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Memory Impairment at a Moderate Altitude Environment

KEYWORDS: hypoxia, psychophysiology, memory, altitude.

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ABSTRACT *Hypoxia induces psychophysiological changes with consequent impairment of cognitive functioning. The purpose of this study was to evaluate the cognitive performance following an ascendance to a moderate altitude. Seven volunteers, underwent a cognitive and physiological evaluation at different times: before ascending, to 4150 m s. l. and after the return from the expedition. The long-term and short-term memory impairment were found at 4150 m s. l. compared with pre and post expeditions at sea-level. This suggests an important effect of moderate altitude hypoxia to human psychophysiological adaptation.*

INTRODUCTION

High altitude is a natural environment characterised by lower barometric partial pressures in oxygen. This physical phenomenon known as hypoxia produces modifications on the physiology of humans in order to adapt to it (Di Giulio, 2013; Lahiri et al. 2002). Nelson (1982) defined the critical threshold for psychophysiological changes around 4000 - 5000 m s. l., which provokes the reduction of clear thinking and increases dizziness (Shukitt & Banderet, 1988). The nervous system suffers after a long exposure without oxygen (Tune, 1964), that explains the cognitive impairment at mountain heights. Several climbers reported a reduction in memory capacity following the ascendance to an extreme altitude, which continued for 75 days after returning to sea-level (Cavalletti & Tredici, 1993; Cavalletti, et al. 1987). Frequently, there has been a difficulty in new information processing (short-term memory), but there are no problems to remembering old events (long-term memory), (Virués-Ortega, 2004). Extreme altitude, impairs attention capacity for several days after returning to sea-level (Cavalletti & Tredici, 1993). Furthermore, the prolonged hypoxia exposure may have a neurodegenerative effect, in aging processes (Di Giulio, 2013).

The aim of this study is to describe the cognitive effects of hypoxia at a moderate altitude and the possible physiological correlation in adapting to it.

MATERIALS AND METHODS

- **Subjects**

Seven healthy volunteers, five males and two females (age 56.86 ± 9.19; education 15.86 ± 3.93) were enrolled in the study. All volunteers have always lived at an altitude of 250 m s. l. and they underwent the same assessment procedure, administered by the same examiner with the same instruments. During the climb, volunteers were free of cognitive enhancer drugs. Women were not in the ovulatory phase during the evaluation. Before any assessments, volunteers carefully read and signed an informed consent to participate in the study and were free to interrupt the testing sessions at any time.

- **Procedure**

Volunteers climbed Mount Ararat (Turkey) for three days. Volunteers underwent cognitive assessment at different times: pre-expedition at sea level (before ascending), at base camp 4150 m s. l. and post-expedition (after returning to sea level), in a standardized condition (the same hour of the morning, before food and drink consumption) with the administration of the following tests: Digit Span (Forward and Backword, Orsini et al. 1987), Corsi (Spinler e Tognoni, 1987), Rey Figure (Rey, 1968), Babcock (De Renzi, 1977), Stroop (Venturini et al, 1983), Trail-Making (test A and B, Giovagnoli et al, 1996). The raw scores obtained were corrected for sex, age and education, with the Italian version of the standardized correction tables.

Furthermore, specific and non-invasive physiological parameters were measured: the saturation of peripheral oxygen (SpO_2), blood pressure (BPmax and BPmin) and heart rate, in pre-expedition (sea-level), at 4150 m s. l. and post-expedition (sea-level). The electronic portable equipment: 503 OXY-5 GIMA (oximeter) and M2 Basic (sphygmomanometer), were used. All volunteers rested before a physiological evaluation. The measurements were performed in three stages and the results were used for the analysis. To assess the effect of moderate altitude on cognitive functions and physiological parameters, several tiled t-tests were computed at three different times (pre expedition, 4150 m s. l. and post-expedition). Where possible, Bonferroni's correction was applied to the t-test results. The descriptive statistics and t-test were performed by means of STATISICA (STAT-Soft; version 8.0). Data were expressed as mean ± SD.

RESULTS

The working memory, evaluated with Digit Span Backward Test and analysed by a t-test showed a significant ($p < 0.05$, corrected) decrease of the working memory scores at 4150 m s. l. (mean 3.65 ± 0.85 SD) compared to the pre-expedition (0 m), (mean 5.08 ± 1.06 SD) and the post-expedition (0 m), (mean 4.94 ± 1.13 SD), $t(6) = -7.07$, ($p < 0.05$) and $t(6) = -4.5$, ($p < 0.05$) respectively. No statistical differences ($p > 0.05$) of working memory was found between pre and post expeditions, $t(6) = 0.54$ (Fig. 1).

