Biology of Sport, Vol. 21 N°2, 2004

EFFECTS OF OXYGEN APPLICATION PRIOR TO EXERCISE ON PERFORMANCE AND REGENERATION

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Abstract. Maximal oxygen consumption is an important performance criterion in endurance sports. Aerobic production is far more effective than the anaerobic one. Thus, to improve maxVO_2 is one of the main aims of athletes involved in endurance oriented sports activities. For this purpose, beside training adaptations, to increase the O_2 content of inspired air may be a theoretically effective means to possibly improve performance and regeneration. First semester physical education students (n=46: 19 females, 27 males) randomly performed two incremental bicycle ergometer tests 2-4 days apart, until subjective exhaustion. Ambient air alone was inhaled through a mask for 15 min until 10 min prior to one of the tests, and was enriched by 5 $l \cdot min^{-1}$ O_2 in the other. A low intensity active regeneration of six min immediately followed the tests. VO_2, Ve (min ventilation), heart rate, EqO_2 (oxygen equivalence), power output, RQ at the anaerobic threshold; VO_2, Ve, heart rate, EqO_2, power output, RQ, pO_2, pCO_2, BE (base excess) and blood pH at exhaustion; heart rate, RQ, blood pH, creatine kinase, urea and lactate upon the regeneration period were compared. The statistical analysis of this prospective, randomised and single blind study was done using the Student t- and Kolmogorov-Smirnov tests. No statistically significant differences were found between any of the above-mentioned parameters. Performance and regeneration of the subjects were not statistically affected during the "prior O_2 inhalation test" as described. Nevertheless, as minimal differences between elite athletes decide about success in competition, it might be worthwhile to further study the subjects, using different protocols. ***(Biol.Sport 21:149-157, 2004)***

Key words: Hyperoxia – Performance – Exercise - Regeneration

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Introduction

A complex approach is needed to obtain higher performance. Not only better training techniques, technical, psychological, and nutritional support are enough, but also different ergogenic aid methods are to be considered to achieve maximal performance. One of these ergogenic aids is hyperoxia.

According Welch, shortly after isolating O_2 in 1774, Priestley anticipated its medical uses and the problem of O_2 toxicity. Studies on hyperoxia during activity suggest additional positive effects on human performance. Maximal oxygen uptake capacity is one of the major performance criteria, especially in endurance activities. A higher maxVO_2 is also an advantage in intermittent activities as soccer, basketball, and the like. So, the use of different hyperoxygenation methods by athletes and teams is not surprising.

Our purpose was to investigate the effects of a protocol application involving hyperoxia prior to exercise on performance and regeneration.

Material and Methods

First semester physical education students (n=46: 19 females, 27 males) were enrolled in this study. Their physical characteristics are shown in Table 1. All participants were informed about the procedure of the study, and their consent was obtained. A detailed physical examination was done before the study.

All participants underwent two bicycle ergometer tests till subjective exhaustion in a time period of 2-4 days. While one of the tests was performed with prior oxygen enriched air application, the other was done without.

The sequence of the tests was randomised. An incremental bicycle ergometer test protocol was applied. Male subjects started at 100 W, female subjects at 50 W. Each stage took 3 min and workload was incrementally increased by 50 W. After subjective exhaustion the resistance was reduced to 30 W, in order to ensure active regeneration.

Oxygen application was started 25 min before the test. The mask for the application was put on for 15 min. The participants were not informed about the nature of the gas inhaled. Oxygen application was accomplished using an oxygen concentrator (VTG Model Oxy-box 6005). The room air was oxygen enriched by 5 liters per min. In resting conditions oxygen concentration of enriched air amounted to approximately 74.4±2.2%. Ten min following the inhalation, the bicycle ergometer test was performed using an electromagnetically braked ergometer (Lode, type Excalibur, Germany).

The spiro-ergometrical investigations during the test were performed by implementing an oxygen analyser (Oxyconbeta, Mijnhardt, Holland). The data for every sequence of eight breaths was extrapolated to a min. Capillary blood was taken from the right ear lobe at rest, in the last 30 s of each stage, at maximal work and in the 3rd and 6th min of the active regeneration period, in order to investigate blood gas and lactate parameters during the test. The evaluation of the lactate and blood gas figures were performed using an Ebio 6666 Analyzer (Eppendorf, USA) and an automatic blood gas system AVL/990 (AVL List GmbH, Germany) respectively. Blood was also withdrawn from the right antecubital veins to determine the urea levels and creatine kinase activities, 24 h following each test. Heart rate was obtained at rest, at the end of each stage, at maximal work and in the 3rd and 6th min of the active regeneration by means of an ECG monitor.

