

Stress, Workload and Physiology Demand During Extravehicular Activity: A Pilot Study

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Abstract

Background: Extravehicular activity (EVA), such as exercise performed under unique environmental conditions, is essential for supporting daily living in weightlessness and for further space exploration like long Mars mission. **Aim:** The study was planned stress, workload, and physiological demands of simulated Mars exploration. **Materials and Methods:** In this study, the six-person crew lived (24 hours) for 14 days during a short-term stay at the Mars Desert Research Station. The heart rates, salivary cortisol, workload, peak oxygen uptake or maximal aerobic capacity of the crew are measured before, during and after an EVA. **Results:** Data for heart rate showed the same trend as peak oxygen uptake or maximal aerobic capacity, with a maximal increase to 85% of peak. The rating of subscale showed a significant increase in EVA as compared to run. Salivary cortisol levels and heart rates were increased in both groups, although significant increased of cortisol levels and heart rates more in EVA as compared to hill running crew members. **Conclusion:** Further study is required on large scale taken into account of limitations of this study and including other physiological and psychological parameters in Mars analog environment.

Keywords: Cortisol, Extravehicular activity, Heart rate, Peak oxygen uptake, Saliva, Stress

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Introduction

Long duration space flights expose human body to microgravity which affects the physiological health drastically. Some of the physiological effects that result from human space flights are bone loss, muscle atrophy, cardiovascular deconditioning, altered sensory motor reactions, fluid redistribution/orthostatic intolerance, etc.^[1] In order to counteract these changes and increase astronaut performance in orbit, cardio vascular exercises as well as resistive exercises has been made a part of the International Space Station missions.^[2] It has been evident that extravehicular activity (EVA) exposes the

crew member to substantial physical stress.^[3] EVA intense activities increase the workload and stress levels of the astronauts. 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 and stress levels response, during short period of physical work.^[4] It is of utmost importance that the crew of aircraft that is to land on Mars should possess adequate physical fitness in order to handle their work tasks and to be prepared for possible emergency situations. Hence, the astronauts need to be physically fit and be capable of performing intense activities. It is known that heart rate and cortisol are one of the parameters that can be measured to know the stress levels.^[5-7]

In the present study we characterized the physiological cost of Mars analogue EVA work by outfitting crew members with a portable expired gas analysis system during training EVA sessions. Also, to find out the correlation between heart rates, stress and cortisol levels, the heart rates, cortisol and workload during EVA.

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Materials and Methods

The six-crew members were selected from 100B ILEWG EuroMoonMars during MDRS (Mars Desert Research Station), Utah, USA. The ages for the crew members ($n = 6$) aged 20-26 [23.6 (2.4)] years. The average and calcium intake of the crew members during mission was 2400 kcal/day (range 2090-3200 kcal/day) and 1267 mg/day (1130-1400 mg/day), respectively. Dietary sodium and potassium intake were maintained at 98 (80-103) and 86 (75-120) mmol/day, respectively. Water intake was ad libitum 1236 (68) ml/day (940-1590) ml/day. Each subject gave written, informed consent for this study which was approved. Each crew members was outfitted for gas analysis during two EVA excursions and two graded hill runs, each performed on a separate day. The EVA excursions were for the purpose of training the crew for geological surveying, were between one and two hours in duration, and were performed while wearing the Mars EVA suit provided for at the Mars Desert Research Station (Mars Society, USA). The hill runs consisted of continually running up and down a 200 m hill path (10% grade). Peak was increased every two minutes at the encouragement of a principal investigator (BR) and the participant was instructed to run until exhaustion. The peak 10 second mean value recorded over the two hill sessions was taken to represent VO_2 peak (peak oxygen uptake or maximal aerobic capacity). Aerobic energy expenditure determined by measured oxygen consumption (VO_2) during EVA sessions was compared relative to peak oxygen consumption (VO_2 peak) recorded during graded hill runs performed on 14 separate days. The heart rates, cortisol, VO_2 of the crew are measured before, during and after an EVA. The workload of the crew is measured using NASA Task load Index (TLX) before and after the EVA. Expired oxygen and carbon dioxide were measured in a breath by breath manner by a Cos Med portable gas analysis system (CosMed, Italy). Heart rate was monitored continuously with Zephyr Bioharness. Saliva samples were collected (Versi-SAL, Oasis, USA) immediately before EVA and after EVA. The samples were immediately frozen at $-4^{\circ}C$, centrifuged and analyzed for biomarker. Salivary cortisol (Salimetrics Inc., PA, USA) was measured. Data was analyzed by using statistical software (SigmaStat, SPSS Inc., USA).

