Assessment Of Physiological Cardio respiratory Parameters During Sub maximal Exercise On Acute Exposure To Normobaric Hypoxia In Healthy Young Males

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Abstract

To estimate changes in SBP, DBP, HR, RR and Lactate Level at Near Sea Level (NSL) and at Simulated altitude (3000meters) at rest and during sub-maximal exercise. Mean Resting values at NSL vs. Hypoxic Chamber were: SBP (127±6vs132±5mmHg), DBP (70±3vs78±6mmHg), HR (72±5vs80±6bpm), RR (25±4vs29±3/min) and LL (2.1±0.35vs2.5±0.42mmol/l). Similarly, mean values at the end of exercise were: SBP (152±9vs169±13mmHg), DBP (83±6vs92±6mmHg), HR (134±12vs155±7bpm), RR (35±6vs51±6/min) and LL (7.11±0.89vs8.01±1.03mmol/l). A significant difference exists in mean resting values of SBP, DBP, HR and RR at NSL and on acute exposure to Normobaric Hypoxia. Sub-maximal exercise in hypoxic conditions appears to depend more on anaerobic metabolism and results in greater sympathetic activity.

Keywords: Cardiorespiratory parameters, Normobaric hypoxia, Sub-maximal exercise, Near Sea Level

Introduction

Exercise and sports has been a fundamental aspect of human life since times immemorial. This could be attributed to the maintenance of physical fitness, entertainment purpose or the modern days craze in glamorous career in sports and the intense desire to be the winner. The human race in its search for a mere challenge has always looked to the mountains as a source of adventure. Thus a large numbers of mountaineers, trekkers, skiers and white water rafting enthusiasts visit high altitude areas every year to indulge in these sports. Exercising and sporting at high altitude has always been a challenge where performance is affected due to hypoxia [1]. With an increasing number of sports tourists and also increasing commercial and military activities at high altitude, interests in the
human physiological responses to high altitude are increasing. Human bodies respond to hypoxia in various ways. Among the most obvious and important are the cardio respiratory changes.

When acutely exposed to a hypoxic environment, all functional systems of the body are affected. Various adjustments in cardiorespiratory system include changes in heart rate, blood pressure, ventilation and oxygen uptake [2]. These parameters vary depending on the exposure to altitude. Ascent to high altitude (hypoxia) leads to an immediate decrease in aerobic exercise capacity [3,4]. With prolonged exposure, endurance for the sub maximal exercise improves but the maximal aerobic capacity does not change [5]. Exposure to hypoxia also causes changes in ventilation. After an initial rise, ventilation continues to increase over 10-14 days due to increasing sensitivity of the peripheral chemoreceptor to hypoxia [1, 5].

Physiological response to exertion on exposure to hypoxia may vary among different populations. It depends upon previous exposure, fitness level, ethnic groups, genetics and the degree of hypoxia [6,7]. Many studies have been done in the white populations on cardiorespiratory response on exposure to high altitude [4,5,7,8,9,10]. However, there are very few studies regarding the physiological cardiorespiratory changes during hypoxic exertion in Asian Indians. This particular study is in Asian Indian healthy young males. The objective of the study was to assess the HR, BP, Lactate Level and RR at rest and during exercise at near sea level, then on exposure to normobaric hypoxia (simulated for 10000 feet).

**Methods**

1) Place of study: Department of physiology in collaboration with An Sports Institute.

2) Study population: Asian-Indian males aged 18-35 yrs. old.

3) Sample size: 30

4) Period of study: 18 months (Nov, 2011 to May, 2013)

5) Study design: Experimental study.

6) Inclusion criteria:
   a) Apparently healthy males (healthy on general examination)
   b) Age of subjects with range from 18-35 yrs. old.

7) Exclusion criteria
   b. Any acute injury to muscles, ligaments and joints.
   c. History and treatment of any psychiatric disorder.
   d. History of major surgical intervention.

8) Secondary exclusion criteria: Subjects shall not perform the exercise at simulated 10,000 feet if, before onset of exercise they have any of the following.
   1) Lake Louis score ≥3.
   2) Complain of dyspnea, Giddiness at rest.
   3) Blood pressure > 160/100 mmHg.

