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Original Article

Blood lactate changes in professional Indian divers under hyperbaric conditions

Surg Cdr Gaurav Sikri^{a,*}, Lt Col S.P. Singh^b, Maj A.B. Srinivasa^c,
Surg Cdr H.B.S. Chaudhry^d

^a Associate Professor, Dept of Physiology, Armed Forces Medical College, Pune 411040, India

^b Professor, Dept of Physiology, Armed Forces Medical College, Pune 411040, India

^c Research Pool Officer, HAMRC, C/O 153 GH, C/O 56 APO, India

^d Classified Specialist (Marine Medicine), INS Satavahana, Naval Base, Visakhapatnam 530014, India

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ABSTRACT

Background: Hyperoxia due to hyperbaric conditions influences lactate metabolism. Previous studies on lactate levels in hyperbaric conditions have reported varied results depending on the depth of evaluation and breathing gas mixture used.

Methods: This study compared post-exercise blood lactate levels of Indian professional male divers (breathing ambient air under normobaric conditions) with their post-exercise blood lactate levels measured under simulated hyperbaric conditions.

Result: In the present study, blood lactate levels in divers were found to have decreased significantly during recovery phase of exercise in hyperbaric conditions of dry diving at 2.8 Atmospheres Absolute (ATA) as compared to normobaric conditions. A significant improvement was observed in physical performance in terms of HR max and duration of exercise.

Conclusion: This study revealed that hyperoxia due to moderate hyperbaric condition leads to improvement in lactate metabolism in muscles and organs (liver and heart) for its removal.

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Introduction

Diving is predominantly associated with sub-maximal exercise intensity involving brief bursts of strenuous activity. This is due to the risks and respiratory limitations inherent to recreational breath-hold and scuba diving. Because of the required waiting periods during ascent from greater depths the major limitations on underwater performance, at least in

recreational diving, leading to fatigue are psychological or perceptual and not physical.^{1,2}

However, military diving for operations, wreck diving for salvage and cave diving for exploration, where divers work in hostile conditions with extended bottom time, are different from recreational diving. Physical limitation of these professional divers may also contribute to fatigue. Traditionally, one of the physical limitations, implicated in fatigue under normobaric conditions, is decline in blood pH produced by lactic acidosis.³

* Corresponding author. Tel.: +91 (0) 8806709800.

E-mail address: dr_gaurav35@gmail.com (G. Sikri).

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There are limited studies on humans which have addressed the issue of changes in blood lactate levels in hyperbaric conditions while breathing air. Hyperbaric conditions leading to hyperoxia and increased work of breathing influence lactate metabolism. Previous studies on lactate levels in hyperbaric conditions have reported varied results depending on the depth of evaluation and breathing gas mixtures used.^{4,5} This study was planned to compare post-exercise blood lactate levels of Indian professional male divers (breathing ambient air under normobaric conditions) with their post-exercise blood lactate levels measured under simulated hyperbaric conditions.

Material and methods

Selection of subjects: 30 serving medically fit divers were randomly selected from the population of professional divers using random number tables and taken as subjects. All divers were actively involved in diving during last 3 years and they indulged in regular moderate exercise as per requirement of their profession. Any diver with any history of medical illness in last 5 years and requiring hospitalization or prolonged medication (beyond one week) were excluded from the study.

Experimental protocol: All subjects were explained the experimental protocol before the start of the study and written informed consent was taken from each subject. Basal resting cardio-respiratory parameters and haemoglobin levels were recorded and documented along the personal details of the individuals. Pulmonary Function Test (PFT) and ECG were recorded for all the subjects. Subjects with any abnormal findings in PFT and ECG were excluded from the study.

Subjects were evaluated twice: first time in normobaric conditions breathing ambient air serving as baseline and second time during dry diving in hyperbaric chamber at 2.8 Atmospheres Absolute (ATA). During pre-diving evaluation, subjects underwent graded exercise with incremental load protocol while breathing ambient air. The load for the exercise was given by using a Bicycle Ergometer (Monark ergomedic 839 E, GIH Sweden). Heart Rate (HR) was measured by using POLAR Wear Link transmitter as part of POLAR RS 400 Heart Rate Monitor (Polar Electro Oy, Finland). Blood Lactate levels were measured during the exercise by using i-STAT Electronic Simulator (i-STAT Corporation USA). Dynamic Spirometry was performed by using Spirobank (Medical International Research Italy).

Pre-diving evaluation of the subjects was done in air conditioned rooms with an ambient temperature ranging from 22 to 25 °C between 0800 h and 1000 h after light breakfast at least 2 h before exercise. Basal Heart Rate (HR), Blood Pressure (BP) and Respiratory Rate (RR) were recorded before the start of the first phase of exercise.

During this visit, ECG recording and PFT were also carried out for the subjects prior to exercise followed by a period of rest after the FVC maneuver. Also, blood samples for haemoglobin estimation were collected before the start of pre-diving exercise bout. Bicycle ergometer was calibrated prior to each session of exercise testing. The exercise protocol was started with 60 W of workload on bicycle ergometer with increase of 30 W after every 2 min while maintaining a constant rpm of 60 during the exercise phase. This phase was stopped when a steady state of respiratory and cardiovascular systems was

achieved (no increase in heart rate observed despite increase in workload) or earlier when subject attained volitional fatigue. Maximum HR (HR max) achieved during the exercise phase along with duration of exercise phase were noted. All subjects were constantly motivated by the observers to continue exercise. The exercise phase was followed by recovery phase of 5 min consisting of cycling on ergometer without load.