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The visual-spatial memory, assessed by means of the Rey Figure Test (delayed copy, long-term memory) and analysed by a t-test, showed a significant ($p < 0.05$, uncorrected) decrease of visual-spatial memory scores at 4150 m s. l. (mean 12.67 ± 12.95 SD) compared to pre-expedition (0 m), (mean 27.67 ± 3.7 SD) and post-expedition (0 m), (mean 28.46 ± 4.37 SD), $t(6) = -3.94$; ($p < 0.05$) and $t(6) = -3.40$; ($p < 0.05$) respectively; while no statistical significance ($p > 0.05$) of visual-spatial memory scores between pre and post-expedition, $t(6) = -0.43$, was found (Fig. 2). No significant results were observed for other cognitive tests.

The vital parameters show significant statistical results. The SpO_2 analysed by the t-test showed a significant ($p < 0.05$, corrected) decrease of SpO_2 at 4150 m s. l. (mean 84.09 ± 4.47 SD) compared to pre-expedition (0 m), (mean 95.23 ± 1.53 SD) and post-expedition (0 m), (mean 96.23 ± 1.11 SD), $t(6) = -6.10$, ($p < 0.05$) and $t(6) = -6.15$, ($p < 0.05$) respectively; while no statistical significance ($p > 0.05$) of SpO_2 between pre and post-expedition, $t(6) = -1.83$, was found (Fig. 3).

Blood pressure was statistically significant at 4150 m s. l. BPmax analysed by the t-test showed a significant ($p < 0.05$, uncorrected) increase of BPmax at 4150 m s. l. (mean 134.28 ± 15.26 SD) compared to pre-expedition (0 m), (mean 119.04 ± 8.68 SD) and a significant decrease compared to post-expedition (0 m), (mean 118.90 ± 9.34 SD), $t(6) = 3.17$ and $t(6) = 4.18$, ($p < 0.05$) respectively; while no statistical significance ($p > 0.05$) of BPmax between pre and post expedition, $t(6) = 0.04$, was found (Fig. 4. A). BPmin analysed by the t-test showed a significant ($p < 0.05$, uncorrected) increase of BPmin at 4150 m s. l. (mean 84.19 ± 7.39 SD) compared to pre-expedition (0 m), (mean 71.47 ± 5.43 SD) and post-expedition (0 m), (mean 72.23 ± 3.75 SD), $t(6) = 3.98$ and $t(6) = 3.85$, ($p < 0.05$) respectively; while no statistical significance ($p > 0.05$) of BPmin between pre and post expedition, $t(6) = -0.33$, was found (Fig. 4. B).

The heart rate analysed by t-test showed a significant ($p < 0.05$, corrected) increase of the heart rate at 4150 m s. l. (mean 83.71 ± 5.50 SD) compared to pre expedition (0 m), (mean 60.52 ± 7.89 SD) and post-expedition (0 m), (mean 58.52 ± 5.24 SD), $t(6) = 8.46$ and $t(6) = 10.06$, ($p < 0.05$) respectively; while no statistical significance ($p > 0.05$) of the heart rate between pre and post expedition, $t(6) = 1.14$, was found (Fig. 5).

No significant correlation was found between cognitive functions and vital parameters. The results of all vital parameters suggest a relevant effect of moderate altitude hypoxia on human physiological adaptation.

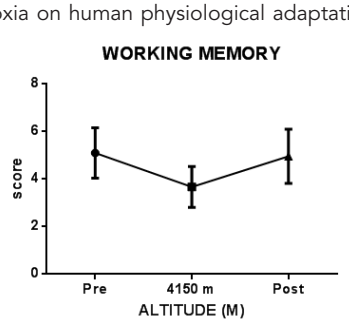

Fig. 1: The hypoxic natural environment induces a significant decrement of the working memory at 4150 m s. l. ($p < 0.05$).

