2011

Blood tests date	*14th February 2011*	*14th March 2011*	*23rd March 2011*
Erythrocyte x10.l^{-1}	**3,87**	**3,78**	**4,11**
Haemoglobin g.l^{-1}	**117**	**113**	**127**
Haematocrit l.l^{-1}	**0,347**	**0,348**	**0,38**
Examination spiro date	*16th February 2011*		*28th March 2011*
VO2 max ml.min^{-1}.kg^{-1}	**61,4**		**73,5**

Beginning of hypoxic programme 16th February finished 11th March = together 24 days

During hypoxic training was the blood saturation ranging from:

1st-6th day on the limit 85-90 %,

7th-12th day on the limit 80-58 %,

13th-20th day on the limit 77-85 %,

21st-24th day on the limit 73-85 %.

After finishing the first part of hypoxy followed by blood taking was noticed decrease of erythrocytes number 2,4 % from start 3,87.10^{12}.l^{-1} on 3,78.10^{12}.l^{-1} (table 1). It is explained by the response of the body and its reaction to defend against dehydratation. It handles about transitive decrease of erythrocytes number, which proves our third final blood taking. After 9 days was observed increase of erythrocytes number to 6,2 % erythrocytes from the initial value 3,87.10^{12}.l^{-1} to 4,11.10^{12}.l^{-1}.

The haemoglobine increase - red blood pigment which helps the body to better oxidation, had in observed period from 14th February to 23rd March 2011 by S.L. similar process as by erythrocytes (table 1). After the second blood taking was observed the decrease of haemoglobine concentration at 3,5 %, and by the final blood test 23rd March 2011 was the number of haemoglobine higher about 8,5 % (from 117 g.l^{-1} to final 127 g.l^{-1}). The decrease of haemoglobine level observed in the second measurement is caused by the increase of the overall capacity blood. The values of haematocrit expell the consequences of decreasement value of haemoglobine. Minor changes were observed also in the values of haematocrit (as an indicator of erythrocytes number to the plasma capacity) after the second blood taking it increased of 0,3 % (from the value 0,347 to 0,348). After the final blood test haematocrit increased to 0,380, which is a measurement from baseline increase of 9,5 % (table 1). Based on this observation, we can conclude that a few days after the haematocrit induced stress is not changing because i tis just starting hemodilution and red blood cell production. After further hypoxic stimulation has temporarily increased the haematocrit value, which correlates well with the results of the leading trials about induction of hemolysis caused by a large increase in plasma volume (Robach, 2012).

VO_2max measured values had at the volunteer S.L. during a hypoxic programe (from 16th February to 30th March 2011) increased to 19,7 % (from 61,4 $ml.min^{-1}.kg^{-1}$ to 73,5 $ml.min^{-1}.kg^{-1}$). VO_2max increase is attached to hypoxic training system as well as aerobic training during the observing period (table 1). The increase demonstrates ostrong volunteer hypoxic effect, but here the important role played the weight of the volunteer, which was at the time of hypoxic training reduced by up to 4 kg. To determine the real increase in VO_2max without weight calculation, we have experienced the real increase VO_2max 11,4 % (from 61,4 $ml.min^{-1}.kg^{-1}$ to 68,3 $ml.min^{-1}.kg^{-1}$).

For the comparison, the avarage value of the VO_2max at climbers is 56,1±9,4 $ml.min^{-1}.kg^{-1}$ and at MTB riders is 51,8±8,1 $ml.min^{-1}.kg^{-1}$ (Prantsidis at al., 2013).

Table 2. Blood components values and VO_2 max by volunteer S.L. in observed period from 3rd May 2012 to 30th July 2012 in natural hypoxic enviro Livigno 1820 m above sea level

Blood tests date	*3rd May 2012*	18th May 2012	*22nd June 2012*	16th July 2012	30th July 2012
Erythrocyte $x10.l^{-1}$	**4,1**	**3,93**	**4,22**	**4,28**	**3,33**
Haemoglobin $g.l^{-1}$	**125**	**126**	**128**	**132**	**110**
Haematocrit $l.l^{-1}$	**0,37**	**0,36**	**0,37**	**0,38**	**0,33**
Examination spiro date			*22nd June 2012*	16th July 2012	
VO2 max $ml.min^{-1}.kg^{-1}$			**64,5**	**69,1**	

The beginning of hypoxic programme in the upland environment 24th June 2012 ending 12th July 2012 = total of 19 days. To better data response collection of blood components, we also took the blood before observing the hypoxic period. Two days before leaving for hypoxic programme (22nd June 2012) to the natural hypoxic environment, we recorded erythrocytes at 4.22 $10^{12}.l^{-1}$. Four days after our return from the natural hypoxic environment, we found out by the blood test and recorded erythrocytes 4,28 $10^{12}.l^{-1}$ which represents a slight increase of 1,4 % (table 2).

