Physical Work Expenditure of Mars Analogue Mission Crew Members

Abstract

Ever since humans began having a presence in space it has been observed that exposure to a microgravity environment initiates a series of adaptations of physiological systems. These adaptations, while appropriate in microgravity, are deleterious and potentially hazardous on return to planetary gravitational fields. These adaptations include: muscle atrophy, cardiovascular deconditioning, orthostatic intolerance, and bone demineralization. In order to counteract these deconditioning effects several countermeasures have been proposed most notably physical exercise. Extravehicular activity (EVA) requires the crew member to engage in stressful and strenuous physical activity (work). No studies to date have quantified or qualified the work done during EVA in a Mars analogue setting. Understanding the work output involved and its effects on various physiologic systems during Mars analogue EVA will help in determining the physical fitness requirements of future planetary explorers upon arrival at their destination. This study will monitor heart rate, oxygen consumption, carbon dioxide production, and core and skin temperature during routine and emergency EVA via remote sensing. Continuing study in this area will help determine a suitable exercise regimen for crew members during long flights.

Literature Review

Space flight has been shown to initiate many physiological adaptations including, but not limited to, muscle atrophy [1], bone demineralization [2], cardiovascular deconditioning [3], and orthostatic intolerance [4]. These events have been linked to reduced gravitational stress on their associated biological systems and can be reproduced to a great extent by strict bed rest at a 6° head down tilt [5]. The duration of microgravity (real or simulated) seems to correlate positively with the degree of adaptation [6,7]. In order to lessen the adaptive effects of space flight many countermeasures have been suggested and implemented. A countermeasure that has been used extensively by the Russian and US space programs is physical exercise and it has been shown that heavy exercise can lessen the effects of microgravity on muscle and cardiovascular deconditioning [8-10]. It is well documented, from data collected on the MIR, Skylab and International space stations, that extravehicular activity (EVA) exposes the crew member to substantial physical stress [11,12]. Use of EVA suits during Mars analogue work, particularly those with helmets exhibiting poor ventilation, has been reported to cause increased exertion, expressed as heart rate response, during bouts of physical work [13]. It is of utmost importance that the crew of a craft that is to land on Mars be physically fit in order to handle their work tasks and to be prepared for possible emergency situations. A journey to Mars will take months to complete and as such an appropriate exercise regime must be in place to ensure the safety and productivity of the crew.

Problem Statement

To date there has been no evaluation made of the physical work involved in Mars analogue EVA activity. In order to prescribe an appropriate exercise protocol for interplanetary crew members, fitness criteria must be clearly defined.

Methodology

Study participants will undertake exercise testing on a treadmill or cycle ergometer before the mission to determine maximal oxygen (VO_2 max) and work capacity. During the mission the following data will be collected continuously before, during, and after EVA:

1. Oxygen consumption and carbon dioxide production collected on a portable gas analyzer. These data will give an indication as to the crew members' aerobic and anaerobic work output.
2. Heart rate will be collected by a personal heart rate monitor.
3. Core temperature will be collected by an ingestible core temperature probe.
4. Skin temperature will be collected by remote temperature sensing patches.
5. Perceived degree of exertion will be reported by the crew member using the Borg rate of perceived exertion scale [14].

Data collected will then be downloaded to a PC/laptop for subsequent analysis.

Proposed Analyses

Analysis will consist of determining the aerobic and anaerobic components of work during Mars analogue EVA during routine and emergency procedures. Also of interest will be the degree of heat stress associated with work performed while wearing Mars analogue EVA suits.

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