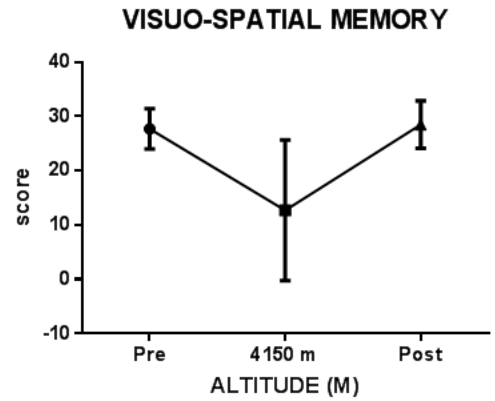

Fig. 2: The hypoxic natural environment induces a significant decrement of the visual-spatial memory at 4150 m s. l. ($p < 0.05$).

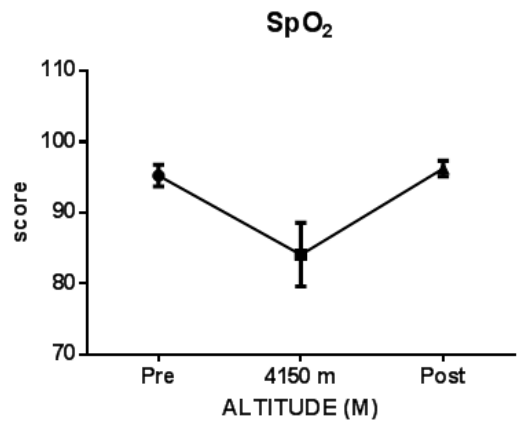

Fig. 3: The hypoxic natural environment induces a significant decrement of SpO_2 at 4150 m s. l. ($p < 0.05$).

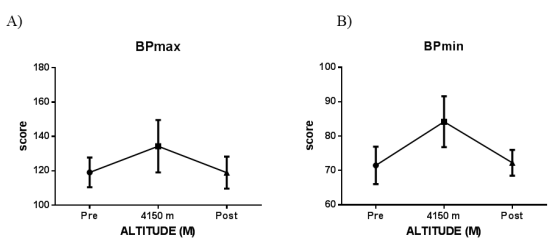

Fig. 4: The hypoxic natural environment at 4150 m s. l. provokes a significant decrement for A) BPmax ($p < 0.05$), while for B) BPmin ($p < 0.05$), at 4150 m s. l.

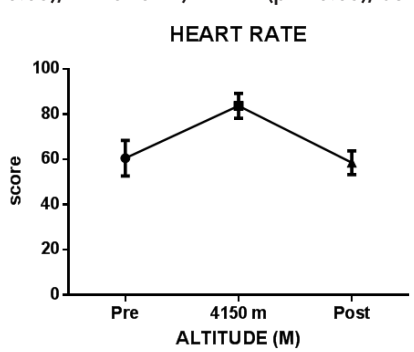

Fig. 5: The hypoxic natural environment induces a significant decrement of the heart rate at 4150 m s. l. ($p < 0.05$).

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DISCUSSION

During the expedition, all volunteers were exposed to moderate altitude hypoxia for three days. At the Ararat base camp (4150 m s. l.), volunteers did not evidence AMS (Acute Mountain Sickness) or any kind of symptoms that could affect the cognitive performance, and they sufficiently rested before test assessments.

Although, several studies investigated the effect of extreme altitude (> 5000 m s. l.) on human cognitive performance (Hornbein et al. 1989; Cavalletti & Tredici, 1993; Nardi et al. 2009), few studies have described the effects at a moderate altitude environment. Our study demonstrates that memory performance was significantly lower also at a moderate altitude. Differently to previous studies, (Cavalletti, et al. 1987; DeAquino Lemos et al. 2012), our study showed the hypoxia long-term memory impairment. The lack of SpO_2 of our volunteers could justify the lower scores of memory performance than sea-level values, as pointed out by Hornbein et al. (1989). Other physiological parameters recorded, such as blood pressure and heart rate, showed the main effect of hypoxia on human physiological adaptation. However, no significant reduction was obtained for executive function and attention capacity, showed by the Stroop Test (Venturini et al, 1983) and the Trail-Making Test (Giovagnoli et al, 1996) respectively. In agreement with several studies that demonstrated the attention impairment only at extreme altitudes (Cavalletti & Tredici, 1993; Bonnon, 2000).

In conclusion, this study demonstrated that memory functions, and in particular long-term memory, were affected by moderate altitude, probably due to the influence of hypoxia on cortical-subcortical structures of the brain.

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DECLARATION. The authors declare that there are no conflicts of interest in relation to this article.

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