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Is decision making in hypoxia affected by pre-acclimatisation? A randomized controlled trial

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HIGHLIGHTS

- Decision making is impaired in hypoxia.
- Pre-acclimatisation might reduce risky decision making in hypoxia.
- Positive affective state may be linked with less risky decision making in hypoxia.

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ABSTRACT

Introduction: Decision making is impaired in hypoxic environments, which may have serious or even lethal consequences for mountaineers. An acclimatisation period prior to high altitude exposures may help to overcome adverse effects of hypoxia.
Thus, we investigated possible effects of short-term pre-acclimatisation on decision making in hypoxia.
Methods: In a randomized controlled study design, 52 healthy participants were allocated to a hypoxia group (HG: short-term pre-acclimatisation by the use of intermittent hypoxia 7 × 1 h at $F_iO_2 = 12.6\%$, equivalent to 4500 m) or a control group (CG: sham pre-acclimatisation 7 × 1 h at $F_iO_2 = 20.9\%$, equivalent to 600 m). The number of risky decisions was assessed using the Game of Dice Task at four time points during a 12-hours stay in hypoxia ($F_iO_2 = 12.6\%$).
Results: 42 (HG: 27, CG: 25) participants completed the study. The number of risky decisions was significantly ($p = 0.048$ as determined by 4 × 2 ANCOVA) reduced in the hypoxia group compared to the control group, partial $\eta^2 = 0.11$, when the age-effect on decision making was controlled. Self-reported positive affective valence prior to decision making was negatively related to the number of risky decisions, $r < -0.38$.
Conclusion: Short-term pre-acclimatisation might influence decision making in hypoxia in a positive way and might be considered as a risk-reducing preparation method prior to exposures to hypoxic environments. Positive affective states seem to have a medium-sized protective effect against risky decision making.

1. Introduction

Exposure to high altitude may have deleterious effects on the human body [1]. When acutely exposed to high altitude, it is mainly the reduced oxygen partial pressure that challenges oxygen delivery to organs causing physical performance impairment [2]. However, the reduced oxygen partial pressure may also adversely affect cognitive function. Complex reaction time, short-term memory, and other cognitive function have been shown to be negatively altered in hypoxic conditions compared to normoxic conditions (see Virues-Ortega et al. [3] for a summary). Impaired cognitive function may increase the injury risk for mountaineers by affecting the ability to make the right decisions in the right moment [4]. Quick and correct decision making becomes especially important when considering the inhospitable and sometimes hazardous environment in high altitude. In these environments, poor human decision making is usually responsible for fatal accidents rather than the environmental conditions [5].

Although previous research suggests that personality traits (e.g., sensation seeking) are connected to the act of participating in mountaineering [6], decision making might be independent of personality traits [7]. Consequently, it seems necessary to further

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investigate decision making in field and experimental studies. In general, experimental studies allow controlling for external influences and therefore offering a more precise measurement of decision making compared to field experiments. A previous experimental study showed that decision making is influenced by hypoxic conditions [8]. Using a crossover design, the authors observed an increase in risky decision making in a hypoxic compared to a normoxic condition [8]. However, the assessments were done after being exposed to hypoxia for 20 min. Mountaineering activities like backcountry ski touring, hiking, or climbing usually take at least a few hours per day and decision making becomes important later on during the activity, especially because of increasing fatigue. The largest number of fatalities in mountaineering expedition members is at the summit bid [9]. Therefore it is important to know if decision making in hypoxia changes over time.

Adherence to proper acclimatisation guidelines (e.g., Netzer et al. [10]) is known to reduce the negative effects of acute hypoxia on physiological functions, due to compensatory cardiorespiratory and haematological adaptations of the human body [11]. Extensive research has been conducted on physiological adaptations and on the prevention of acute mountain sickness by pre-acclimatisation (e.g. Faulhaber et al. [12]). Much less is known of possible effects of pre-acclimatisation on cognitive function. Recently, Guerra-Narbona et al. [13] reported evidence that pre-acclimatisation might influence cognitive function in mice. Given the strong connection between cognitive function and decision making [14], pre-acclimatisation might also affect decision making in hypoxia. Human decision making is considered an important risk factor in high altitude and is part of risk reducing intervention campaigns [15]. If decision making is positively altered by a pre-acclimatisation phase, it would help to reduce accidents and injuries due to wrong decisions. Although gradual acclimatisation following proper acclimatisation guidelines remains the “gold standard” for pre-acclimatisation, there is growing interest in the effects of intermittent pre-acclimatisation protocols in hypoxic chambers [16].

