

THE IMPACT OF HYPEROXYGENATION ON PERFORMANCE AND RECOVERY DURING REPEATED 200m RUNNING LOAD OF SUBMAXIMAL INTENSITY

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Abstract

The possibility of using inhalation of concentrated oxygen in repeated 200m run of submaximal intensity has been a part of our research within VEGA 1/1175/12 project. The aim of the presented paper was to verify the impact of short term hyperoxygenation on repeated short term load of submaximal intensity with short-distance runners. We conduct the research by testing athletes during endurance training aiming at developing anaerobic lactate capacity. The athletes were observed during two mode trainings (6x200m runs) and they inhaled concentrated oxygen in experimental and placebo measurements/exposures. We evaluated the efficiency according to performance and speed of recovery. Based on the data gathered we found that inhalation of concentrated oxygen had a positive effect on repeated short term submaximal performance in the model described. It also had a positive effect on the process of recovery.

Key words: short-distance running, speed endurance, hyperoxygenation, anaerobic performance, lactate

Introduction

The problem of inhalation of concentrated oxygen has been researched by many authors (Bannister and Cunningham, 1954; Welch, 1982, 1987; Snell et al., 1986; Plet et al., 1992; Knight, 1996; Takafumi and Yasukouchi, 1997; Morris et al., 2000; Harms, 2000; Peltonen, 2001; Wilber, 2003, 2004; Kay et al., 2008; Suchý et al., 2008, 2010 a, b; Pupiš et al., 2009, 2010 a, b). Most authors confirmed positive effects of hyperoxygenation on athlete's organism. However, some researches did not prove positive effect of oxygen inhalation on performance. Murphy (1986) did not record positive effect of oxygen inhalation especially in medium term and long term loads. Robbins et al. (1992) and Yamyji and Shepard (1985) came to a similar conclusion in case of short term submaximal or maximal loads. Máček and Radvanský et al. (2011) questioned previous researchers and found that inhalation of oxygen mixtures can increase the amount of oxygen in blood by 1 ml in 100 ml of blood. However, if one takes into consideration that 100 ml of blood contains approximately 20 ml of oxygen, the increase makes 5 %. At the same time, the authors admit that it takes up to 12 hours after the load relief to redress the balance between O₂ and CO₂ and it takes several hours for the organism to get rid of the redundant lactate. In general we can say that lack of oxygen has a negative effect on performance and it prolongs the process of recovery. A question rises, whether this is also truth vice versa. It could work due to increased saturation of blood and tissues by oxygen and decreased anaerobic activity of working muscles which accelerates recovery and the return to original values (Haseler et al., 1999, Nummela et al., 2002). One-time or repeated short term applications of concentrated oxygen or hyperoxic

mixtures can temporarily increase the saturation of tissues by oxygen. This effect can be used for acceleration of the regeneration in interrupted loads (Nummela et al., 2002, Suchý et al., 2008, 2010 a, b). Positive effect of hyperoxygenation decreases with prolonged load because the organism is not able to create supplies of oxygen due to limited capacity of tissues to tie up nonphysiologically increased amount of oxygen (Robbins et al., 1992). Yamaji and Shepard (1985) speak of persisting effect of inhalation of concentrated oxygen for several tens of seconds up to several minutes. Kato et al. (2004) confirmed that the load in the conditions of hypoxigenation disturbs the pH level and thus creates an assumption that hyperoxygenation could lead to more effective utilization of lactate. Heigenhauser et al. (2006) confirmed significant relation between accumulation of lactate and concentration of oxygen in the inhaled air. Nummela et al. (2002) confirmed significant dependency of saturation of blood by oxygen during the load and the concentration of inhaled oxygen in the inhaled air. The possibility of the usage of inhalation of hyperoxygenated mixture in repeated 200 m running load of submaximal intensity has been a part of our research within our grant project VEGA 1/1175/12. In 200 m running two anaerobic metabolisms coexist – non-lactate and lactate metabolism. According to Semiginovský and Vránová (2001) anaerobic non-lactate metabolism is related to a load lasting 10-15 seconds (with the potential energy of 21-33 kJ) and the lactate metabolism to a load lasting 45-90 seconds (with the potential energy of 125-420 kJ). According to Havlíčková et al. (2008), pre-start heart frequency of a 200 m runner reaches 130 bpm (SD 21) and 190 bpm (SD 9) after running.