Results

The average VO_2 peak recorded during the hill runs was 56.6 (2.67) ml/kg/min and peak VO_2 reached during a given EVA was 35.87 (0.78) ml/kg/min. Data for heart rate showed the same trend as VO_2 , with a maximal increase to 85% of peak [Figure 1]. The rating of subscale showed a significant increase in EVA as compared to run [Figure 2]. Also rating of subscale showed a significant increase during EVA as compared to before and after.

A good correlation between NASA TLX and salivary cortisol levels ($r = 0.68$, $P < 0.001$). Salivary cortisol levels were increased in both groups [Figure 3], although significant increased of cortisol levels ($P < 0.05$) more in EVA as compared to hill running crew members. Heart rates increased in both groups [Figure 4], although significant increased of heart rates ($P < 0.01$) more in EVA as compared to hill running crew members. There was positive relation between the rise in salivary cortisol concentration and max VO_2 ($r = 0.78$, $r = 0.75$; EVA and hill running, respectively). There were good correlation between heart rate and cortisol levels ($r = 0.69$, $r = 0.72$; EVA and hill running, respectively).

Discussion

This pilot study showed that a typical Mars analogue EVA requires a sustained challenging physical effort. The peak

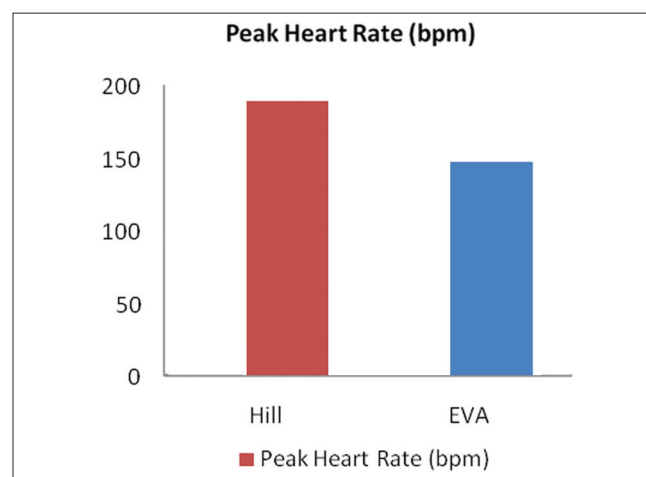


Figure 1: Peak heart rate achieved during hill runs and EAV (Figure 1 showing that heart rate was significantly increased during EVA task as compared to hill runs)

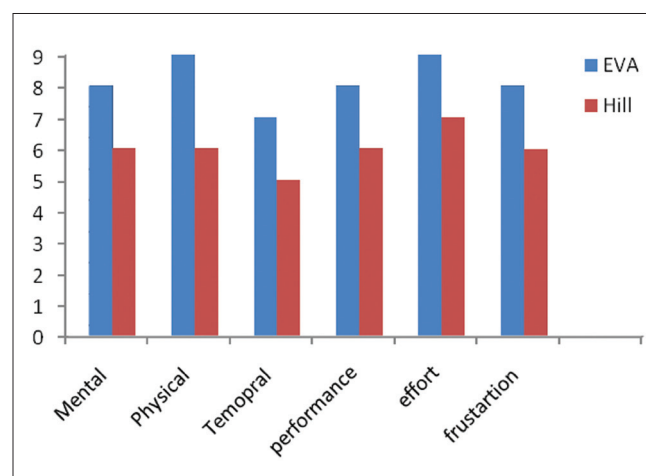


Figure 2: Average task load index (TLX) during hill runs and EVA (Figure 2 showing that average was significantly increased during EVA task as compared to hill runs)