This is a temporary reduction in the number of erythrocytes, as shows our third final blood test. After 18 days we noticed a significant decrease in red blood cells (3,33). 21 % decrease compared to the first measurement of erythrocyte is explained by more difficult endurance training 3 days before the blood test. This corresponds to research Robach et al (2012), which describes the impact of harder training session that induces strong responses and causes hemolysis. Harder training with hemolytic power reduces the total volume of red blood cells. Also the measured values copy the values measured with the runners 48 hours after completion of the half marathon race (Duka, 2006). In the observed period (22nd June 2012 – 30th July 2012) by S.L. had the increase of haemoglobin similar tendency as by erythrocytes a retikulocytes as we observed also by artificial hypoxy in 2011. After the second blood test we have recorded an increase in total haemoglobin concentration of 3 % in the subsequent final blood collection 30th July 2012, the amount of hemoglobin has been reduced by 14 % compared to the initial measurement (from 128 $g.l^{-1}$ to a final 110 $g.l^{-1}$). Reduction of haemoglobin level observed in the third measurement corresponds to a comparable decrease of blood components (red blood cells and reticulocytes) which are related (table 2). VO_2max measured values have by the volunteer S.L. increased by 7,1 % (from 64,5 $ml.min^{-1}.kg^{-1}$ to 69,1 $ml.min^{-1}.kg^{-1}$). The VO_2max increase is refered to an artificial hypoxy, hypoxic training system as well as aerobic training during the observed period.

Relative increase supply of tissues with oxygen, is reflect in the results of table 2 greater ability capacity of blood to transport oxygen.

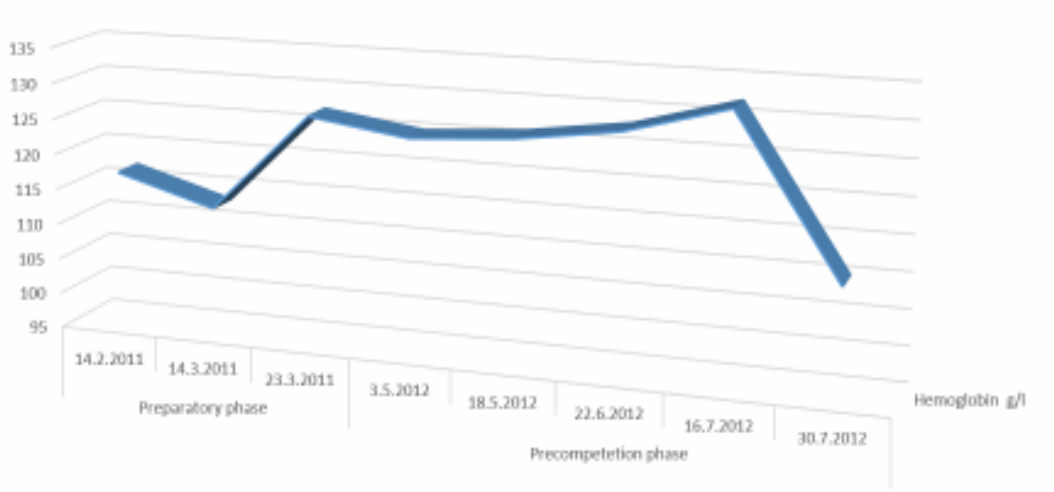

Fig. 1. Process of haemoglobin during both observed periods

Monitored blood haemoglobin index (fig. 1) has significantly increased in comparison of the initial values before pre hypobaric - natural hypoxy in comparison with normobaric - artificial hypoxy.

The same results of significant haemoglin and hematocrit decrease were observed in the study of Duka (2006), what encourages us to conclusion that during hypoxic programme (artificial and natural hypoxy) comes immediately after few daysto a temporary traumatic damage of erythrocytes. The released iron ions can exchange lipid peroxidation and oxidative stress as well.

Results of blood components after artificial hypoxy on the third day of acclimatization in everyday environment were significantly reduced under the initial level. The reason for the reduction is the reaction of the body, in order to prevent dehydration. In inference of this comes to the increase in blood volume. Another reason for the reduction of blood components on the third day of acclimatization to the everyday environment is "endurance stress", which is caused by hypoxic training. This can be characterized as a temporary reduction in the number of red cells and other monitored blood components. This thesis is supported by the final blood components values, which afterwards acclimatized to a normal environment got over their initial levels. It is caused by increased level of erythropoietin, a hormone, which reacts by the red cell production. Consequently, as a defense of our body, increases the amount of red blood cells and reticulocytes. In the artificial intermittent hypoxy has been recorded a strong increase of blood components as well as VO_2max. By the last i.e. the final venous blood test, together with spiroergonomic examination on the ninetienth day after hypoxic acclimatization programme. On the other hand *in the natural hypoxy* on the fourth day of acclimatization to the familiar environment all blood components grew to the initial values, which was caused by positive erythropoiesis. As the stay in natural hypoxy is constant for three weeks, blood flow regulation is stabilized and there are no fluctuation rises and falls of the blood volume in the blood stream. Significant changes can be seen in the pulmonary, brain circulation and blood flow in the kidneys. This has for result the unstable blood volume fluctuation in the interrupted artificial hypoxy. It is possible that after long lasting hypoxy application might also the regulatory mechanisms in mentioned organs stabilize. We assume that after the natural hypoxy comes the effect faster than in the artificial one. On the eighteenth day of acclimatization to a familiar environment in natural hypoxy after venous blood test, blood components except reticulocytes (erythrocytes, haemoglobin, haematocrit) fell below the initial level. Reticulocytes in our research grew by 300 %. This large increase in reticulocytes is justified by the culmination of a process called erythropoiesis, phase II hematopoiesis. This fact is peculiar to hypoxic stress and reflects with the increased red blood cells together with the culmination on the 7-8 day (Jelkmann, 2009). As contrast to the red cells, which as a result of physiological changes in a woman's body were washed up. It was also reflected the impact of harder training sessions of the volunteer before the blood donation, which caused acute response and the short-term reversible hemolysis, which corresponds with the research Juel et al. (2003). Another explanation for the large increase of reticulocytes is, that the volunteer had been just after the menstrual periods when higher estrogen level contributed to the absorbing of erythropoiesis by direct inhibition of erythropoietin. However, this fact does not affect the start of the hematopoietic creation of reticulocytes.

Conclusions

We have proved with our research that the utilization of higher altitude is one of the essential options how to increase performance in triathlon. Athlete´s stay in uplands already belongs to the traditional concept as a part of the annual training cycle.

Our discovery proves, that the use of both alternatives of hypoxic training in artificial hypoxy at least 60 minutes per day for about three weeks, has a positive response to improvement of the blood quality and functional indicators (significant improvement in VO_2 max). According to this the body is able to use oxygen more effitiently which has as the result in an improved sports performance. Our discovery demonstrates the positive influence of natural hypoxy (minimum stay 19 days) to improvement of blood components, as well as improving VO_2max. By regulating the oxygen blood saturation blood in this method, each athlete has faster adaptation to hypoxic environment and thus may be fully involved in the training process.

We confirmed in both cases the physiological and biochemical effects of hypoxic training, improvement of aerobic energetic metabolism, increased labour of the cardiovascular system and also the growth in the already mentioned erythropoietin, which is related to increasing levels of red blood cells and consequently better oxygenation of the body and thus improvement of athletic performance. Beside planning the annual training cycle for the top event for triathlete, has the hypoxic training in connection with its good food and systematic management training a big importance.

Based on the results we suggest to our volunteer to include into the annual training cycle both alternatives of hypoxic training. From the time or financial point of view it is a volunteer or her coach decision which alternative will be included in a long-term vision training. Method of artificial hypoxic training is time-consuming and less expensive, without necessity to travel to the upland environment. Due to the results which we found out in the measurement of VO_2max, we recommend to include to the concept of an annual training cycle such resources, which will help the volunteer experiment increase VO_2max.

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