Several authors speak of the increase of lactate concentration after 200 m running, however, the range of lactate level varies. Laczo and Nedelický (2004) state that in 200 m running the lactate concentration reaches 15-18 mmol.l⁻¹. According to Hautier et al. (1994) the level of lactate reaches 10,3 (SD 0,8) mmol.l⁻¹ 3 minutes after finishing 200 m run. During intensive muscle load lactic acid (C₃H₆O₃) is produced. It immediately dissociates to lactate (C₃H₅O₃), i.e. lactate anion (La⁻) and hydrogen cation (H⁺) which is the primary cause of the disturbance of acidosis during the load. Human body can resynthesize the lactate into glycogen. Havlíčková et al. (2008) confirms that sufficient supply of oxygen must be provided after anaerobic activity to resynthesize energy sources and to liquidate acidosis. In sport training it is very important to synchronize quality and quantity. In the process of achieving the quality, the effect of quantity can be seen in energy exhaustion connected with muscle weakness. The causes of muscle weakness are probably complex. During a short term intensive load the level of phosphocreatine is a very important factor. After exceeding one's physical limits, the level of phosphocreatine decreased dramatically. At the same time, the concentration of inorganic phosphate increases (Jones, 2008). Inorganic phosphate significantly influences muscle contraction by entering the sarcoplasmic reticulum and by ejecting the calcium cation (Allen et al., 2008). In case of aerobic environment creatine is rephosphorized into high-energy phosphocreatine (Haseler et al., 1999). At the same time, inorganic phosphate is being decreased. In this way hyperoxygenation can contribute to acceleration of regeneration. Different means of speed endurance development are being used in the preparation phase of short-distance running training. They are all used for the development of anaerobic lactate capacity. During the submaximal intensity load the running distance is 60 -300 m, the rest interval is 2-6 minutes and it depends on the workload volume. The load lasts 7-40 seconds and the intensity presents 90-95% of the maximum intensity. Total volume in 6-8 running distances can be up to 2 kilometers. The stronger intensity and longer distances, the longer rest intervals are needed. As the racing period gets closer, the intensity must be increased, the rest interval must be prolonged, the volume must be decreased and the training gradually changes into anaerobic lactate performance training. In sprint training the speed endurance is the most flexible feature thus it provides the biggest space for performance increase – especially after using all natural speed reserves. Both submaximal aerobic exercise and interval training can improve the body's ability to buffer and tolerate lactate. However, only intense interval training can increase various important components of anaerobic power and capacity. Submaximal aerobic exercise does not and may even decrease anaerobic enzyme activity not good for speed development!) (Astrand, Rodahl, 1986; Abernethy et al., 1990; Plisk, 1991; Viru, 1993; Viru, 1995; Brooks, 1996). The aim of this paper is

to verify the impact of short term hyperoxygenation on repeated short term submaximal intensity load with short-distance runners on the basis of endurance speed training, which develops anaerobic lactate capacity. We assumed that short term oxygen inhalation will have a positive effect on repeated anaerobic performance and it will result in increased performance and faster recovery after load. The research was executed in compliance with Medical Association Declaration of Helsinki – Ethical Principles for Medical Research Involving Human Subjects that was amended in October 2008 in Seoul (www.wma.net). In order to verify our hypothesis we decided to conduct a double experiment – inhalation of concentrated oxygen from an oxygen concentrator EverFlow between repeated 200m runs. The probands inhaled either concentrated oxygen or placebo (controlling measurement) from the same device using a special inhalation mask following the instructions provided on the cover. The oxygen concentrator contained 90-95% oxygen and a placebo of 20-21% of oxygen. The probands did not know whether they had inhaled oxygen concentrator or a placebo. Before they took the tests they had been given instructions about inhaling.

Methods

Research process

The research was conducted in a training hall of Sport Grammar School in Banská Bystrica; the training hall is equipped with tartar track surface on 170 m round, December 7 and December 14, 2010. Device Lactate Plus (Nova Biomedical) was used for measuring the lactate level.

Procedure

- 1) 4-1 minutes before the first run the probands inhaled oxygen/placebo for 3 minutes.
- 2) 6 x 200 m run with rest interval 7 minutes, 6 minutes, 5 minutes, 4 minutes, 3 minutes; during the rest intervals the probands inhaled oxygen/placebo for a minute.
- 3) 3 minutes after the final run the level of lactate was measured from blood sample obtained by fingerstick.
- 4) 5 minute long inhalation of oxygen/placebo.
- 5) 15 minutes after the last run the level of lactate was measured from fingerstick sample.

Information about probands

- Š.M. (male), 19 years old, junior, height: 181 cm, weight: 77 kg, specialization: 200m running, length of training: 6 years
- R.O.(male), 16 years old, juvenile athlete, height: 183 cm, weight: 70,5 kg, specialization: 110m and 400m hurdle-run, length of training: 3 years
- M.I. (female), 19 years old, junior, height: 176 cm, weight: 56 kg, specialization: 400m running, length of training: 4 years
- T.M. (female), 16 years old, juvenile athlete, height: 157 cm, weight: 46 kg, specialization: 100m running, length of training: 2 years.