**Procedure And Protocols**

a) Subjects reported to the laboratory between 14:00-16:00 Hr. on the day of the test.
b) The procedure of the test was explained to the subjects prior to testing.
c) Written informed consent was taken.
d) Subjects were told to have a light meal 2 hours prior to the exercise tests.

Exercise Protocol
Subjects had undergone 3 exercise tests sessions.
1. Session I: At Near Sea Level (NSL).
   All subjects performed a maximal exercise test on a bicycle ergometer.
2. Session II: At Near Sea Level (NSL).
   All subjects performed sub maximal exercise (≈60% of the VO\textsubscript{2}max as assessed in session I.)
3. Session III: All Subjects exposed to 4 hours of Normobaric Hypoxia equivalent to 10,000 feet in a hypoxic chamber. Each performed a Bicycle Ergometer exercise test to ≈60% of VO\textsubscript{2}max for 10,000 feet in the 4\textsuperscript{th} hour of exposure. The VO\textsubscript{2} max for 10,000 feet was calculated as 85% of VO\textsubscript{2} max at sea level.
4. The three exercise sessions were at least 72 hours apart.

Exercise protocol for session I
Subjects underwent standard warm-up exercise before the test. (Slightly sweating and not panting or 10-12min running in tread mill at 6-8 km/hr.)

   a) Subject started the exercise with 50 watts for 2 minutes and then increased 25 watts every 2 minutes until exhaustion.
   b) Serial measurements of lactic acid were done by use of Lactate Pro Test Strips.
   c) BP, HR, RR were monitored during the end of each stage.

Exercise protocol for session II
Subjects performed the same procedures as session I, but the exercise was terminated when ≈60% of VO\textsubscript{2} max was achieved.

Exercise protocol for session III
All the subjects entered the normobaric hypoxia chamber capable of simulating altitude up to 6000 meters. They were exposed to only 10,000 feet (3000 meters.) for 4 hrs. The exercise test was performed in the last hour of exposure to 10,000 feet.

   a) General Examination and Respiratory system examination was done for all subjects before and after the exercise at (simulated 10000 feet)
   b) HR, BP, RR and Lactate Level were measured before the entry into the normobaric chamber and every 30 minutes then after until decent to near sea level.
   c) Subjects performed the same graded incremental protocol using the Bicycle Ergometer but were allowed to exercise only up to ≈60% of the predicted VO\textsubscript{2} max. for the simulated altitude.

Exercise Stoppage Criteria (applied for all exercise sessions)
1) BP increases ≥200/120 mmHg.
2) Irregular pulse.
3) Complains of headache, dyspnea, giddiness, chest pain, and muscle cramps.
4) Subject inability to carry on the exercise.

**Statistical analysis**

Student’s paired t-test was done to find out the mean difference between various cardiorespiratory parameters measured at Near Sea Level and in Hypoxic Chamber. P value <0.05 was considered to be statistically significant.

**RESULTS**

Following are the cardiorespiratory parameters measured at rest and during exercise on Bicycle Ergometer at Near Sea Level and in Normobaric Hypoxia chamber. A significant difference (P<0.05) between the parameters at rest and during incremental exercise is observed. All the parameters were measured during the end of each stage of the exercise.

**HEART RATE:** HR was measured using the polar Heart Rate chest strap (Fig. A). Mean Heart Rate at Rest and during Different Stages of Exercise showed to be significantly higher (P<0.05) in the simulated altitude as shown in Table 1 and depicted in the graph.

| Table-1: Mean Heart Rate (±SD) (BPM) at Rest and during Different Stages of Exercise. |
|-----------------------------------------------|---|---|---|---|---|---|---|
| NSL   | IIR-0 | 72±5 | 81±7 | 92±10 | 102±12 | 116±12 | 125±12 | 134±12 |
| HC    | 80±6  | 91±9 | 103±10 | 102±13 | 129±9 | 142±11 | 155±7 |
| P value | 0.0017 | 0.0005 | 0.0056 | 0.0037 | 0.0079 | 0.0051 | 0.0001 |

P < 0.05 is significant

**Blood Pressure:** BP was measured using the Omron automatic electronic BP measuring machine (Fig. B). Mean DBP was higher at the Hypoxic Chamber but the increase was not progressive with the increase in the exercise intensity (table 3 and graph). Mean SBP was seen to be significantly higher in the simulated
altitude as shown in table 4 and the graph.

