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Effect of short-term hyperoxia on model exercise in basketball

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***Aim*. Aim of the study was to verify the influence of the short-term repeated inhalation of air with higher concentration of oxygen (FiO_2=30%) on regeneration and fine motor skills after repeated anaerobic exercise in basketball.**

***Methods*. Research subjects (N.=10) completed two test sessions with a three-day interval in between them. Each session covered two identical basketball tests at maximal intensity lasting two minutes. In the pause between the tests the research subjects intermittently inhaled air with higher concentration of oxygen or placebo in random order. Time, success rate and number of shots at the basket were recorded during the sessions, as were regeneration processes (changes in lactate concentrations and heart rate).**

***Results*. The results confirmed, with both statistical (P<0.05) and substantive significance, the positive influence of inhaling air with higher concentration of oxygen on reducing the heart rate (on average by 10% immediately after the test and by 22.5% 390 seconds after completing the test) and the lactate level (on average by 4.7% and 3.2% during exercise in the first and second test respectively and by 5% and 4.2% respectively at rest). We did not demonstrate (P<0.05) the influence of inhaling concentrated oxygen on the success rate of shots at the basket.**

***Conclusion*. The data acquired confirm the positive influence of short-term hyperoxia on accelerating regeneration in repeated model-specific basketball exercise, but the influence on fine motor skills was not established.**

KEY WORDS: Hyperoxia – Basketball - Exercise.

One of the key factors influencing performance in sport is a player's adaptation to alternating aerobic and anaerobic exercise, which is primarily influenced by the speed of regeneration between these types of exercise. Inhaling concentrated oxygen increases the oxygen supply to the working muscles *via* various underlying mechanisms.[1] Thus in recent years the experiments on the impact of various higher oxygen concentrations on improved performance and accelerate regeneration, primarily in top-level sport, have been performed.

For these reasons, when oxygen at a higher than usual concentration is inhaled, the intensity of exercise can be increased in comparison with the usual conditions.

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However, the influence of concentrated oxygen on concentration and the accuracy of fine neuromuscular coordination remains an open question.

The literature [2-7] reports that the inhalation of a hyperoxic mixture has a positive influence on 2-3 minute lasting performance immediately following the inhalation. The reason is evidently the greater saturation of the blood and tissues with oxygen and the lower anaerobiosis in the working muscles, which accelerates subsequent recovery and the return to the initial values. Single or repeated short-term inhalation of hyperoxic mixtures has a temporary effect on increasing oxygen saturation of the tissues, which can be used to accelerate regeneration in intermittent exercise.[8] The inhalation of 90-100% oxygen during exercise can increase the oxygen intake by approximately 10%.[9]

The results of studies on concentrated oxygen in sport are controversial: some papers have proved benefits;[2, 10-12] however, other studies have not shown any positive effects, especially for medium-term and longer exercise [13] or for brief intervals at submaximal or maximal intensity.[12, 14] A meta-analysis [15] summarises studies of the influence of concentrated oxygen on performance, but only a few studies, to our knowledge, have so far been published on the influence of hyperoxia on accelerating regeneration processes between repeated anaerobic exercises (in ice hockey players [11] and cross-country skiers [16]).

The Jugo test is a standard basketball test where the player shoots at the basket from 10 different positions. The positions for shooting are indicated by markers, half of which are at a distance of 6.25 m from the basket, and the other half are 4.25 m from the basket. After shooting at the basket the test subject must always run to retrieve the ball and dribble it to the next marker. Total number of shots at the basket was counted and successful attempts were recorded by two independent assistants. Regarding the anticipated limited time of the physiological influence of hyperoxia on the organism, we decided to modify the Jugo test and to reduce its duration to two minutes instead of usual five. The modified Jugo test represents a typical situation of repeated exercise with incomplete or insufficient regeneration, as usually occurs in basketball matches. Naturally the true course of a match is significantly influenced by a range of different technical and tactical factors.

In the literature we were only able to find a few studies with similarly designed research projects, and these demonstrated an improvement in maximal anaerobic capacity after inhaling O-PUR (the name used for Oxyfit abroad) in a range of 3-6%.[17] Pupiš *et al.*[18] published a pilot study on the influence of hyperoxia on the success rate for shooting at the basket and the regeneration process for two players. In the literature we did not find any publications on the influence of inhaling concentrated oxygen on concentration in sport.