During our research all athletes were healthy; as for their all-year training cycle, they were in their preparation stage at the beginning of their special sport preparation. We used the following characteristic features in order to evaluate the effect in pair comparisons: average change, relative change, and Cohen's kappa coefficient. Blahuš (2000) measures the average change in the units of the constant observed and defines the average change as the difference between the average constant before and after the activity of the factor observed, i.e. $d = x_1 - x_2$, where x_1, x_2 = average of the constant observed before or after the activity of the factor observed. Relative change is defined as the percentage of the average change within the overall average of the constant observed, i.e. $d_r = d/x$ where x = overall average of the constant before and after the activity of the factor observed. Figures of relative change are expressed in percents. Cohen's kappa coefficient d_x or d_d is for the purposes of pair comparison defined in two versions (Hendl, 2004). In our paper we used the following version of Cohen's coefficient: $d_x = d/s_x$, where s_x = deviation of values of the constant before and after the activity of the factor observed. Hendl (2004) proposes the following interpretation of the data gathered: $d > 0,8$ expresses major effect; value d in interval 0,5 to 0,8 expresses medium effect; value d in interval 0,2 to 0,5 expresses minor effect; $d < 0,2$ expresses almost no effect.

Results and discussion

Table 1. Time and lactate levels of the athletes

Name	Average (s)	Max. (s)	Min. (s)	LA 3' (mmol.l ⁻¹)	LA 15' (mmol.l ⁻¹)
Š.M. placebo	25,5	26,2	25	12,2	12,8
R.O. placebo	26,8	28,3	26	14,0	14,3
M.I. placebo	30,1	32,2	28,7	12,0	13,7
T.M. placebo	34,2	35	33,4	14,6	15,6
Š.M. oxygen	26,05	28,8	24	15,3	13,1
R.O. oxygen	26,2	27,5	25,1	12,2	8,8
M.I. oxygen	29,1	31,5	28	13,7	10,3
T.M. oxygen	33,6	35,4	32,6	13,4	10,4
Average P	29,2	30,4	28,3	13,2	14,1
Average O	28,7	30,8	27,4	13,7	10,7
% diff. P-O	-1,4%	1,2%	-3,1%	3,3%	-32,4%

Due to small number of team members we will proceed by individual evaluation of the athletes. Athlete Š.M. achieved worse results in runs where his performance was enhanced by inhalation of concentrated oxygen compared to those runs in which he was given placebo (the oxygen-enhanced result was worse by 0,5 seconds – see table 1). His result time was affected by ineffective stamina management in individual runs while the difference between his best and worst result in oxygen-enhanced runs was as big as 4,8 seconds in comparison with placebo-enhanced runs where the difference was only 1,2 seconds.

Due to this fact it is impossible to evaluate the impact of inhaled oxygen on the performance of Š.M. However, the inhalation had a positive effect on the body's reaction after the workload. In experimental measurements the lactate level reached 15,3 mmol.l⁻¹, after the controlling measurement it was 12,2 mmol.l⁻¹. The recovery after experimental measurement was faster, the lactate level decreased 15 minutes after the load decreased by 3,1 mmol.l⁻¹ in comparison with the placebo measurement where we recorded increase by 0,6 mmol.l⁻¹. Athlete R.O. is a proof of a positive effect of inhalation of oxygen concentrator on one's performance and recovery (table 1).

In comparison with the preceding athlete, the difference between the best and worst time achieved in R.O.'s case was minimal in both measurements: 2,3 seconds in placebo measurement and 2,4 seconds in experimental measurement. He reached better performance in placebo measurement by 0,6 seconds as well as better maximal and minimal time. The inhalation of oxygen concentrator also had positive effect on the body's response to the load. The lactate level reached 12,2 mmol.l⁻¹ after three minutes in experimental measurement and 14,0 mmol.l⁻¹ in controlling measurement. As for the recovery assessment, experimental measurement after 15 minutes reflected a 3,4 mmol.l⁻¹ decrease in comparison with controlling measurement which showed a 0,3 mmol.l⁻¹ increase in lactate levels. The biggest impact of inhalation of concentrated oxygen on one's performance was seen in case of the athlete M.I. (table 1). The differences in times achieved during the tests were the same: in both cases the difference between the best and the worst time was the same – 3,5 seconds. In experimental measurement M.I. achieved a result better by 1,0 seconds than in the controlling measurement. Lactate level in experimental measurement taken after three minutes after final run was higher (13,7 mmol.l⁻¹) than in controlling measurement (12,0 mmol.l⁻¹). As for the recovery assessment, experimental measurement after 15 minutes reflected a 3,4 mmol.l⁻¹ decrease in comparison with controlling measurement which showed a 1,7 mmol.l⁻¹ increase.

Juvenile athlete T.M. reached better performance and recovery indicators in experimental measurement (table 1). The difference in times was bigger in experimental measurement (2,8 seconds) than in controlling measurement (1,6 seconds). In experimental measurement M.I. reached time by 0,6 seconds better than in controlling measurement. The positive effect of inhalation of oxygen concentrator was also seen in the body's response to the load. The lactate level reached 13,4 mmol.l⁻¹ after three minutes in experimental measurement and 14,6 mmol.l⁻¹ in controlling measurement. As for the recovery assessment, experimental measurement after 15 minutes reflected a 3,0 mmol.l⁻¹ decrease in comparison with controlling measurement which showed a 1,0 mmol.l⁻¹ increase in lactate levels.

Table 2. Statistics about athletes' performances

	Š.M	R.O.	M.I.	T.M.
Average placebo	25,55	26,88	30,08	34,22
Average oxyfit	26,05	26,17	29,1	33,66
D	-0,5	0,71	0,98	0,56
d _r difference (%)	2,1	-3,6	-3,3	-1,6
d _x	0,39	1,18	0,73	0,64

Based on the evaluation according to Cohen's kappa coefficient, the change in the parameters observed was significant in case of three athletes (table 2). Figures of athletes M.I. and T.M. reflect medium effect of oxygen and figures of athlete R.O. reflect major effect of oxygen. Relative change in their results is not large/significant (1,6-3,6%), however, from the perspective of expert evaluation even these changes are considerably important in their effect on short term performance. Based on the data gathered we assume, that inhalation of concentrated oxygen has a positive impact on repeated short term submaximal performance in the case study that we described. The results also show that inhalation of concentrated oxygen has a positive effect on the process of regeneration. Fast regeneration has a positive effect on lactate levels. Different results documented during the experiment are a convincing proof of the fact that inhalation of

95-99% oxygen positively effects final performance. A research conducted with greater amount of athletes could lead to the confirmation of this statement. We have found several studies documenting similar research, e.g. those that recorded maximal anaerobic capacity increase due to inhalation of concentrated oxygen by 3-6% (Smatlan., Gabrys and Gabrys, 2000; Suchý, 2010).

Conclusion

Based on the data gathered here we can make the following conclusions: 1) The results of three out of four athletes document medium up to strong positive effect of inhalation of concentrated oxygen during 6x200m run. In the case of one athlete the positive effect of concentrated oxygen was not confirmed due to his inappropriate stamina management, 2) Inhalation of concentrated oxygen did not have an impact on correct speed estimation, 3) Inhalation of concentrated oxygen did not have an effect on lactate level 3 minutes after repeated submaximal intensity load, 4) The positive effect of concentrated oxygen was definitely confirmed 15 minutes after the run in the recovery phase. This was seen in the decrease of lactate level by ¼ in experimental measuring in contrast to the increase of lactate in placebo measurements.

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UTJECAJ HIPEROKSIGENACIJE NA IZVEDBU I OPORAVAK TIJEKOM PONAVLJANIH TRČANJA NA 200M S OPTEREĆENJEM SUBMAKSIMALNOG INTENZITETA

Sažetak

Mogućnost korištenja udisanja koncentriranog kisika u ponovljenom trčanju na 200m bio je dio našeg istraživanja u sklopu projekta VEGA 1/1175/12. Cilj ovog rada bio je provjeriti utjecaj kratkoročne hiperoksigenacije na ponovljenim kratkotrajnim opterećenjima submaksimalnog intenziteta u kraćem sprintu. Provedeno je istraživanje testiranja sportaša tijekom treninga izdržljivosti u cilju razvijanja tolerancije na anaerobne laktatne kapacitete. Rezultati sportaša su bilježeni kroz dva moda treninga (6x200m staze) i uz udisanje koncentriranog kisika u eksperimentalnom i placebo mjerenju / izloženosti. Procijenjena je učinkovitost prema performansama i brzini oporavka. Na temelju prikupljenih podataka utvrđeno je da je udisanje koncentriranog kisika imalo pozitivan učinak na ponovljanje kratkoročne submaksimalne izvedbe u opisanom modelu. Ona je također imala pozitivan utjecaj na proces oporavka.

Ključne riječi: kratki sprint, brzinska izdržljivost, hiperoksigenacija, anaerobne sposobnosti, laktati

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