Effect of prolonged exercise in a hypoxic environment on cardiac function and cardiac troponin T

R E Shave, E Dawson, G Whyte, K George, D Gaze, P Collinson


Background: Exercise induced cardiac fatigue has recently been observed after prolonged exercise. A moderate to high altitude has been suggested as a possible stimulus in the genesis of such cardiac fatigue.

Objective: To investigate if exercise induced cardiac fatigue and or cardiac damage occurs after prolonged exercise in a hypoxic environment.

Methods: Eight trained male volunteers completed the study (mean (SD) age 33.5 (8.8) years, height 1.79 (0.08) m, body mass 77.7 (8.3) kg, VO2-max, 67.4 (6.3) ml/kg/min). After ethical consent. The subjects completed two 50 mile cycle trials on a normobaric hypoxic trial was completed in a commercially available hypoxic chamber (Edge4 Ltd, London, UK). Within the chamber, the hypoxic environment is generated by a nitrogen dilution technique, which maintains a constant FiO2 of 15% (simulating an altitude of about 2500 m). Subjects were not blinded to the conditions. Echocardiographic assessments and whole blood (venous) collection was completed before the start of exercise, immediately after exercise, and then again 24 hours after exercise, all in normobaric normoxic conditions.

Echocardiographic assessment was completed using a Hewlett-Packard HP Sonos 1000 (2.5 MHz transducer) with simultaneous electrocardiograph recordings. M-Mode images were taken to measure wall and cavity dimensions during both systole and diastole. Variables of systolic function (fractional shortening (FS), stroke volume (SV) and cardiac output (Q)) were calculated using the measurements obtained during M-mode examination. At the time of echocardiographic assessment, blood pressure was measured by standard auscultation techniques. Left ventricular meridional wall stress was calculated as a measure of left ventricular afterload using the formula of Reichek et al.14 Pulsed wave Doppler interrogation of mitral valve inflow velocities was performed to assess diastolic function. Peak early filling (E wave, cm⁻¹) and peak late filling (A wave, cm⁻¹) velocities were measured, and the ratio of early to late diastolic filling (E:A) was calculated.

Whole blood samples (5 ml) were drawn from an antecubital vein and allowed to clot. They were then centrifuged, and the serum was drawn off and frozen (−20°C) for later analysis. Serum samples were assayed for cardiac troponin T (cTnT) using electrochemiluminescence technology in an Elecsys 1010 automated batch analyser (Roche Diagnostics, Mannheim, Germany).

SV, FS, Q, E, A, and E:A were statistically analysed using a two way repeated measures analysis of variance, with α set at 0.05. Differences in completion time were analysed using Student’s t tests. cTnT was analysed descriptively.

RESULTS

Completion times for the normobaric hypoxic and normobaric normoxic trials were not significantly different (mean (SD) 125 (6) v 126 (7) min respectively). No significant differences were observed across time or between trials for SV, FS, E, A, or E:A (table 1). Q was significantly raised immediately after exercise in both trials (p<0.05); no difference was observed between trials. cTnT was increased

METHODS

Eight trained male volunteers completed the study (mean (SD) age 33.5 (8.8) years, height 1.79 (0.08) m, body mass 77.7 (8.3) kg, VO2-max, 67.4 (6.3) ml/kg/min). After ethical approval from the universities’ ethics committees and before the start of the study, each subject provided written informed consent. The subjects completed two 50 mile cycle trials on a Kingcycle training rig (Kingcycle, High Wycombe, Buckinghamshire, UK), randomly assigned from normobaric normoxia and normobaric hypoxia and separated by 14 days. The trials were completed at an intensity equivalent to lactate threshold (previously determined in normobard normoxia). Temperature was controlled during both trials (21°C). The hypoxic trial was completed in a commercially available hypoxic chamber (Edge4 Ltd, London, UK). Within the chamber, the hypoxic environment is generated by a nitrogen dilution technique, which maintains a constant FiO2 of 15% (simulating an altitude of about 2500 m). Subjects were not blinded to the conditions. Echocardiographic assessments and whole blood (venous) collection was completed before the start of exercise, immediately after exercise, and then again 24 hours after exercise, all in normobaric normoxic conditions.

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Abbreviations: cTnT, cardiac troponin T; EICF, exercise induced cardiac fatigue; FS, fractional shortening; Q, cardiac output; SV, stroke volume
Cardiac function after exercise in a hypoxic environment

The results of this study suggest that 50 miles of cycling at an intensity equivalent to lactate threshold in either normobaric normoxia or normobaric hypoxia does not induce reductions in either left ventricular systolic or diastolic function. The impact of altered heart rates on serial measurements of diastolic function has been debated. In the present study, minimal release of cTnT after prolonged exercise has been shown in a limited number of subjects in previous studies. \( \text{cTnT} \) release after prolonged exercise cannot be elucidated. It is possible that such cytosolic leakage may be caused by free radical mediated injury, and as such may explain why the cTnT release in this study was only observed in the normobaric hypoxic trial where free radical production would be increased. It is noteworthy that any suggestions of the potential mechanisms responsible for such cTnT release are only speculative. It is not suggestive of acute myocardial infarction, but rather represents a level of minor cardiac damage. Further work is warranted into the factors that may interact to induce minimal cardiac damage in certain people.

**CONCLUSIONS**

A 50 mile cycle trial at lactate threshold in either normobaric normoxia or normobaric hypoxia does not induce cardiac dysfunction or evidence of cardiac damage in most subjects. Some, however, may show evidence of minimal cardiac damage. Further work is warranted into the factors that may interact to induce minimal cardiac damage in certain people.

**Take home message**

Two hours of vigorous exercise in either a normobaric hypoxic or normobaric normoxic environment in trained subjects does not produce exercise induced cardiac fatigue. Minimal cTnT release may, however, be observed in some subjects, the long term implications of which are yet to be elucidated.

**Table 1**

<table>
<thead>
<tr>
<th>Echocardiographic and humoral variables before, after, and 24 hours after exercise in normobaric normoxia and normobaric hypoxia</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Normoxic</strong></td>
</tr>
<tr>
<td><strong>Before</strong></td>
</tr>
<tr>
<td>SV (ml)</td>
</tr>
<tr>
<td>Q (l/min)</td>
</tr>
<tr>
<td>FS (%)</td>
</tr>
<tr>
<td>E wave (cm⁻¹)</td>
</tr>
<tr>
<td>A wave (cm⁻¹)</td>
</tr>
<tr>
<td>E/A</td>
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<tr>
<td>HR (beats/min)</td>
</tr>
<tr>
<td>BP (mm Hg)</td>
</tr>
<tr>
<td>Diastolic</td>
</tr>
<tr>
<td>LVMWS (g/cm²)</td>
</tr>
<tr>
<td>LVDD (cm)</td>
</tr>
<tr>
<td>Myoglobin (μg/ml)</td>
</tr>
<tr>
<td>CK-MB (μg/l)</td>
</tr>
<tr>
<td>cTnT (no of positive results)</td>
</tr>
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</table>

Values are mean (SD).

*Significantly different from values obtained before exercise (p < 0.05).

HR, Heart rate; BP, blood pressure; CK-MB, creatine kinase-myocardial band; cTnT, cardiac troponin T; LVDD, left ventricular internal diameter in diastole; LVMWS, left ventricular meridional wall stress; FS, fractional shortening; Q, cardiac output; SV, stroke volume; E wave, peak early filling; A wave, peak late filling; E/A, early to late diastolic filling.
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Accepted 14 January 2003

REFERENCES


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doi: 10.1136/bjsm.2002.002832