WADA (as at 1 January 2012) does not consider supplementing with concentrated oxygen to be doping.[19]

The aim of our study was to verify the influence of inhaling air with higher concentration of oxygen (30%) on performance in model basketball exercise. Specifically, we focused on the hand-eye fine motor skills, as judged by the success rate of shooting at the basket, and the regeneration process for repeated short-term exercise.

In line with this research objective, we formulated two hypotheses:

— H1: the short-term repeated inhalation of air with higher concentration of oxygen has a positive influence on a specific fine motor skill judged by the success rate of shooting at the basket in repeated basketball tests;

— H2: the short-term inhalation of air with higher concentration of oxygen has positive influence on the regeneration process following a specific two-minute test.

Materials and methods

The hypotheses were tested using an experimental model of the intermittent inhalation of concentrated oxygen or a placebo from Oxyfit canisters, with dosage accord-

ing to the distributor's recommendations, between two repeated basketball "Jugo" tests. Oxyfit is manufactured by Newpharm SA and the importer for the Czech Republic and Slovakia is Linde Gas a. s. According to the manufacturer, a canister of Oxyfit contains 99.5% oxygen. The inhalation was performed using the manufacturer's original masks with openings through which the concentrated oxygen is inhaled from a canister mixed with ordinary air. The concentration of oxygen in the inhaled air was 30%, which was counted as the ratio of the individual maximal free ventilation and the amount of concentrated oxygen leaving the Oxyfit canister in two seconds. These measurements were carried out using an MIR Spirobank II analyser (producer MIR - Medical International Research, Italy) with accuracy (according to the manufacturer) of ± 3%.

The canister with the placebo was filled with ordinary air and, like the inhalation mask, it looked identical to Oxyfit.

Subjects

The research was conducted on female basketball players (N.=10) who regularly play in the top Slovak and French basketball leagues (Table I). They stated that they were in good health during testing. At the time of testing the players were in a transitional period following the end of the season, and so they completed training exercises of approximately 5-7 hours per microcycle.

Testing procedures

Testing was conducted twice over four days (Banská Bystrica, Slovakia), so that the players would have sufficient time between the tests for regeneration. Both test sessions were identical and included two two-minute Jugo tests, between which the research subjects inhaled Oxyfit (mixed with regular air from openings in the special inhalation mask) or the placebo for the entire duration of the test, in a random order. A new canister was always used for each test. Neither the research subjects nor the research workers knew whether Oxyfit or the placebo was being inhaled. Figure 1 summarizes the testing schedule.

In accordance with the instructions, for each inhalation using the special inhalation mask, the research subjects pressed

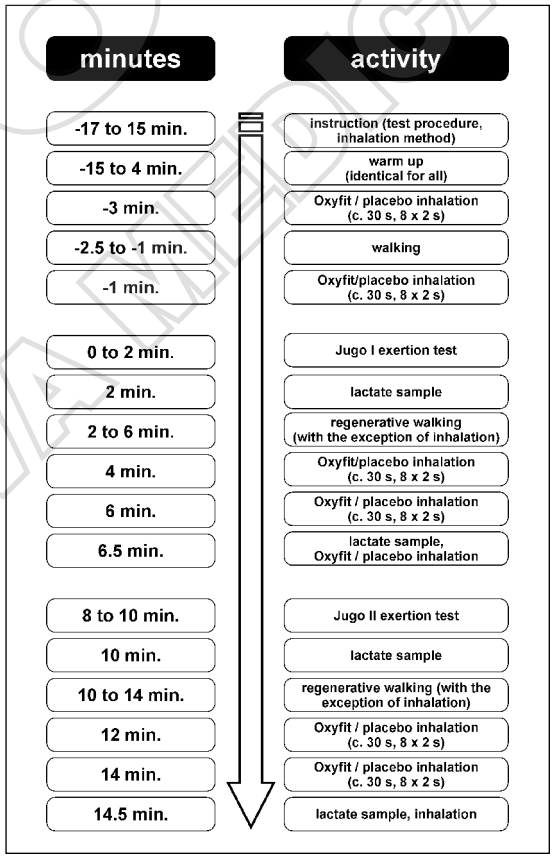

Figure 1.—Test schedule.

TABLE I.—*Research subjects (N.=10).*

Research subject	Age (years)	Height (m)	Weight (kg)	Active sport (years)	Vital lung capacity (L)
Mean/SD	22.7±0.4	1.80±0.3	67.3±4.6	13.3±3.12	4.8±0.2

Active sport: systematic sport activity at a performance level.

the canister cap eight times at an interval of approximately two seconds. Each inhalation was guided by the same member of the project team, who monitored the duration of pressing the canister cap.