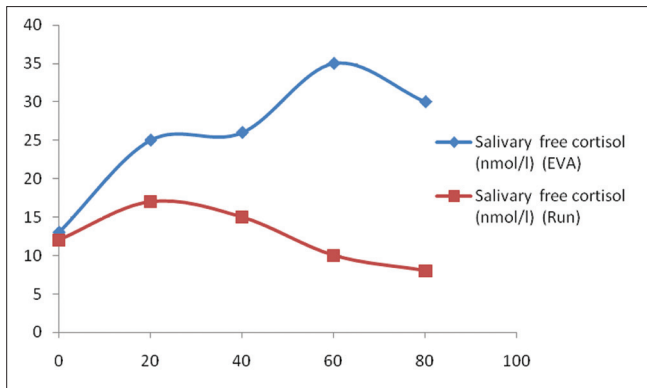


Figure 3: Salivary cortisol levels during hill runs and EVA (Figure 3 showing that salivary cortisol levels were significantly increased during EVA task as compared to hill runs)

VO_2 levels reached of $\sim 85\%$ of peak VO_2 are higher than exercise.^[8] The rating of subscale showed a significant increase in EVA as compared to hill run. It might be due to higher stress situation during EVA task as compared to hill run which is supported by significantly increased of salivary cortisol levels and heart rates during EVA task as compared to hill run. During exercise, when the max O_2 consumption exceeds 60% an increase in the epinephrine and cortisol concentrations occurs. During stress condition vasopressin stimulates the release of corticotropin-releasing factor, which in turn leads to the release of ACTH (Adrenocorticotrophic Hormone).^[9] The highest value of cortisol was reported in aerobic capacity exercises.^[10] Whereas anaerobic exercise for a brief period led to no changes whatsoever in the sporting subjects, with aerobic exercise an increase in the cortisol and ACTH hormone secretion was observed.^[11] A good correlation between NASA TLX and salivary cortisol levels were found. The positive relation between the rise in salivary cortisol concentration and max VO_2 was found. In the light of these findings the changes in cortisol levels observed in this study was supported by previous study.^[12]

A lack of accurate methods of VO_2 max estimation by treadmill or cycle ergometer testing protocols and less number of subjects were main limitations of this study. Notwithstanding of these limitations this investigation was able to observe authentic physiological phenomena in the unique environment of the Mars analogue environment. Continuation of aerobic fitness during the long trip to Mars will be considerably more difficult. So, new training methods and medicinal therapy will have to be explored that can not only maintain aerobic fitness to the levels specified, but also address muscle atrophy and bone demineralization due to microgravity.

These results suggest that salivary cortisol rhythms may be successfully employed for estimating circadian rhythms and related stress decrements in astronauts

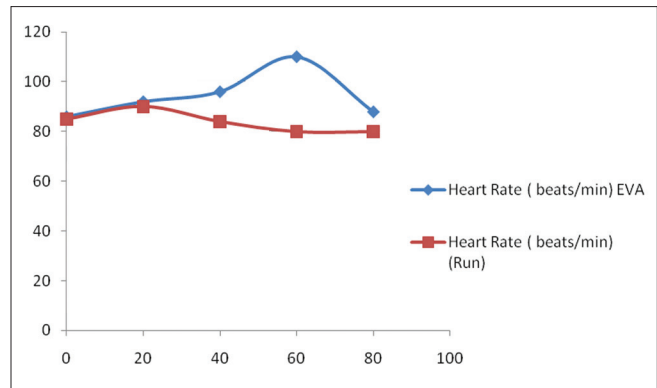


Figure 4: Heart rate during hill runs and EVA. (Figure 4 showing that heart rate was significantly increased during EVA task as compared to hill runs)

during space missions. We can use these salivary markers for mentoring of stress and workload parameters during selection of astronauts, during mission and after mission because being a noninvasive, cost-effective, less time consuming, easy to use and non-infectious.

Further study is required on large scale taken into account of limitations such as large sample size, no applicable of statistical analysis method due to small sample size, using standardized measuring methods, taking into account of more serum and salivary stress biomarkers, with and without helmet of this study and including other physiological and psychological parameters in Mars analog environment.

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