The following parameters were investigated:

1. At the anaerobic threshold (4.0 $mmol \cdot l^{-1}$ lactate): heart rate, workload, VO_2 (oxygen consumption), Ve (respiratory volume per min), RQ (respiratory quotient: VCO_2/VO_2), and EqO_2 (oxygen equivalence: Ve/VO_2).

2. At maximum workout: heart rate, VO_2, Ve, EqO_2, RQ, blood lactate, pH, pO_2 (partial oxygen pressure), pCO_2 (partial CO_2 pressure) and BE (base excess).

3. As regeneration parameters: heart rate, pH and lactate values in the 3rd and 6th min of the regeneration. Creatine kinase (CK) activities and urea values 24 for hours after the tests.

Statistical methods: Student-t tests for paired parameters were used in this prospective, randomised and single blind study. Variance homogeneity was tested using the Kolmogorov-Smirnov test.

Results

Physical characteristics of the participants are depicted in Table 1.

Table 1
Physical characteristics of the participants

N	Age (year)	Weight (kg)	Height (cm)	BFP (%)	BSA (m^2)
46	20.9±2.9	70.9±11.3	177.3±10,5	16.3±5.9	1.87±0.20

(BFP: body fat percentage, BSA: body surface area)

Table 2
Values at the anaerobic threshold (4 mmol·l^{-1} lactate)

	NA	NA+ 5 l·min^{-1} O_2	Kolmogorov Smirnov test	Student t-Test
Performance (W)	194.5±55.4	199.8±58.3	P>0.05	P>0.05
HR (beats min^{-1})	169±11	168±12	P>0.05	P>0.05
VO_2 (ml·min^{-1}·kg^{-1})	36.0±6.8	36.1±6.9	P>0.05	P>0.05
Ve (l·min^{-1})	71.2±18.1	71.6±20.3	P>0.05	P>0.05
RQ	0.97±0.40	0.96±0.50	P>0.05	P>0.05
EqO_2 (%)	26.8±2.9	26.8±2.6	P>0.05	P>0.05

(NA: normal air, NA+5 l·min^{-1}: enriched oxygen, W: watt, P>0.05: not significant)

Table 3
Values at maximal workout

	NA	NA+ 5 l·min^{-1} O_2	Kolmogorov Smirnov test	Student t-Test
Performance (W)	267.8±74.7	274.4±69.6	P>0.05	P>0.05
VO_2 (ml·min^{-1}·kg^{-1})	50.5±8.3	51.1±8.0	P>0.05	P>0.05
Lactate (mmol·l^{-1})	9.8±1.8	10.3±2.1	P>0.05	P>0.05
HR (beats·min^{-1})	187±8	188±7	P>0.05	P>0.05
Ve (l·min^{-1})	135.3±39.1	133.7±33.8	P>0.05	P>0.05
RQ	1.1±1.1	1.1±0.1	P>0.05	P>0.05
EqO_2 (%)	36.1±4.3	33.9±3.8	P>0.05	P>0.05
pH	7.18±0.47	7.18±0.61	P>0.05	P>0.05
pO_2 (mmHg)	90.7±8.5	89.3±6.7	P>0.05	P>0.05
BE	31±2.9	31.6±2.4	P>0.05	P>0.05
pCO_2 (mmHg)	-15.8±2.2	-15.4±3.1	P>0.05	P>0.05

(NA: normal air, NA+5 l·min^{-1}: enriched oxygen, W: watt, P>0.05: not significant)

No statistically significant differences were found between the enriched oxygen and normal air inhalation procedures prior the workout. Between all the respective parameters at the anaerobic threshold, at maximal workout and in the regeneration phase, the statistical evaluation revealed no significant differences ($P>0.05$) (Table 2, Table 3 and Table 4).

However, mean performance was found to be slightly higher following enriched oxygen inhalation prior to the workout.

Table 4
Recovery values

	NA	NA+ 5 $l \cdot min^{-1}$ O_2	Kolmogorov Smirnov test	Student t-Test
RQ at 30 s	1.11±0.06	1.10±0.06	P>0.05	P>0.05
3rd min HR (beats/min)	133±11	134±11	P>0.05	P>0.05
3rd min pH	7.170±0.063	7.161±0.065	P>0.05	P>0.05
3rd min lactate (mmol/L)	10.9±1.6	10.9±1.9	P>0.05	P>0.05
6th min HR (beats/min)	125±10	125±12	P>0.05	P>0.05
6th min pH	7.176±0.043	7.196±0.112	P>0.05	P>0.05
6th min lactate (mmol/L)	10.6±1.6	10.1±2.1	P>0.05	P>0.05
24th hour CK (U/I)	79.3±37.3	101.2±72.7	P>0.05	P>0.05
24th hour urea (mg/dl)	28.0±7.5	26.6±6.4	P>0.05	P>0.05

(NA: normal air, NA+5L/min: enriched oxygen, W: watt, P>0.05: not significant)

Discussion

The effect of hyperoxia on athletic performance is a popular investigation field since the beginning of the 20th century [14,28,29]. Several studies report certain effects of hyperoxia during exercise on performance [15,22,31]. For practical purposes, the effects of hyperoxia are more interesting when applied before the competition.