Prior to testing the participants were instructed on correct inhalation and were asked to complete the test (which, in the standard five minute form, was familiar to them) with maximal effort. During testing all participants were intensively verbally motivated.

At the end, the basketball players were asked when they had believed to inhale the placebo and when Oxyfit. After providing their responses they were informed of the true sequence.

Statistical analysis

The physiological part of testing was evaluated using the continuous recording of heart rate (HR) [7] using Polar Team 2 (producer Polar electro oy, Finland). To simplify evaluation, the start and the end of all the tests were recorded in the program. From the intervals recorded, the program then automatically calculated the average and maximal values attained. The blood lactate concentrations were established from fingertip blood samples and analysed using Lactate Pro LT-1710 (producer Arkay, Inc., Japan), which according to the manufacturer is accurate to ± 3%.

Microsoft Excel 2007 was used for subsequent processing and analysis. We compared the results of the mean variables monitored attained in the tests under experimental and control conditions, the differences between the results of the first and second tests and the regeneration process (evaluated on the basis of changes in the concentration of lactate in the blood and the HR values) using a paired sample t-test ($P<0.05$). We monitored the substantive significance for the differences in the variables monitored using Cohen's d effect coefficient.[8] For a comparison of changes in performances, we set substantive significance at an absolute level of greater than 1.5%.

The design of the research project was in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the Faculty of Physical Education and Sport at Charles University in Prague. All participants signed the informed consent form.

Results

Testing was carried out in accordance with the stipulated design. According to the tested subjects themselves, the HR values and the concentrations of lactate obtained, all of them gave maximal performance in all the tests.

The results of the repeated "Jugo" tests (both statistically and substantively) demonstrate (Table II, Figure 2) that the inhalation of concentrated oxygen does not have a significant influence on the success rate of shooting at the basket. In this model of repeated specific basketball exercise, the inhalation of concentrated oxygen does not influence the standard of the motor skills, which is one of the key preconditions for successful shooting.

The main reason for the refutation of H1 was the low reliability of the test used, which was influenced by the fact that during the test, with each player the ball would

TABLE II.—*Success rate at shooting for the players monitored (N.=10) in modified "Jugo" tests under experimental and control conditions.*

Indicator/values ascertained	TEST I. total shots at the basket (number)	TEST I. successful shots at the basket (number)	TEST II. total shots at the basket (number)	TEST II. successful shots at the basket (number)
Mean placebo/SD	21.5±2.0	9.6±12.0	21.1±2.4	11.4±5.5
Mean Oxyfit/SD	21.1±0.6	9.4±5.7	21.0±1.5	10.3±14.9
P	0.238	0.432	0.392	0.208
d difference placebo-Oxyfit (%)	-1.8	-2.6	-0.6	-10.4

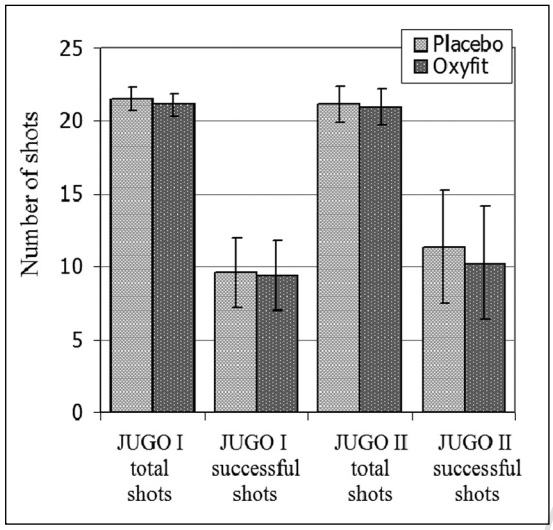

Figure 2.—Success rate at shooting for the players monitored (N.=10) in modified "Jugo" tests under experimental and control conditions.

repeatedly bounce off the court, and the player would have to run for the ball and return to the court. The time needed to retrieve the ball depended on where the ball landed and the player's position at the time, so the amount of time lost varied greatly.

The values ascertained for lactate in capillary blood statistically and substantively (at a medium significance level) confirm that the inhalation of concentrated oxygen has a positive influence on a reduction in the lactate concentration in the fourth minute after the first and second test in comparison with the placebo. In the fourth minute after the second test a reduction in the lactate concentration was recorded that was on average a quarter lower following the inhalation of concentrated oxygen in comparison with the placebo.

The differences in the lactate values immediately after completing the first and the second tests (under control and experimental conditions) are not statistically significant, but from the perspective of substantive significance and sports practice we rate the average reduction in the lactate values of 8.4% (0.6 mmol·L^{-1}) and 10.3% (1.1 mmol·L^{-1}) as a value that influences the regeneration process and subsequent performance in additional short-term exercise (Table III, Figure 3).

The HR [beats·min^{-1}] values demonstrate with statistical and substantive significance the positive influence of inhaling concentrated oxygen on lower mean values during exercise and rest, with the exception of HR_{max} in the second test. The lower HR values during the pause (by 5.0% on average) and after the second test (by 5.9% on average) are important in terms of performance dur-

TABLE III.—*Concentration of lactate in the blood and HR values for the players monitored (N.=10) during testing under experimental and control conditions.*

Measurement time/values ascertained (mmol·L^{-1})	Immediately after TEST I	4.5 min after TEST I	immediately after TEST II	4.5 min after TEST II
Mean placebo/SD	8.2±2.1	7.9±3.7	11.1±8.6	9.8±10.6
Mean Oxyfit/SD	7.6±4.8	7.3±2.5	10.0±4.9	7.8±3.9
P	0.140	0.015	0.055	0.039
d difference placebo-Oxyfit (%)	-8.4	-7.6	-10.3	-22.6

Measurement time/values ascertained (beats·min^{-1})	HR_{mean} -3 to 0 min	HR_{max} -3 to 0 min	HR_{max} TEST I.	HR_{mean} TEST I.	HR_{mean} pause	HR_{min} pause
Mean placebo/SD	111.3±25.7	128.6±39.7	180.8±34.4	170.4±20.0	124.4±18.5	101.1±10.6
Mean Oxyfit/SD	99.4±59	113.6±61.2	176.8±21.7	162.6±34.5	118.3±37.4	89.5±11.7
P	0.002	0.001	0.041	0.020	0.020	0.011
d difference placebo-Oxyfit (%)	-11.3	-12.4	-2.2	-4.7	-5.0	-12.2

Measurement time/values ascertained [beats·min^{-1}]	HR_{max} TEST II	HR_{mean} TEST II	HR_{mean} rest	HR_{min} rest
Mean placebo/SD	184.4±33.5	173.6±21.2	141.6±16	114.4±21.7
Mean Oxyfit/SD	181.6±23.2	168.1±19.9	135.8±24.4	105.8 ± 29.9
P	0.092	0.042	0.003	0.002
d difference placebo-Oxyfit [%]	-1.5	-3.2	-4.2	-7.8

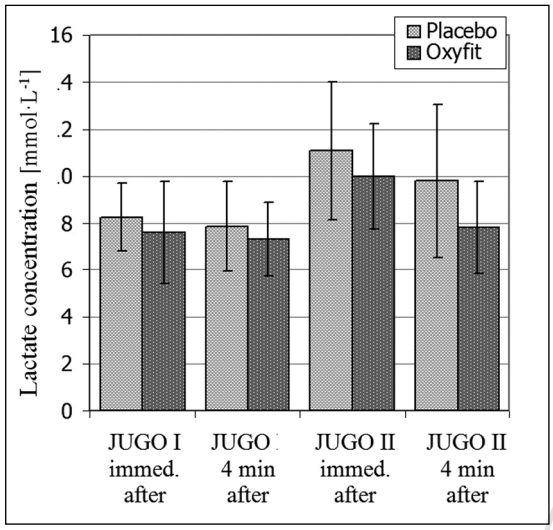

Figure 3.—Concentration of lactate in the blood for the players monitored (N.=10) during testing under experimental and control conditions. P: statistical significance.

ing a match, as they indicate a lower level of exertion and a higher proportion of aerobic capacity. Lower HR in the pause and after the second test indicates better regeneration, and therefore the commencing of further exertion with a higher level of regeneration (Table III).

The differences between the results of the first and second "Jugo" tests under experimental conditions in comparison with the placebo (evaluated using changes in the concentration of lactate in the blood and the HR values) unambiguously confirm that, under the specific conditions of the test we conducted, the inhalation of concentrated oxygen has a positive influence on the physiological processes monitored. By extension the results also confirm that the inhalation of concentrated oxygen has a positive influence on the regeneration process. The acceleration of regeneration in the pause between intervals of maximal exertion with the inhalation of concentrated oxygen positively influences the values of heart rate and lactate during the subsequent repeated exercise.

The subjects were not able to distinguish between inhaling placebo and concentrated oxygen (when asked, 50% of the subjects indicated the testing sets while inhaling placebo).

Discussion

The influence of hyperoxia on the tolerance of physical activity, oxygen consumption during performance, metabolism, and the lactate response during and after performance, and on oxygen partial pressure, has been monitored extensively, as covered in the review article.[20] Fewer works have been published on the influence of hyperoxia on regeneration following exercise.

The link between hyperoxia and recovery is based on the physiological principles of the energy for muscle contraction and relaxation. Following physical exercise beyond a particular individual critical limit, muscular weakness sooner or later appears [21, 22] and manifests itself in various ways.[23] The causes of muscular weakness are likely complex, but it seems that a significant factor is the level of phosphocreatine, which falls significantly once the individual's critical limit has been exceeded, while the concentration of inorganic phosphate rises.[21] On entering the sarcoplasmic reticulum, inorganic phosphate can – by means of the calcium release – significantly influence subsequent muscle contraction.[24] Only under aerobic conditions is creatine re-phosphorylated into high-energy phosphocreatine,[3] accompanied by a reduction in inorganic phosphate. In this way hyperoxia can accelerate regeneration.

One study [25] lists mean HR values for female basketball players during a match as 170 ± 8 (beats·min^{-1}), and also [26] lists values of 175 ± 13 (beats·min^{-1}) for female basketball players at the national level. The mean HR values during testing therefore corresponded to the values usually achieved during a match. The lactate concentrations immediately after completing each test confirm the maximal effort of the research subjects, as they recorded higher values than those usually achieved in a match. Female basketball players at the national level record mean values for lactate immediately after each quarter of a match in the range 5±2.3 (mmol·L^{-1}) [25, 27] and the Rodriguez-Alonso study [26] shows similar mean values of 5.2±2.7 (mmol·L^{-1}). In its physiological

aspects the exercise model tested therefore approximately represents the situation of repeated two-minute sport-specific exercise with incomplete or insufficient regeneration, as usually occurs in basketball matches. Naturally the true course of a match is significantly influenced by a range of different technical and tactical factors.

The modified Jugo test used proved unreliable, as for each player, once or twice in each test the ball bounced off the court, and she had to retrieve it and return to the appropriate marker. The time lost by sprinting off the court for the ball and then dribbling it back resulted in differences in the total number of shots. Sprinting for the ball and returning to the appropriate marker could have influenced reduced shooting success rate. It would be possible to confirm or refute this claim by, for example, using a continuous determination of position (a GPS signal on an outdoor court) that would enable us to monitor the time, absolute and mean speed for sprinting off the court for the ball. Current HR and the shooting success rate after the ball bounces off the court could be then adjusted to the data on position. For these reasons, in our opinion the influence of inhaling concentrated oxygen on the standard of the motor skill, tested using the number of shots at the basket and the success rate, could not become apparent.

The reliability of the test would be increased if a member of the research team always passed a new ball to the player from the area under the basket immediately after the ball shot had touched the basket or the backboard. This would reduce exertion and the HR and lactate values would be lower, so the inhalation of concentrated oxygen could have a lesser influence on subsequent regeneration. The results of the test would also be influenced by the speed and accuracy of the passes by the research team member.

In designing the study we considered measuring the level of blood oxygen noninvasively with pulse oximetry, but in light of technical and organisational difficulties we did not implement this method.

In our opinion it would be more interesting to carry out a similar experiment in which concentrated oxygen would be inhaled continually during the whole test.

Conclusions

The results confirm the positive influence of hyperoxia on accelerating regeneration in a repeated model of specific basketball exercise. On the basis of our measurements and the positive results of analogous studies,[11, 12, 15, 16, 18, 28] we believe it would be appropriate to use this permitted way of improving performance between repeated short-term anaerobic exercise to a greater extent in sport than is presently the case. The influence of hyperoxia on fine motor skills was not confirmed, but that may be due to the low reliability of the test chosen.

On the basis of testing the influence of inhaling concentrated oxygen on a repeated special basketball test, we found that in comparison with a placebo:

— the short-term repeated inhalation of air with higher concentration of oxygen does not have a significant positive influence on the success rate and number of shots at the basket, i.e. we did not confirm the hypothesis H1;

— the short-term repeated inhalation of air with higher concentration of oxygen has a significant positive influence on reducing blood lactate values in the fourth minute after the completion of the test, and on the heart rate values during exercise and rest, *i.e.* we confirmed the hypothesis H2.

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