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Evaluation of External Cardiac Massage Performance During Hypogravity Simulation

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INTRODUCTION

Preservation of astronaut crew health during an exploration mission to the Moon or Mars will be crucial to mission success. The likelihood of a life-threatening medical condition occuring during a mission to Mars has been estimated by NASA to be 1% per year (Johnston, 1998; Johnston, Campbell, Billica, & Gilmore, 2004). Since basic life support is a vital skill in critical care medicine, plans must be in place for cardiopulmonary resuscitation in both microgravity and hypogravity (i.e., on the surface of the Moon or Mars).

Following the design of a body suspension device to simulate a hypogravity environment, subjects performed external chest compressions in 1G, 0.17G (Lunar), 0.38G (Mars), and 0.7G (Planet X). Chest compression adequacy was assessed by means of rate and depth. Heart rate immediately before and after three minutes of chest compression gave a measure of rescuer fatigue. Elbow flexion was measured using an electrogoniometer in order to assess the use of arm muscles to achieve chest compressions.

This study found that the mean depth (Lunar and Mars) and rate (Mars) of chest compression was below American Heart Association recommendations during hypogravity simulation in the female group. Furthermore, elbow flexion proved to be significantly greater during Lunar and Mars hypogravity simulation than that of the 1G control condition, suggesting that upper arm force may be used to counter the loss of body weight in an attempt to maintain adequate chest compression under these conditions.

BACKGROUND

A new initiative announced by the United States aims to resume manned lunar expeditions with a landing planned for 2015, and ultimately a manned mission to Mars (White House Press Secretary, 2004). Japan's long-term vision resembles those of U.S. President George W. Bush and European space officials, who hope to land astronauts and robots on the Moon as a first step to sending a manned space mission to Mars

(Exploration of Mars and the Moon, 2006; Future of Human Space Flight, 2006). Over the next decade, the Japan Aerospace Exploration Agency (JAXA) plans to call for scientists to develop robots and nanotechnology for surveys of the Moon and design a rocket and space vessel capable of carrying cargo and passengers. By 2015, JAXA will review whether it is ready to pour resources into manned space travel, possibly building a base on the Moon. A decision to try for Mars and other planets would be made after 2025 (Japan Space Flight History, 2005). Plans regarding manned trips to the Moon and Mars are not restricted to the United States and Japan. European and Russian scientists have set out a route map for manned missions to Mars that aims to land astronauts on the Red Planet in less than 30 years. A human mission to the Moon, proposed for 2024, would demonstrate key life-support and habitation technologies, as well as aspects of crew performance and adaptation to long-distance space flight. The ESA has planned two flagship missions to Mars-ExoMars that would land a rover on the planet in 2009, and Mars Sample Return would bring back a sample of the Martian surface in 2011-2014. Other test missions will include an unmanned version of the flight that would eventually carry astronauts to Mars (ESA, 2006).

The diagnosis and treatment of acute and chronic medical conditions have been identified by all space agencies as one of the highest priorities for both current orbital space flight and future exploration class missions to the Moon and Mars. In particular, there is a need for evidence-based guidelines and techniques for management of medical emergencies during such missions. To date, all mortalities in space flight have been the consequence of sudden catastrophic technological failures, which have left no opportunity for corrective action (Telemedical Emergency Management, 2004). However, significant morbidity has occurred, including type I decompression sickness (Apollo 11), urinary tract infection (Apollo 13), cardiac arrhythmias (Apollo 15, Mir station 1987), N_2O_4 pneumonitis (Apollo-Soyuz test project), and prostatitis, sepsis, and hypothermia (Salyut 7). These health issues have thus far not required advanced life support measures but have on occasion required the prophylactic deorbiting of the crew member (Telemedical Emergency Management, 2004).

A higher incidence of acute and life-threatening medical problems may be anticipated with the increasingly longer space missions and extravehicular activity requiring increased physical labor as developmental activity in space progresses. In addition, selection criteria in terms of age and health are in many ways less stringent than those of the early days of human space flight. Thus the rare but potential likelihood of serious medical incidents, such as a life-threatening cardiac event, must be anticipated and adequately prepared for.

Cardiac arrest can be in the form of asystole, pulseless ventricular fibrillation or electromechanical dissociation, which are the results of primary cardiac diseases such as coronary artery disease or a cardiomyopathy, trauma, or secondary to diseases of other systems (e.g., respiratory failure). Since its introduction in the 1960s (Safar, 1961), modern cardiopulmonary resuscitation (CPR) with manual chest compressions at its foundation has been shown to improve survival after cardiac arrest (Cummins, Eisenberg, Hallstrom & Litwin, 1985; Ritter et al., 1985). Many studies have confirmed the haemodynamic significance of delivering consistent, high quality, infrequently interrupted chest compressions (Wiggington, Miller, Benitez & Pepe, 2005).

Basic life support and CPR are essential features of current astronaut training. NASA astronauts are currently trained in two techniques. The first utilizes the Crew Medical Restraint System on the International Space Station to restrain both patient and provider so that chest compressions are performed in a manner similar to the standard terrestrial method. The second is the so-called Hand Stand method (Hamilton, 2003; Jay, Lee, Goldsmith, Battat, Jaurrer & Suner, 2003). These and other available options, such as the Evetts-Russomano technique (Evetts, 2004; Evetts, Evetts, Russomano, Castro, & Ernsting, 2004; Evetts, Evetts, Russomano, Castro, & Ernsting, 2005) developed by the King's College London, UK, and the Microgravity Laboratory PUCRS, Brazil, have been based on previous and ongoing research to address the need to perform CPR in orbital microgravity. In this environment, the delivery of rescue breaths does not present a major technical problem. The main challenge is the application of sufficient force to the victim's chest in the absence of weight, which provides the main source of compression force under the standard terrestrial method. In the absence of data to suggest alternative requirements, all the above methods have aimed to match the terrestrial standards of CPR set by the American Heart Association (2006) and the European Resuscitation Council (Handley, Monsierus, & Bossaert, 2001).

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