Table-2: Diastolic Blood Pressure (±SD) (mmHg) at Rest and during different Stages of Exercise.

<table>
<thead>
<tr>
<th></th>
<th>DBP-0</th>
<th>DBP-1</th>
<th>DBP-2</th>
<th>DBP-3</th>
<th>DBP-4</th>
<th>DBP-5</th>
<th>DBP-6</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSL</td>
<td>70±3</td>
<td>72±3</td>
<td>75±4</td>
<td>75±5</td>
<td>76±3</td>
<td>80±5</td>
<td>83±6</td>
</tr>
<tr>
<td>HC</td>
<td>78±6</td>
<td>81±3</td>
<td>85±12</td>
<td>88±11</td>
<td>89±7</td>
<td>90±6</td>
<td>92±6</td>
</tr>
<tr>
<td><strong>P value</strong></td>
<td>0.0094</td>
<td>0.0077</td>
<td>0.0227</td>
<td>0.0127</td>
<td>0.0018</td>
<td>0.0022</td>
<td>0.0105</td>
</tr>
</tbody>
</table>

P value < 0.05 is significant

Table-3: Systolic Blood Pressure (±SD) (mmHg) at Rest and during different Stages of Exercise.

<table>
<thead>
<tr>
<th></th>
<th>SBP-0</th>
<th>SBP-1</th>
<th>SBP-2</th>
<th>SBP-3</th>
<th>SBP-4</th>
<th>SBP-5</th>
<th>SBP-6</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSL</td>
<td>127±6</td>
<td>128±6</td>
<td>134±7</td>
<td>136±19</td>
<td>142±7</td>
<td>150±7</td>
<td>152±9</td>
</tr>
<tr>
<td>HC</td>
<td>132±5</td>
<td>136±13</td>
<td>148±19</td>
<td>151±16</td>
<td>159±18</td>
<td>164±15</td>
<td>169±13</td>
</tr>
<tr>
<td><strong>P value</strong></td>
<td>0.0047</td>
<td>0.1177</td>
<td>0.0675</td>
<td>0.0513</td>
<td>0.0547</td>
<td>0.0283</td>
<td>0.0034</td>
</tr>
</tbody>
</table>

P value < 0.05 is significant
Respiratory Rate: Using Stethoscope and visualizing the chest movement, RR was measured. In all the subjects Respiratory frequency in the hypoxic chamber was significantly increased compared to the Near Sea Level (table 4 and graph).

Table-4:Mean Respiratory Rate (±SD) (per minute) at Rest and during different Stages of Exercise

<table>
<thead>
<tr>
<th></th>
<th>RR-0</th>
<th>RR-1</th>
<th>RR-2</th>
<th>RR-3</th>
<th>RR-4</th>
<th>RR-5</th>
<th>RR-6</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSL</td>
<td>25±4</td>
<td>24±5</td>
<td>26±5</td>
<td>28±6</td>
<td>30±5</td>
<td>33±6</td>
<td>35±6</td>
</tr>
<tr>
<td>HC</td>
<td>29±4</td>
<td>30±5</td>
<td>34±6</td>
<td>38±7</td>
<td>42±5</td>
<td>49±7</td>
<td>51±6</td>
</tr>
<tr>
<td>P value</td>
<td>0.0122</td>
<td>0.0024</td>
<td>0.0081</td>
<td>0.0034</td>
<td>0.0056</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

P value <0.05 is significant

Lactate Level: LL was measured using the Nova Lactate Plus Test Strips (Nova Biomedical Waltham, MA 02454 USA). Most of the subjects had significantly increased lactate level at rest and during exercise in the hypoxic chamber (table 5). However, 3 of the subjects who had been exposed to the chamber intermittently since 4 days showed little change in their lactate level.
Table 5: Mean Lactate Level (±SD) (mmol/L) at Rest and during different Stages of Exercise.

<table>
<thead>
<tr>
<th></th>
<th>LL-0</th>
<th>LL-1</th>
<th>LL-2</th>
<th>LL-3</th>
<th>LL-4</th>
<th>LL-5</th>
<th>LL-6</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSL</td>
<td>2.1±0.35</td>
<td>2.3±0.42</td>
<td>3.1±0.48</td>
<td>3.9±0.42</td>
<td>4.54±0.49</td>
<td>5.67±0.68</td>
<td>7.11±0.89</td>
</tr>
<tr>
<td>HC</td>
<td>2.49±0.42</td>
<td>2.81±0.59</td>
<td>3.81±0.71</td>
<td>4.56±0.89</td>
<td>5.56±0.89</td>
<td>6.54±0.65</td>
<td>8.01±1.03</td>
</tr>
<tr>
<td>P value</td>
<td>0.0014</td>
<td>0.0007</td>
<td>0.0044</td>
<td>0.0258</td>
<td>0.0008</td>
<td>0.0049</td>
<td>0.0148</td>
</tr>
</tbody>
</table>

P value < 0.05 is significant

Mean Lactate Level at Rest and during Exercise stages

![Graph showing lactate level at rest and during exercise stages]

Fig. C. Lactate plus (for measuring lactate level)

Discussion

It is well observed in studies done in Caucasians and other populations that the exercise capacity decreases on acute exposure to high altitude [4,38]. This varies among different populations, ethnic groups, genetics and people previously exposed to high altitude [6,7]. This study is particularly in Asian Indian healthy young males. In the present study it was observed that a significant difference exists in mean resting values of SBP, DBP, HR, RR and Lactate Level at NSL and on acute exposure to Normobaric Hypoxia. Sub-maximal exercise in hypoxic conditions appears to depend more on anaerobic metabolism and results in greater sympathetic activity.

The physiologic challenge of even medium altitude becomes readily apparent during physical activity. Altitudes challenge comes directly from the decreased ambient Po2 rather than the total reduced barometric pressure per se or any change in relative concentrations (percentage) of gases in inspired air [15,16]. The progressive changes in the environments oxygen pressure and in various body areas is termed “oxygen transport cascade”. The reduction in Po2 and accompanying arterial hypoxia precipitates the immediate physiologic adjustments to altitude and longer-term acclimatization [4,8,17].

The hypoxic cardiorespiratory response is a complex interplay between several distinct mechanisms, and specialized chemoreceptor cells that regulate
cardiovascular and ventilatory response sense the $O_2$ level decrease [1,18,19]. The normal hemodynamic response to acute hypoxia consists of an increase in HR and a modulation of the vascular tone, with vasodilatation of peripheral vessels and constriction of the vessels of the pulmonary vasculature to shunt blood away from the poorly ventilated region [1,20,21,22]. In the study subjects the increase in HR is prompt. This confirms that small reductions in $PaO_2$ are detected by peripheral chemoreceptors eliciting the sympathetic chemo reflex [14,19]. On the ventilatory side, the normal response consists of a gradual increase in ventilation that intensifies over the following hours and days [2,5].

Many authors have described a rise in the sympathetic tone or a vagal withdrawal in response to acute exposure to hypoxia at rest [1,13,14]. The data obtained in this study also reflected these responses.

A study done by Michele M Ciulla et al on effects of simulated altitude (Normobaric hypoxia-4850m) on cardiorespiratory parameters showed increase in Heart Rate but arterial pressure and respiratory response were unaffected [4].

In this study, the lactate level at rest in both the conditions (NSL and Hypoxic Chamber) were only slightly different. But the lactate level progressively increased with the incremental exercise in the Bicycle Ergometer. It is significantly higher during the submaximal exercise in the Hypoxic Chamber suggesting the dependence on anaerobic metabolism. Anaerobic glycolysis supplements the aerobic ATP-regenerating mechanism resulting in increase in the lactate level when aerobic regeneration of ATP is partially limited by an inadequate oxygen supply.

The wide range of oxygen tensions found in healthy tissue makes it difficult to establish a universal value to define hypoxia. The medical definition of high altitude consists in an elevation of 2700–5500 m above sea level [2]. In our study we have set the $FiO_2$ equivalent to an altitude of 3000 meters. This Cardiorespiratory response might be used for studies aimed to predict the adverse effects of high altitude in Asian Indian populations.

**Conclusion**

A significant difference exists in mean resting values of SBP, DBP, HR, RR and Lactate Level at NSL and on acute exposure to Normobaric Hypoxia. Sub-maximal exercise in hypoxic conditions appears to depend more on anaerobic metabolism and results in greater sympathetic activity.

**Acknowledgement**

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References


