Hyperbaric Oxygenation and Blood Lactate Clearance: Study in Sixty Male Naval Cadets

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The research was aimed to study the effects of a 30 minute exposure to 2.5 ATA with 100% O_2-inhalation on lactate concentration after muscular fatigue from incremental exercise on a cycle ergometer. The subjects were 60 male naval cadets aged 20-23 years whose physical fitness was equivalent to the average athletes. All volunteers participated in the first VO_2 max exercise test to obtain their baseline data and randomly assigned into 3 groups of 20. The 3 groups were: Rest recovery group (RR), Oxygen recovery group (OR), and the Hyperbaric oxygenation (HBO_2) recovery group (HR). The volunteers took the incremental exercise test (Ordinary Lamp Protocol) on a cycle ergometer to exhaustion, then rested according to the above assigned groups. Blood samples were taken from each volunteer before the experiment, at exhaustion and every 5-minute intervals after the exhaustion for 30 minutes and immediately assayed for lactate concentration. The results showed significant decrease of blood lactate concentration at 15, 20 and 25 minutes intervals after the exhaustion in the HR group compared to the others. It might be initially concluded that HBO_2 enhanced the rate of lactate removal from peripheral blood vessels, therefore it shortened the recovery time.

Keywords : *Hyperbaric oxygenation, Lactate clearance*

J Med Assoc Thai 2004; 87 (Suppl 2): S218-22
e-Journal: *http://www.medassocthai.org/journal*

Lactic acid is produced in every kind of muscular exercise. During exercise, lactate accumulation is an important biochemical change which causes fatigue[1]. Lactic acid can be an inhibitor to muscular contraction during a high intensive work, and hence limits physical performance[2,3]. The phenomenon is particularly important in sport such as tracking, swimming and cycling in which athletes may have to compete in more than one event during the course of competition which concludes within the same day. Therefore, it is essential to find a suitable method to fasten blood lactate clearance as well as to shorten the duration of recovery.

Numerous studies have reported that after intense exercise, the rate of blood lactate disappearance was higher during continuous aerobic work than during the resting recovery. Studies in animal models showed that most of the lactate produced during vigorous exercise was removed by direct oxidation (55-70%)[4]. Besides, excess post-exercise oxygen consumption has been known since the early 1900s. Since then, enormous researches on the roles of O_2 involvement in various aspects of exercise have been reported.

Hyperbaric oxygenation (HBO_2) has been used to enhance tissue healing and to speed up recovery after exercise as well as an ergogenic aid to exercise performance. In 1966, Weglicki et al [5]. found that less lactate was produced during exercise in dogs that were exposed to hyperbaric oxygenation (3 ATA), compared to normobaric O_2 inhalation. Most of the studies were involved with the administration of hyperbaric oxygenation prior to exercise or sport events[6-8]. Some used HBO_2 for speeding up healing after sport injuries [11,12]. Few reports, however, existed regarding the use of HBO_2 for recovery from fatigue. In the present study, the authors intended to examine the effect of HBO_2 on blood lactate clearance in young male subjects after fatigue from exercise.

Material and Method

Subjects

Sixty male naval cadets aged 20-23 years subjected to participate in this study with written informed consent and permission from the School Director of the Royal Thai Naval Academy. The study

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protocol was reviewed and granted permission by the Ethics Committee of the Faculty of Medicine, Chulalongkorn University. The subjects recruited were free from illness which might be affected by the exposure to HBO_2. These included URI, chronic sinusitis, seizure disorders, emphysema, history of spontaneous pneumothorax, thoracic surgery, otoscherosis and congenital spherocytosis. The subjects were randomly assigned into 3 groups of 20, according to the recovery conditions. Group I was the rest recovery group (RR group), they sat on chairs beside the ergometer at ambience; Group II, O_2 recovery group (OR group), they sat on chairs beside the ergometer at ambience wearing O_2 mask and O_2 bag (O_2 flow 10 litres/min); Group III, HBO_2 recovery group (HR group), they sat inside the hyperbaric oxygen chamber (inhalation 100% O_2 with a mask under 2.5 ATA pressure).