Capillary blood lactate levels along with heart rate were measured at 3 min (L3 and HR3) and 5 min (L5 and HR5) of the recovery phase. The subjects underwent evaluation for the same parameters following the same incremental exercise protocol while breathing ambient air on bicycle ergometer in hyperbaric chamber at 2.8 ATA after 7 days. All subjects were instructed to follow their normal exercise routine avoiding unaccustomed physical activity for 7 days till next evaluation was completed. None of the subjects reported any unusual activity during intervening 7 days.

Statistical analysis: All data were expressed in Mean $\pm$ 2 SD. Pre and Post-exercise data were compared using Student's paired 't' test. Statistical significance meant that 'p' value of the statistical test was ≤ 0.05 .

Results

The mean age of the subjects was 29.43 ± 6.82 years. Mean Haemoglobin of the subjects was found to be 13.8 ± 2.32 gm/dl with mean basal HR of 59.73 ± 10.24 beats per minute (bpm), mean basal RR of the subjects was 16.47 ± 2.8 breaths per minute and basal Mean Arterial Pressure was 104.7 ± 8.38 mmHg at the time of inclusion in the study. All subjects had PFT values within normal range for age, gender and ethnicity with no parameters suggesting of either obstructive or restrictive lung disease. ECGs of all subjects were within normal limits with no abnormalities detected. The comparison of mean HR max, L3, HR3, L5, HR5 and duration of exercise under normobaric and hyperbaric conditions (after 7 days) is as per Table 1.

Discussion

In the present study, it was observed that blood lactate levels in divers decreased significantly at 3 min and 5 min of recovery phase of exercise in hyperbaric conditions of dry diving at 2.8 ATA as compared to normobaric conditions. A significant improvement was seen in physical performance in terms of HR max and duration of exercise.

Our findings are similar to a German study carried out at 3 ATA (equivalent to 30MSW depth). They reported significant lower peripheral blood lactate levels at depth for all workloads as compared to control conditions. This significant fall in lactate levels was contribution of overall improvement in lactate metabolism at elevated ambient pressure, especially in the working muscles and the organs responsible for the lactate reduction, i.e., the liver.⁴

Improvement in lactate metabolism under hyperbaric conditions while breathing air was possibly due to the 'extra' 0.86 ml of dissolved Oxygen per 100 ml of blood, assuming 21% Oxygen in the ambient air (Dissolved O₂ = 0.003 ml/dL blood/

Table 1 – Changes in various parameters on exercise in hyperbaric conditions.

	Normobaric (1 ATA)	Hyperbaric (2.8 ATA)	Paired 't' test
Mean HR max (bpm)	155.03 ± 15.34	157.57 ± 14.7	t = 8.43, df = 29*
Mean lactate at 3 min (L3) (mM/L)	9.5 ± 1.32	9.09 ± 1.16	t = 8.2, df = 29*
Mean HR at 3 min (HR3) (bpm)	128.47 ± 19	125.03 ± 19.88	t = 7.17, df = 29*
Mean lactate at 5 min (L5) (mM/L)	8.07 ± 1.12	7.92 ± 1	t = 4.32, df = 29*
Mean HR at 5 min (HR5) (bpm)	86.43 ± 18.6	85.9 ± 16.26	t = 0.89, df = 29 (NS)
Mean duration of exercise (sec)	459.43 ± 74.54	466.83 ± 80.44	t = 6.49, df = 29*

*p ≤ 0.05 (significant); NS = Not significant.
ATA = Atmospheres Absolute; HR = Heart Rate; bpm: beats per minute; mM/L = milli Moles per Litre.

mmHg PO₂). This amounts to 43 ml of additional O₂ in an adult assuming the blood volume to be 5000 ml at rest. Not withstanding the fact that during exercise cardiac output increases substantially which in turn results in delivery of much more amount of Oxygen available at the working muscle for delivery to tissues even if it is assumed that mixed venous saturation is 50%.

It is suggested that the increase in O₂ content helped in delaying the formation and accumulation of lactic acid by alleviating the anaerobic conditions in exercising muscles. Evidence also suggests decreased glycolysis due to improved muscle oxygen content in hyperbaric conditions resulting in fall in lactate levels.⁶

Other suggested mechanisms leading to the lower blood lactate levels during recovery phase in our physically fit professional divers is increased activity of Lactate dehydrogenase (LDH) enzyme leading to rapid lactate clearance but this requires further elucidation. Activity of this enzyme has been studied in physically fit individuals and was found to be significantly higher in hyperoxic conditions.⁷

In conclusion, this study revealed that hyperoxia achieved due to moderate hyperbaric condition leads to improvement in lactate metabolism in muscles and organs (liver and heart) for its removal. On account of lower blood lactate levels observed after graded exercise under hyperbaric conditions in the present study it is suggested that lactate accumulation after exercise may not be responsible for perception of fatigue by military divers after diving. Other factors attributable to fatigue in literature like increased potassium levels, rise in body temperature and fluid loss could be leading to perception of fatigue but that will require further evaluation by undertaking more studies in allied settings.

Nevertheless, the effect of this phenomenon at moderate depth needs to be assessed on diving performance of Indian professional divers in the form of field studies. Also, studies on the effect of hyperoxic gas mixtures on disappearance of lactate during exercise recovery can pave way for better understanding of interaction between blood lactate levels and dissolved blood oxygen content.

Conflicts of interest

All authors have none to declare.

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