We aimed to study the effects of oxygen application prior to exercise on several physiological parameters that are important in performance and regeneration. The main question was whether it would be possible to get similar effects with an enriched oxygen application protocol prior to exercise. Discussion will be made according to the response of each parameter investigated.

Performance: As can be seen from Tables 1 and 2, our study lacked to reveal any statistically significant differences between workloads obtained. Nevertheless, the figures were slightly higher with the enriched oxygen application compared to that with normal air. According to Bannister and Cunningham [6], it is possible to increase the performance significantly using enriched oxygen inhalation during exercise. Best results were obtained with 60-70% O_2. Further studies in the following years displayed similar results [13,14]. However, the study protocols were questionable (no randomisation, no single or double blind use, etc.).

Better-designed studies yielded positive effects of oxygen inhalation during exercise on performance [1,15]. Wilson and Welch stated that it would be possible to enhance this positive effect when using O_2 concentrations up to 100% [31].

In studies with oxygen inhalation prior to exercise, limited positive effects or no effects on performance were reported [16]. The application timing, duration and concentration have a key role on the results. Therefore, different protocols should be tested to get optimum results. Our protocol resulted in a slightly increased performance. Even min differences in elite athletes may motivate us for further investigation.

Oxygen consumption (VO_2): We obtained similar scores at the anaerobic threshold and maximum workout. Previous researchers stated that it is impossible to increase oxygen delivery and consumption without increasing cardiac output or a-v O_2 difference [7,27]. Nevertheless, there are studies stressing an increase in arterial oxygen concentration when enriched oxygen is applied during exercise [15,16,22]. Peltonen reported en increased maximum oxygen consumption, which was over-related to the increase in performance. Some investigators explained this with an interaction with the calcium metabolism [11].

Blood lactate: Our protocol was unable to affect the lactate levels significantly at anaerobic threshold, maximum performance and regeneration. Lower lactate levels at submaximal activities are reported in the literature [31,32] when enriched oxygen is applied during exercise. Similar results were obtained during maximum workouts [1,19]. We assume that concentration and duration of enriched oxygen application in our protocol was unable to result in significant effects on the lactate metabolism.

Heart rate, RQ, Ve and EqO_2: Lower heart rates in submaximal activities [15,17,22] and no changes with maximal activities [15] are reported in the literature when enriched oxygen is supplied during exercise. Prior oxygen application failed to affect the heart rate in our study.

RQ and EqO_2 scores displayed no differences either. However, with additional oxygen application during exercise the RQ value is reported to decrease [29,31]. This indicates a shift of energy substrate utilisation towards the lipids. In endurance activities this might be very interesting. Theoretically, glycogen sparing can delay the onset of perceived fatigue. The question is how long and how much oxygen is required to get such lasting effects. Possible oxygen intoxication should never be forgotten during prolonged applications with high oxygen doses.

A higher concentration of inhaled oxygen during exercise is reported to decrease Ve. This decreased ventilation is probably due to chemoreceptor function. A positive effect of decreased ventilation would be less energy used in the respiratory muscles. This can affect the performance in intermittent and endurance activities. Our results revealed no significant differences. However, once again, the dosage and concentration of the oxygen application prior to exercise has to be investigated.

pH, pO_2, pCO_2 and BE: In agreement with the results in the literature [15], we found no significant differences in these parameters during maximal performance. In fact, Adams and Welch [1] reported no differences in H^+ concentration in maximal exercises with hypoxia, normoxia or hyperoxia.

Urea and CK: No statistically significant differences were found in our study for these parameters. The literature supports our findings [9]. Considering the non-significant effects on the abovementioned parameters at the anaerobic threshold and maximum performance levels, we couldn't expect differences in the regeneration parameters either.

Conclusion

It is obvious that our oxygen application protocol prior to exercise did not affect significantly the chosen parameters in terms of workload and regeneration, in the physical education students selected, with the given test protocol. Still, the slightly higher performance scores are worthwhile to carry further investigation, especially considering the possible effects in elite athletes. Timing, duration and concentration of the oxygen used needs more focus.

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Accepted for publication 04.07.2003

Acknowledgment
Many thanks to Michael Rodziewicz for his great help in testing the participants