Before the tests were conducted, the baseline characteristics according to performance capacity of each subject including; age, weight, height, maximum heart rate (HR_{max}), maximum oxygen consumption ($VO_{2\,max}$), and maximum workload (WL_{max}) were performed and recorded.

Measurement of maximal oxygen uptake

Maximal oxygen uptake (VO_{2max}) was determined using an electromagnetically braked bicycle ergometer (Lode) and breath by breath gas analyzer (Quinton Metabolic Cart, Quinton Instrument Co.,Ltd.). The instrument was calibrated before each test with a standard gas mixture according to the directions of the manufacturer. Prior to the start, the subjects were advised to rest for 5 minutes, then, instruction was given and they were allowed to familiarize themselves with the testing procedures. The test started with 3 minutes warm up at 25 watts (60-80 rpm), then the subject pedaled at a workload of 50 watts and increased by 25 watts every minute. Oxygen consumption and carbon dioxide production were printed out every 30 second intervals during the test. Heart rate was recorded using the Polar Accurex Plus heart rate monitor (Polar Electro, Finland). The test was stopped when the subject met two of the following criteria: 1) a test heart rate reached 90% HR_{max} of the age related theoretical maximum (220-Age), 2) respiratory exchange ratio (RER) > 1.1. and 3) exhaustion (the subject was unable to continue pedaling at the prescribed rate).

Recovery after exhaustion protocol and sample collection

To begin the study, four subjects were accommodated for testing on separate days, but at approximately the same time of the day, to avoid the effect of circadian rhythm. Firstly, the subjects were advised to rest for 5 minutes, then, Polar Acucrex Plus was used to monitor their heart rate. An indwelling venous catheter was secured into an arm of each subject, an initial blood sample was drawn and immediately assayed for resting blood lactate concentration. Using a Monark bicycle ergometer (model 818), the test started with 3 minutes warm up at 25 W (60-80 rpm), then, the subject pedaled at a workload of 50 W which was increased by 25 W every minute. The pedaling was kept constant at 60-80 rpm until exhaustion. At exhaustion or timed 0, another blood sample was taken immediately before starting the assigned rest protocol. A blood sample was collected every 5 minutes for a period of 30 minutes during the rest protocol. All blood samples were immediately assayed for blood lactate concentration using the automated analyzer (YSI 1500 Sport). Prior to the experimental study, quality control for blood lactate assay was carried out using the manufacturer's protocol. The %CV for intra-assay and inter-assay was 6.979 and 7.235 respectively.

Statistical analysis

The results were expressed as the mean $\pm$ SD. Kolmogorov-Smirnov test was used to evaluate the normallity. Test of equality of variance was performed by Levene's test. Two-way analysis of variance was used in comparisons over the control (rest recovery) and both oxygenation groups. Post hoc multiple comparison tests was performed by Bonferroni significant difference tests. A *p value* less than 0.05 was considered to have statistical significance.

Results

The sixty naval cadets recruited for the study were physically healthy and active. Their mean and SD values of age, weight, HR_{max}, $VO_{2\,max}$, lactate and WL_{max} of the 3 recovery groups are given in Table 1. The data presented in Table 1 indicate a rather homogeneous distribution of subjects between the groups. During exercise to exhaustion and recovery protocols, all the subjects were cooperative and all recovered without any adverse event. The HBO_2 recovery group was closely observed during their study in the chamber through a closed circuit monitor. After completing the recovery protocols, every subject stayed for another 30 minutes at ambience for observation before returning home. In all modes of recovery, the peak lactate values were obtained from

Table 1. Comparison of physical performance of naval cadets between groups (Mean ± SD)

	Rest recovery (RR group)	Oxygen recovery (OR group)	Hyperbaric recovery (HR group)
Number of subjects	20	20	20
Age (yrs)	21±2	21±2	21±2
Weight (Kg)	65.1±5.6	61.0±6.8	64.2±6.4
HR_{max} (beats/min)	180±7.2	180.8±7.9	178.6±7.8
$VO_{2\,max}$ (ml/min/Kg)	48.0±3.5	50.0±5.7	50.6±6.9
WL_{max} (Watt)	276.2±18.9	285.0±22.6	276.2±33.9
Baseline lactate (mmol/L)	1.4±0.6	1.5±0.4	1.5±0.3

the blood samples taken 5 minutes after the exercise exhaustion. Mean ± SD values of peak lactate of the RR, OR and HR group were 12.3 ± 2.0, 13.0 ± 2.1 and 12.4 ± 2.8 mmol/L, respectively (Table 2). The tests of between-subjects effects on blood lactate concentration are given in Table 3. Treatment and time had a significant effect on the blood lactate concentration. Otherwise, there was no interaction effect between treatment and time on blood lactate level. As shown in Table 4, there was significant difference in blood lactate concentration between the RR and HR group (mean difference = 1.248, 95% CI = 0.553-1.943). However, there was no significant difference in blood lactate concentration between the RR and OR group. Moreover, lactate removal rate was fastest in the HR group when compared with the RR and OR group throughout the 30 minutes recovery time.

Discussion

The homogeneity of the sixty subjects who participated in the present study helped abolish most confounders. The results of the present study demonstrated that the concentration of blood lactate was decreased with statistical significance in the HR group compared with the RR group. Moreover, the rate of blood lactate clearance in the HR group was faster than blood lactate clearance in the RR and OR groups. A few reports described the effect of HBO_2 on blood lactate clearance during recovery from exercise. Cabric et al, 1991[10] reported that exposure to 100% O_2 for 60 min at 2.8 ATA could increase the treadmill time to exhaustion and contrast with the findings of other groups[13,14]. They observed a lower blood lactate concentration during exertion in the HBO_2 treated group but without any statistical significance and suggested that hyperbaric oxygenation could improve tissue oxygenation with more O_2 retention to overcome tissue hypoxia during recovery[10].

The effects of normobaric and hyperbaric oxygenation on lactate clearance might be viewed through another aspect based on the physiology of O_2 transport in the body. The quantities for 100 ml of blood breathing air at sea level (normobaric) with an arterial pO_2 of about 95 mmHg are 19 ml bound as oxyhemoglobin and 0.3 ml in plasma. However, it is only this physically dissolved O_2 that is available for transport into tissues. The larger volume of hemoglobin bound O_2 is not all readily available. Giving O_2 under hyperbaric conditions, the pO_2 in plasma of 400 mmHg tremendously increases the gradient for O_2 that is readily available for transfer into tissues and sub-cellular organelles especially mitochondria, where oxidation of lactate takes place[14,15].

The data of the present study show a lag period of 5-10 min before a rapid decline of blood lactate takes place. The lag time is possibly caused by the transport of blood lactate from its generating site

Table 3. Results of the tests of between-subjects effects on blood lactate concentration

Source	df	F	P value
Mode of recovery	2	12.593	<.001
Time	6	41.986	<.001
Mode of recovery *time	12	.877	.571

Mode of recovery *time = interaction between mode of recovery and time
The p value is significant at the .05 level

Table 2. Blood lactate concentration in various modes of recovery

Modes of Recovery*	Blood lactate concentration (mmol/L) 0 min	5 min	10 min	15 min	20 min	25 min	30 min
RR group(n=20)	11.1±2.1	12.3±2.0	12.3±2.3	11.6±2.3	10.3±2.4	9.0±2.0	7.7±1.8
OR group(n=20)	11.3±1.9	13.0±2.1	12.7±2.3	11.6±2.8	10.1±2.3	8.4±2.1	7.4±1.9
HR group(n=20)	11.1±2.7	12.4±2.8	11.1±2.9	9.4±3.0	8.3±2.7	7.2±2.4	6.1±2.2

* RR, OR and HR stand for rest recovery group, oxygen recovery group and hyperbaric oxygen recovery group, respectively

Table 4. Multiple comparison on mean difference of blood lactate concentration between mode of recovery and time

Mode of recovery(I)	Mode of recovery(J)	Mean Difference(I-J)	P value	95% CI
RR group	OR group	-0.016	0.998	-0.711 to 0.694
	HR group	1.248	<0.001	0.553 to 1.943
Time of collected blood sample(I)	Time of collected blood sample(J)	Mean Difference(I-J)	P value	95% CI
RR group				
0 min	5 min	-1.140	1.000	-3.274 to 0.995
(post exhaustion)	10 min	-1.233	1.000	-3.367 to 0.902
	15 min	-0.458	1.000	-2.592 to 1.677
	20 min	0.830	1.000	-1.305 to 2.964
	25 min	2.103	0.058	-0.032 to 4.238
	30 min	3.411	<0.001	1.276 to 5.545
OR group				
0 min	5 min	-1.779	0.291	-3.987 to 0.430
(post exhaustion)	10 min	-1.376	1.000	-3.584 to 0.833
	15 min	-0.337	1.000	-2.545 to 1.872
	20 min	1.253	1.000	-0.956 to 3.461
	25 min	2.898	0.002	0.689 to 5.106
	30 min	3.945	<0.001	1.736 to 6.154
HR group				
0 min	5 min	-1.262	1.000	-3.980 to 1.457
(post exhaustion)	10 min	0.024	1.000	-2.694 to 2.742
	15 min	1.666	1.000	-1.053 to 4.384
	20 min	2.840	0.032	0.122 to 5.558
	25 min	3.892	<0.001	1.173 to 6.610
	30 min	4.935	<0.001	2.216 to 7.653

RR, OR and HR stand for rest recovery group, oxygen recovery group and hyperbaric oxygen recovery group, respectively
The p value is significant at the .05 level

to metabolizing tissues. The lag time may also be attributed to the counterbalance between vasoconstriction effect of high pO_2 against the high gradient pO_2 transferred into sub-cellular organelles. The aspect, therefore, needs further investigation. Apart from the faster decline in blood lactate concentration, the subjects in the HR group looked fresher and more ready for another bout of exercise or sport competition. The non-measurable benefit gained from HBO_2 should be taken into consideration in preparing athletes for repeated competitive events.

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ไฮเปอร์แบริกออกซิเจนต่อการลดกรดแลคติกในเลือด : การศึกษาในนักเรียนนายเรือ

ธาดา สืบหลินวงศ์, นันทพร เอกตาแสง, สมพล สงวนรังศิริกุล

งานวิจัยนี้ต้องการศึกษาผลของการสูดดม O_2 100% ภายใต้แรงดัน 2. 5 ATA ต่อระดับซีรัมแลคเตทในผู้ที่กล้ามเนื้อล้าจากการปั่นจักรยานวัดงาน อาสาสมัครนักเรียนนายเรือจำนวน 60 คน อายุระหว่าง 20-23 ปี ร่างกายแข็งแรงเทียบเท่าเกณฑ์เฉลี่ยของนักกีฬา อาสาสมัครทุกคนได้รับการทดสอบวัด VO_{2max} ก่อนแบ่งกลุ่มละ 20 คนเป็น 3 กลุ่ม ได้แก่ กลุ่มนั่งพัก (RR group) กลุ่มพักและสูดดมออกซิเจน (OR group) และกลุ่มสูดดม O_2 100% (HBO_2) ที่ 2.5 ATA (HR group) การทดลองดำเนินการโดยให้อาสาสมัครปั่นจักรยานวัดงานจนกล้ามเนื้อล้า แล้วพักตามกลุ่มที่ได้รับการกำหนดข้างต้น เจาะเลือดอาสาสมัครแต่ละคน ก่อนออกกำลัง เกิดกล้ามเนื้อล้า และทุก 5 นาทีหลังกล้ามเนื้อล้าต่ออีก 30 นาทีเพื่อวิเคราะห์ปริมาณซีรัมแลคเตททันที ผลการศึกษาพบว่าระดับซีรัมแลคเตทลดลงอย่างมีนัยสำคัญที่ 15, 20 และ 25 นาทีหลังเกิดกล้ามเนื้อล้าในกลุ่มสูดดม O_2 100% ภายใต้แรงดัน 2.5 ATA เมื่อเทียบกับกลุ่มอื่น จึงอาจสรุป ในเบื้องต้นว่า HBO_2 เร่งการกำจัดแลคเตทจากกระแสเลือดและย่นเวลาฟื้นตัวจากอาการกล้ามเนื้อล้า