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# Psychological strain: Examining the effect of hypoxic bedrest and confinement

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## HIGHLIGHTS

- Hypoxia exerts negative effects on mood.
- Ambulation ameliorates hypoxia-induced psychological strain.
- Sustained bedrest decreases positive emotions.

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## ABSTRACT

The aim was to assess the effect of a 10-day exposure to the environmental stressors anticipated in future lunar habitats on indices of psychological strain. In addition to the reduced gravity of the Moon, future habitats on the Moon will likely maintain a hypobaric hypoxic environment. The hypobaric environment will eliminate the need for long decompression profiles prior to each extra-vehicular activity. We investigated the indices of psychological strain during three 10-day conditions, designed to assess the separate and combined effects of inactivity/unloading and normobaric hypoxia on several physiological systems. Eleven male participants underwent three 10-day campaigns in a randomised manner: 1) normobaric normoxic bed rest (NBR), 2) normobaric hypoxic bed rest (HBR) and 3) normobaric hypoxic ambulatory confinement (HAMB). The most negative psychological profile appeared on day 10 of the HBR and HAMB (hypoxic) conditions. Concomitantly, a decrease in positive emotions was observed from baseline to day 10 of the HBR and NBR conditions. Thus, confinement in a hypoxic environment seems to exert a negative effect on an individual's psychological mood.

## 1. Introduction

Due to the normal ambient gas pressure within the International Space Station, preparation for extravehicular activity (EVA) — during which astronauts are enclosed in a space suit at about one third of an atmosphere [1] — requires several hours of slow decompression and oxygen prebreathing to minimise the risk of decompression sickness. To reduce the preparation time for EVAs the ambient gas within future planetary habitats will be hypobaric and hypoxic.

Studies have confirmed that the changes observed in several physiological systems over a given period of time in participants rendered inactive and confined to a horizontal position (bedrest), are similar in nature and magnitude to those observed in astronauts during a sojourn in space of equal length [2]. The principal effect of the bedrest model is the unloading of the weight-bearing bones, postural muscles and the withdrawal of the head-to-foot gravity vector with its resultant effect on the pressure gradients in blood vessels. Consequently, the bedrest ground-based analogue for studying microgravity effects on physiological systems has also been used to study countermeasures that would minimise the adaptive changes noted in astronauts during their space missions. In addition to physiological changes, previous research on the psychological effect of bedrest has shown a detrimental effect on mood [3,4] and cognitive function. However, the lack of consistency among these findings [5] supports the need for further research. On the other hand, exercise has a positive effect on participants' mood, affect and mental health [6] increasing the positive emotions (e.g. vigour) while decreasing the negative ones (e.g. tension, anger). The effect of exercise on individuals' mood and affect is highly dependent on exercise

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(type, duration, intensity) and on participants' characteristics (age, physical condition).

Recently, the estimated 500-day confinement anticipated during a return mission to Mars has been simulated by confining a group of participants to the living quarters envisaged on the space vehicle to Mars. The main aim of the Mars500 study was to investigate the interaction of the crew, performance of various tasks and also to assess the indices of psychological strain. The present study adds a new dimension to such confinement studies, by introducing deconditioning induced by sustained inactivity and physical unloading in a hypoxic environment.

Understanding the psychobiological mechanisms of successful adaptation to adverse environments provides important information regarding human function and needs. Several studies have examined the psychological and affective responses to high altitude exposure [7]. Exposure to high altitude with a consequent reduction of oxygen supply to the central nervous system is associated with a variety of neuropsychological impairments [8] including alterations in a person's psychological mood, behaviour and cognitive function. The symptoms that appear during exposure to hypoxic environments include impairments of coordination, vision, cognitive function, alertness, and vigour. Concomitantly, these symptoms are usually accompanied by increases of apathy, anxiety, negative mood, fatigue, confusion, hostility and generally an increase of a person's negative psychological characteristics [7,9,10].

The effects of hypoxia on mood, behaviour and cognitive function seem to be unclear, presumably due to different characteristics measured, methods of measurement as well as in the duration and degree of the hypoxic exposure. In addition, although significant changes in mood, behaviour and cognition are revealed during exposure to high altitude, to a great extent these changes appear related to the substantial individual variation of adaptation to altitude. Thus, large inter-individual differences might reflect differences in the cognitive appraisal of the situation, which is important for one's adaptation to a stressful environment [11].

To better capture participants' psychological changes in the present study the Profile of Mood State (POMS) [12] and the Positive Affect and Negative Affect Schedule (PANAS) [13] were used. The POMS and PANAS are two well-established instruments measuring psychological responses in sport and exercise settings [14]. Far from the wide use of the specific instruments in previous research, the reasons for selecting the POMS and PANAS are based on the fact that the choice can provide the opportunity to compare the current findings with previous ones avoiding methodological issues or contradictory results because of the different instruments used. In addition to the above, the construction of the two instruments has been based on the different theoretical background providing a broad approach and comprehensive assessment, which includes “scales assessing fearful/anxious, sad/depressed, and anger/hostile mood, as well as some type of positive affect” (p. 294) [14].