Thus, the aims of the study were a) to analyse decision making over a 12-hours period in hypoxia and b) to study the effects of short-term pre-acclimatisation on decision making in an experimental study. We hypothesized that short-term pre-acclimatisation might positively alter decision making in hypoxia.

2. Materials and methods

2.1. Design

The present study was conducted in a double-blinded randomized controlled fashion and was embedded in a larger study previously published [17]. Briefly, after collecting demographic data, the participants were exposed to a familiarisation trial in normobaric hypoxia ($F_iO_2 = 12.6\%$, corresponding to 4500 m) for a duration of 12 h (without physical activity) to familiarize with the hypoxia and the measurement procedure. To avoid an acclimatisation effect due to the familiarisation trial, a de-acclimatisation period (4 weeks) was included. The participants were randomly assigned to either hypoxia group (HG) or control group (CG), stratified by sex and the severity of acute mountain sickness according to the Lake Louise Scoring system (Roach et al. [18], compare measurement section). One week of pre-acclimatisation or sham pre-acclimatisation followed: HG received 7×1 h of passive intermittent hypoxia exposures at $FiO_2 = 12.6\%$ for pre-acclimatisation and CG 7×1 h at $FiO_2 = 20.9\%$, corresponding to 600 m, for sham pre-acclimatisation. During the pre-acclimatisation phase, the participants were not able to perceive any indicator of the group assignment (e.g. FiO_2 values). The pre-acclimatisation phase was supervised by a researcher not involved in further analyses. The follow-up contained a 12-hours long normobaric hypoxic condition with the identical procedure as in the familiarisation trial. All relevant parameters were assessed in the follow-up. Participants were allowed to leave the hypoxic chamber, when they felt unable to stand the exposure to hypoxia any longer. After completing all measurements, the participants were asked to guess their group assignment (CG or HG).

All hypoxic exposures were performed in the normobaric hypoxia chamber (Hypoxico OHG, Traunstein, Germany) of the Department of Sport Science, University of Innsbruck, at 600 m above sea level. The study protocol was approved by the ethics committee of the Medical University according to the principles of the Declaration of Helsinki and all participants signed a consent form after obtaining written and spoken information about the study procedure. The participants did not get financial compensation for their participation in the study.

2.2. Participants

In total, 77 participants were recruited to participate in the initial study. Exclusion criteria were cardiovascular, respiratory, and neurological diseases, migraine, chronic headache, smoking, permanent residence > 1000 m, an overnight stay at altitudes > 2500 m in the previous month, and exposure > 2500 m two weeks prior to the starting of the study [17]. For detailed participant flow, see Fig. 1.

Since this is the first study to assess the effect of short-term pre-acclimatisation on decision making to our knowledge and we were not able to estimate the dropout rate in the hypoxic conditions, no a priori power analysis was conducted. However, Pighin et al. [8] stated an effect size of partial $\eta^2 = 0.15$ for the difference between normoxic and hypoxic conditions. Ideally, short-term pre-acclimatisation may be able to compensate this large-sized effect. Using G*Power 3.1 [19], we calculated for the present study a required effect size of partial $\eta^2 = 0.12$ to be considered significant, which is below the reported effect size of Pighin et al. [8].

2.3. Measurements

2.3.1. Decision making

To examine decision making in hypoxia the computer-based Game of Dice Task [20] was used. The Game of Dice Task can be considered a well-established task to measure decision making in laboratory situations showing good criterion validity ($r_s = 0.71$, Brand et al. [20]) and good discriminant validity [20,21]. The detailed procedure of the Game of Dice Task is described in Brand et al. [20]. Briefly, the participants received a fictive starting capital and were exposed to a gambling situation in front of a computer, where they threw a virtual dice after having guessed which number will appear. The guess consisted of 1, 2, 3, or 4 numbers, which resulted in different winning probabilities and heights of gains/losses. If the dice showed one of the guessed numbers the participants won, if not the participants lost. Choosing 1 or 2 numbers (winning probability: 33.3% or less, high gains/losses) were regarded as risky decisions, choosing 3 or 4 numbers (winning probability: 50.0% or more, low gains/losses) were regarded as non-risky decisions. The participants were advised to maximize their fictive starting capital within 18 dice throws. Immediately after each dice throw the participants were informed about their gains/losses via the computer interface.

Every time the original version of the Game of Dice Task is played, all 18 numbers of the dice throws appear in the same order, which allows to predict the numbers, if the game is played several times like in the present study. We therefore adapted the Game of Dice Task by applying a random sequence with a uniformly distributed incidence of every number.

The number of risky decisions during the Game of Dice Task was regarded as the main parameter for decision making and the primary outcome of the study (compare Brand et al. [20]).

We included four data collection points (after 2, 5, 8, and 10 h) in hypoxia.