In order to understand the singular and combined effects of hypoxia and reduced gravity on the indices of psychological strain, the present study took advantage of two experimental paradigms. Thus, the purpose of the present research was to examine the psychological responses of participants rendered inactive in hypoxic and normoxic environments. The responses observed during hypoxic bedrest were compared with responses observed during a condition where the subjects were ambulatory and active, but were confined to the hypoxic living quarters. Based on previous research, we expected hypoxia, as well as, bedrest to have a detrimental effect on the participants' psychological profile (an increase of negative and a decrease of the positive psychological characteristics), while we expected exercise to counteract these effects.

## 2. Material and methods

This study was part of a larger research programme investigating the effects of future lunar and planetary habitats on different physiological systems, specifically, the separate and combined effects of hypoxia and inactivity on the function of several physiological systems. The current study focussed on the indices of psychological strain.

### *2.1. Participants*

Participants were recreationally active lowland Slovene residents (<500 m). Eleven healthy males successfully completed the study. Their baseline characteristics were (mean ± SD age: 24.09 ± 2.2 years; stature: 1.80 ± 0.07 m; body mass: 72.5 ± 12.1 kg; BMI: 22.4 ± 3.2 $kg \cdot m^{-2}$; body fat: 21.7 ± 4.9%; $VO_{2max}$: 42.8 ± 4.4 $ml \cdot kg^{-1}\ min^{-1}$).

The participant recruitment process was based on the European Space Agency (ESA) recommendation regarding the standardisation of bedrest study conditions. Potential participants were recruited through local advertisement and the respondents were invited to attend individual interviews by a panel of investigators. Exclusion criteria included a medical history of respiratory, haematological or cardiovascular illness, recent altitude exposures (<2 months), participation in dietary programmes (<6 months), the use of drugs or medications and a history of mental illness or depression. The participants were given an extensive briefing regarding the study protocol. All participants gave their written informed consent to participate in the study, which was approved by the National Committee for Medical Ethics at the Ministry of Health (Republic of Slovenia) and performed according to the guidelines of the Declaration of Helsinki.

### *2.2. Experimental design*

The 10-day bedrest and hypoxia confinements were conducted at the normobaric hypoxic facility of the Olympic Sport Centre, Planica (Rateče, Slovenia), situated at an altitude of 940 m above sea level. One floor and several laboratories in this facility can be maintained hypoxic by regulating and reducing the fraction of oxygen in the ambient air (fraction of inspired oxygen: $F_iO_2$) using a Vacuum Pressure Swing Adsorption (VPSA) system (b-Cat, Tiel, The Netherlands). For the purposes of this study, the participants were exposed to a target simulated altitude of 4000 m. The VPSA generated and delivered an oxygen depleted gas mixture to each hypoxic room. A sample volume of the gas in each hypoxic room was withdrawn automatically every 15 min and analysed for $O_2$ and $CO_2$ contents. In the event that the $O_2$ content of the room differed from the pre-set value an immediate adjustment was made to the $O_2$ delivery. If the $F_iO_2$ in the room did not increase to the desired level, a large industrial-type fan would be activated ventilating the room with air from the external environment. In addition, for safety reasons, an alarm would be activated, alerting the staff to the problem. Furthermore, each participant was issued a personal clip-on type of oxygen analyser (Rae PGM-1100, California, USA), which provided an indication of the oxygen fraction in its close proximity. In this manner each participant could also monitor the $O_2$ levels within the room.

The participants were invited to take part in three 10-day confinements in this balanced crossover design study. The three conditions were: 1) normobaric normoxic bedrest trial (NBR; actual altitude of 940 m above sea level); 2) normobaric hypoxic bedrest trial (HBR; target simulated altitude equivalent to ~4000 m); 3) normobaric hypoxic ambulatory confinement (HAMB; target simulated altitude equivalent to ~4000 m): in this trial, the participants were ambulatory, but were confined to the hypoxic area of the facility. The participants were divided into one of the above groups. The design of the experimental facility at the Olympic Sport Centre, Planica allowed all the three conditions to be conducted simultaneously. Thus, in the first experimental campaign approximately one third of the participants were in the NBR condition, a third in the HBR and a third in the HAMB conditions. In the second and third campaigns the participants underwent the remaining conditions. The ascent to simulated altitude in the HBR and HAMB trials followed the standard mountaineering guidelines and therefore it was achieved over a three-day period. The target simulated altitudes were therefore: