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Original article

Mental fatigue and emotional states following high altitude hypoxia exposure

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SUMMARY

Altitude is a hypoxic environment known to induce several psychophysiological changes. Previous studies found an increase of the negative emotions and a decrease of positive emotions at high altitude. In addition, hypoxia modifies the normal physiological parameters observed at sea level. In the present study we firstly hypothesized, that high altitude may affect the somatization status and mental fatigue; secondly, that altitude is not a sufficient condition to generate psychiatric disturbances. Moreover, the third hypothesized is an increase of the negative emotions and a decrease of the positive emotions.

Seven volunteers climbed a mountain and underwent psychophysiological assessment during three distinct times: before ascendance (at sea level), at Ararat Base Camp (hypoxic natural environment 4150 m a. s. l.) and after ascendance (at sea level). Volunteers underwent psychological tests assessing somatic symptoms, perceived excertion and positive/negative emotions. At Base Camp, a significant increase of somatic symptomatology was observed in respect to sea-level scores. We found a significant increase in mental fatigue at Base Camp in respect to sea-level scores. An increase of positive emotional states and a reduction of negative states at Base Camp in respect to seal level values was found. The physiological measurements showed a significant decrease in saturation of peripheral oxygen and a significant increase for heart rate scores at Base Camp in respect to sea-level scores, as well as significant correlation with psychological tests.

This preliminary research shows that high altitude impairs the psychophysiological functions and it could be considered an important parameter to predict the climbers adaptation to hypoxia.

Key words: mental fatigue, emotional states, mountain altitude, environmental hypoxia, psychophysiology

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Conflict of interest
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Introduction

Altitude is a natural environment characterized by a hypoxic condition. Hypoxia is a reduction of partial pressure of the oxygen, causing a lack of oxygen in the blood. The human brain suffers a long time without oxygen, and at an extreme altitude condition, it may be irreversibly damaged [1]. Hypoxia causes an imbalance of the physiological homeostasis [2-4] with dramatic impairment of the psychophysiological functioning, such as fatigue [5-7].

The first distinction between physical and mental fatigue is that of Angelo Mosso in 1891 [8]. Physical fatigue can be defined as the result of neurochemical and muscular activity, whereas mental fatigue is the result of defensive strategies intended to preserve the 'mental health' of a person in extreme conditions, including the mood state of tiredness or exhaustion induced by the prolonged time of stressful cognitive activity [9]. It can be considered as a temporary impairment of cognitive functions and it is one of the major reasons of accidents at mountain level. When mental fatigue occurs, frequently anxiety and panic attack, and, in some extreme cases, also depersonalization, fear and loss of control [10], accompanied it. Above all, hypoxia induces psychophysiological changes in mood states, in cognitive functions and in the sensory perpcetions [5,6,11]. Abnormal visual, auditory and somatosensory- perceptions, that can be defined hallucinatory experiences, are very common at extreme altitude (above 5000 m a.s.l)[12]. These alterations are the result of a lack of serotonin caused by hypoxia, as poited out by Young [13], who investigated the relationship between low levels of serotonin and low mood and high impulsivity in people living at a high altitude, that may induce climbers' death for suicide. It has been stated that the critical altitude threshold for psychological changes is at around 4000-5000 m a.s.l [14,15], and when this threshold is overpassed, depression, anger [7], paranoid ideation and obsessive-compulsive symptoms are observed [14],with also, in extreme cases, a loss of consciousness and orientation [16]. However, several physiological parameters, such as blood pressure, heart rate, breath rate and ventilatory response, that signal an imbalance of the body homeostasis, are predicting of psychophysiological impairment [6,17,18]. Despite numerous investigations about effects of high altitude hypoxia exposure, data about the role played by the high altitude environment on the perception of emotions are lacking. Present study aims to fill this gap. In particular we hypothesized that high altitude may affect the somatization status and mental fatigue, but it is not a sufficient condition to generate psychiatric disturbances. We hypothesized an increase of the negative emotions and a decrease of the positive emotions. In order to verify this hypothesis, we investigated the correlation between the physiological parameters (collected during the expedition) and the variation of the emotional states.

Materials and methods

Subjects

Seven (7) healthy volunteers, (5 males and 2 females, age 56.86 ± 9.19 years old), climbed Mount Ararat (Eastern Turkey) for three days. Before the expedition, volunteers were selected after appropriate cognitive assessment and a psychiatric interview. The exclusionary criteria was the inappropriate cognitive level and the general medical, neurological and psychiatric disorders in the present as well as in the history of the subject. All volunteers usually lived at 250 m a.s.l. and were not expert climbers. The numerosity of sample is in line with the mean participants in mountain expedition.

Instruments

Psychometric tests

We administered three questionnaire: the Self-Report Symptom Inventory-Revised [19], the Rated Perceived Exertion Scale [20], the Positive and Negative Affect Schedule Questionnaire [21].

The Self-Report Symptom Inventory-Revised (SCL-90 R) is a five-point Likert self- reported scale allowing to measure specific aspects of the personality. The SCL-90 was very fast and it is usually used like general measure of psychiatric symptomatology in both clinical and research context. It consists of 90 Items divided into 11 scales:

- Somatization (SOM) subscale assesses the uncomfortable body perception: subjective somatic state. The symptoms are focused with cardiovascular, gastrointestinal and respiratory apparatus. Muscular pain and the other body anxiety symptoms are other components of this scale;
- Obsessive-Compulsive (O-C) includes the typical symptoms of obsessive-compulsive syndrome. The items focused on persistent thoughts and irrepressible actions;
- Hypersensitivity-Interpersonal (I-S): includes the uncomfortable and the inadequacy feelings of yourself. The typical feeling manifestations are low self-efficacy and awkward interpersonal relationships;
- Depression (DEP) includes the items related to the typical clinical manifestations of the depression syndrome. The DEP scale assesses the social retire, lack of motivation, loss of energy, feeling of desperation and kill oneself through;
- Anxiety (ANX): includes the items that evaluate the general anxiety symptoms: irritability, tension, panic attacks, feeling of fear, trepidations;
- Hostility (HOS) includes the items that evaluate the typical negative through, feeling and behaviour. In particular, HOS detects clinical manifestation of anger, aggression and irritability;
- Phobic Anxiety (PHOB). The items detect a persistent fear reaction for a specific person, place or situation. This reaction is irrational and excessive than the stimulus;
- Paranoid Ideation (PAR) describes the typical manifestation of the paranoid thought: projective thought, hostility, suspiciousness, grandeur, reference to oneself, fear of autonomy loss;
- Psychoticism (PSY) includes items of primary symptoms of schizophrenia as well as the social retire;
- Sleep Disorders (SLEEP) assesses the sleep disorders;
- Global Severity Index (GSI): it is a global indicator of psychological distress level.
- The Rated Perceived Exertion Scale (RPE) assesses the rate of the perceived exertion in sport athletes. It consists of a Likert-like scale ranged from 0 ("nothing") to 11 ("maximum possibility"). Volunteers an-

swered three statements and the mean values were used for statistical analysis.

The Positive and Negative Affect Schedule Questionnaire (PANAS) is considered a reliable instrument used and validated in sport science, also in clinical and research contexts. It consists of 20 items of which, 10 items assess the Positive Affect (PA) and 10 assess the Negative Affect (NA). Volunteers answered a five-point likert-scale ranging from 1 (“very little or nothing”) to 5 (“most”).

Psychophysiological measures

Since the described imbalance of the human cardiovascular system during exposure to the hypoxic environments [4-6,9], measuring the cardiovascular parameters is necessary in order to establish the physiological trend of the body condition and, then, to correlate this with the psychological status. The electronic portable pulse oximeter 503 OXY-5 GIMA® (Oximeter) has been used to collect the Saturation of Peripheral Oxygen (SpO_2). This represents index of the blood oxygen saturation measured in percent variation (%) with normal values identified with 99%.

Moreover, we used the M2 Basic Omron® (Sphygmomanometer) to measure the pressure as a blood strength intensity on vasal artery. BPmax and BPmin represent the maximum and minimum blood pressure values, respectively, measured in mmHg and (normal range values between 120 and 80 mmHg). Moreover, with the same instrument we measured the Heart Rate (HR), representing the number of the heart pulses in one minute (normal range values: 60-90 beats per minutes) and Breath Rate (BR), that is the number of the breath rate in one minute (normal range values: 12-20 cycles per minutes).

Procedures

All the evaluations were conducted in different times and at two different altitudes as follow: before ascendance and at sea level (Pre-Exp), at 4150 m a.s.l. (Base Camp) and after descent at sea level (Post-Exp). The volunteers underwent a psychophysiological evaluation and psychometric assessment in a standardized condition (the same hour of the morning, before food and drink consumption). At Pre-Exp and Post-Exp (i.e., at sea level) the assessment was carried out in the same quiet and ventilated room, whereas at Base Camp the assessment was performed in a quiet and large tent. Volunteers were asked to rest before the psychophysiological and psychometric assessment; they were free to interrupt the testing sessions at any time. Before the test assessment, they read and signed an informed consent to participate in the study. At sea level and during climbing, the volunteers were free of drugs, and women were not in the ovulatory phase.

The Base Camp assessment was conducted on August 14th, in ideal weather conditions and the air temperature was 15°C. All experimental procedures were not invasive and in line with ethical principles of the Helsinki Declaration 2008.

Data analysis

To quantify the effects of altitude on psychological functioning assessed by SCL-90 R, RPE, two different repeated-measures of Analyses of Variance (rmANOVA) were computed with one repeated-measure factor “Time” considering Pre-Exp, Base Camp and Post-Exp, for each subscale of the SCL-90 and the RPE scores.

Moreover, in order to quantify the effect of altitude on positive and negative emotions, a mixed-model ANOVA, with one repeated-measure factor “Time” and one within-group factor the PA-NA scores) was carried out with PANAS scores. To assess the relationship between the scores of the three different questionnaires, a rank Spearman’s correlation coefficient was calculated and, where possible, a Bonferroni’s multiple comparison correction was also applied.

To assess the effects of moderate altitude on physiological parameters during the expedition, we calculate the differences between the maximum and minimum values as Δ = (max-min) for the SpO_2, the BPmax, the BPmin, the HR and the BR, for each time; (Pre-Exp, Base Camp and Post-Exp). The obtained Δ values were considered as dependent variables. To assess the effect of “Time” on the psychophysiological results, we tested the normal distribution with the Kolmogorov-Smirnoff Test, and the homogeneity of variances with the Levene’s Test. If these criteria were violated, non-parametric tests were applied. The descriptive statistics, ANOVAs and Spearman’s rank coefficient correlation were performed by means of STATISICA (STATSoft 8.0). Data were expressed as a mean ± standard deviation.

Results

For the SCL-90 R, the rmANOVA showed significant effect of “Time” on SOM ($F(2,12) = 12.76$; $p < 0.05$). The Base Camp period showed higher significant values (0.71 ± 0.36) in respect on the Pre-Exp (0.46 ± 0.16; $p < 0.05$) and the Post-Exp (0.29 ± 0.23; $p < 0.00$), (Fig. 1A). No significant results were observed for other SCL-90 R subscales.

Similarly, the rmANOVA showed significant effect of “Time” on the RPE Scale scores at Pre-Exp, at Base Camp and at Post-Exp ($F(2,12) = 75.24$; $p < 0.0001$). The Post–Hoc comparison showed significantly higher RPE Scale scores for the Base Camp condition (7.47 ± 1.66) respect on the Pre-Exp (1.93 ± 0.31; $p < 0.00001$) and the Post-Exp (4.04 ± 1.07; $p < 0.001$), (Fig. 1B). Whereas, the Post-Exp period showed higher RPE Scale values than the Pre-Exp period ($p < 0.001$).

The PANAS Questionnaire showed a significant effect of “Time” ($F(2,24) = 6.24$; $p < 0.01$) and a significant

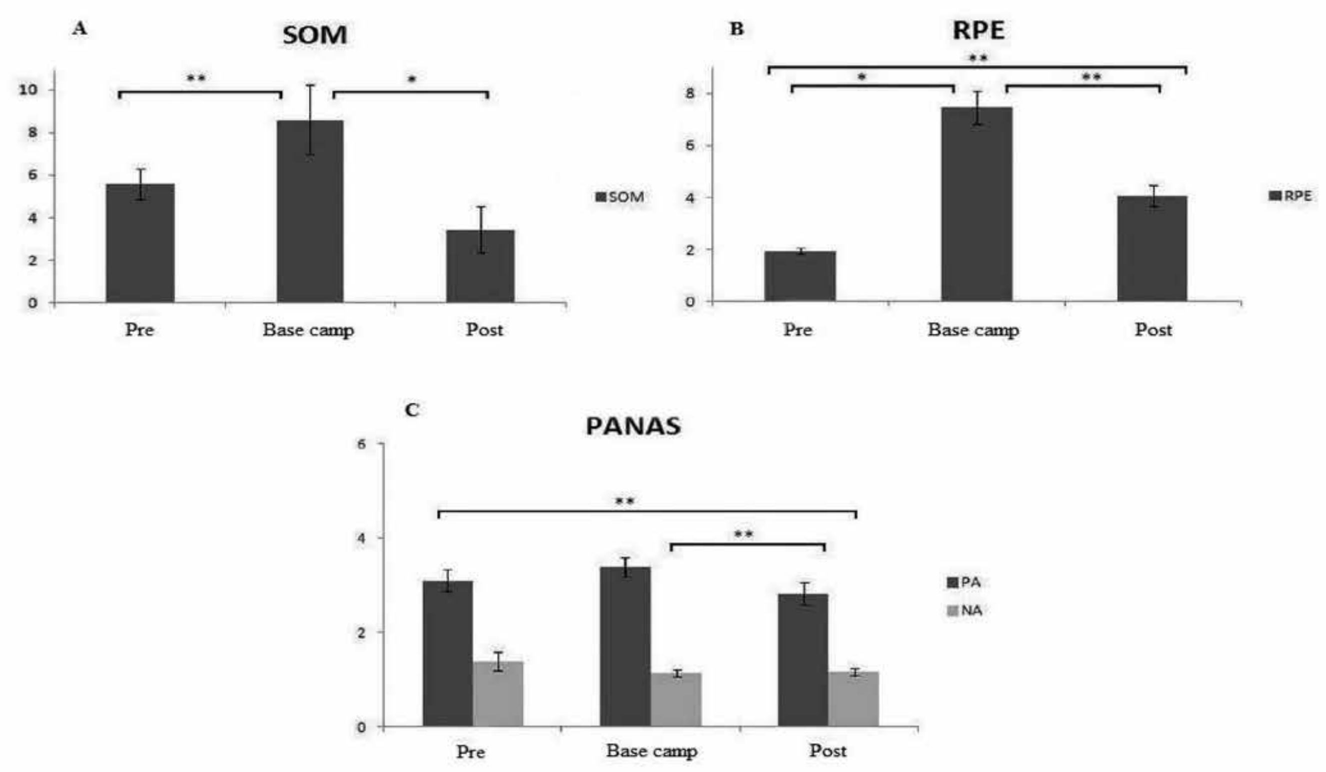

FIGURE 1. *The histograms show as hypoxic natural environment induces progressive and significantly increments of the somatic symptoms at hypoxic station, p < 0.05 (A); a significant increment of the perceived exertion at hypoxic station, p < 0.05 (B); a significant increment of the positive affective and significant decrement of the negative affective state, p < 0.05 (C). Vertical bars denote the standard errors of mean (SEM).*

interaction "Time x PA-NA" ($F(2,24) = 7.55$, $p < 0.005$). At Base Camp (PA: 3.38 ± 0.51) the values were higher compared to the Post-Exp period (2.82 ± 0.61). The values of the Pre-Exp period (NA: 1.38 ± 0.52) were higher compared to the Post-Exp period (1.17 ± 0.21), ($p < 0.01$), (Fig. 1C). The Duncan's post-hoc for interaction "Time x PA-NA" highlighted a significant difference for PA compared to Time, but not for the NA.

The physiological measurements showed significant results for the SpO_2 and the HR. The SpO_2 showed a significant difference for Time ($F(2,12) = 31.73$, $p < 0.01$). Duncan's post-hoc test revealed significant difference between the Pre-Exp (95.23 ± 1.42) and the Base Camp period (84.09 ± 4.14; $p < 0.001$) and between the Base Camp (84.09 ± 4.14) and the Post-Exp period (96.23 ± 1.03; $p < 0.001$) (Fig. 2A). The rmANOVA on HR showed significant main effect of "Time" ($F(2,12) = 55.75$, $p < 0.0001$). Duncan's post-hoc test revealed a significant difference between the Pre-Exp (60.52 ± 7.30) and the Base Camp period (83.71 ± 5.09; $p < 0.0005$); as well between the Base Camp (83.71 ± 5.09) and the Post-Exp period (58.52 ± 4.85; $p < 0.0001$) (Fig. 2C).

No significant results were obtained for the BPmin, the BPmax and the BR (Fig. 2B,D,E).

To assess the relationship between the SOM, the RPE and the PANAS (sub-scale PA and NA) values, Spearman's rank correlation was calculated. We observed a significant positive correlation between the RPE Post-Exp values and the SOM Post-Exp values ($rho(7) = 0.77$, $p < 0.05$ uncorrected). Significant relationship was observed between sub-scale PA and RPE for the Post-Exp values ($rho(7) = 0.80$, $p = 0.03$) and the SOM values for the Post-Exp period ($rho(7) = 0.81$, $p < 0.03$).

To assess the relationship between the SCL90-SOM, the RPE and the PANAS values and the psychophysiological parameters, Spearman's rank correlation was calculated. We observed a significant positive correlation between the Base Camp values of the SOM and the BPmax ($rho(7) = 0.84$, $p < 0.05$) as well as the values recorded at the Pre-Exp period for the SOM and the HR ($rho(7) = 0.88$, $p < 0.05$). Significant negative correlation was observed between the Pre-Exp values of the SOM and the BR ($rho(7) = -0.79$, $p < 0.05$) (Fig. 3).

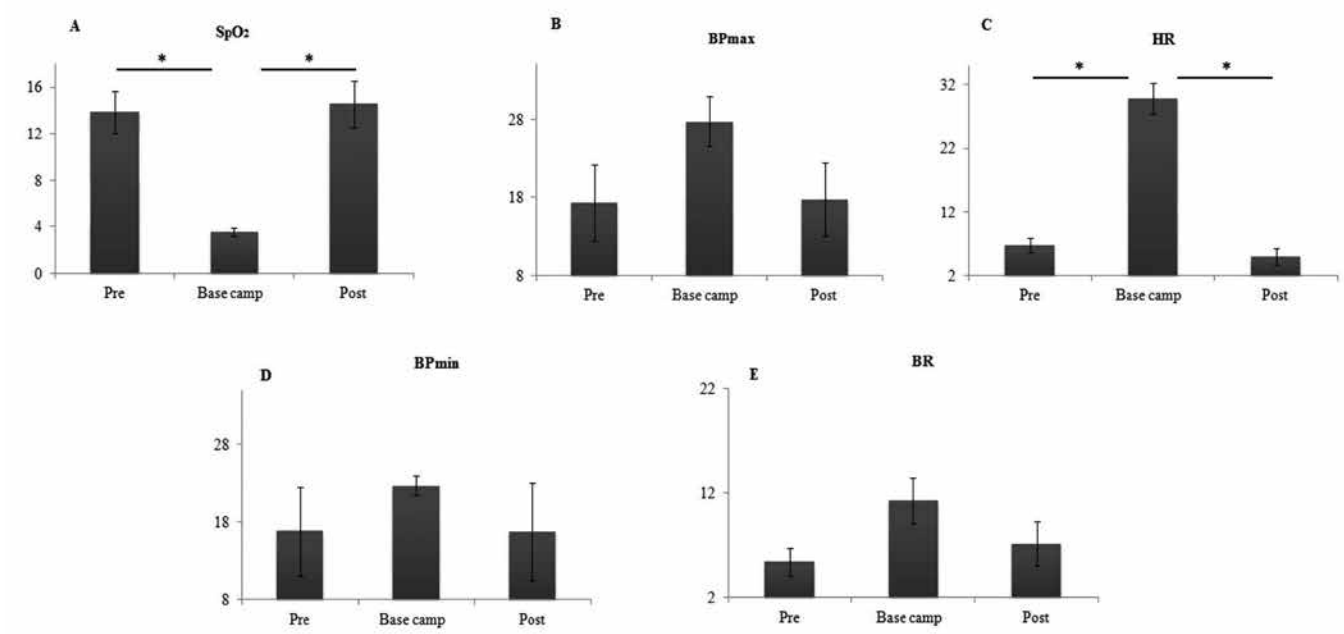

FIGURE 2. *The histograms show as hypoxic natural environment induces a significant decrement of the saturation of peripheral oxygen at hypoxic station, $p < 0.05$ (A); a significant increment of the heart rate at hypoxic station, $p < 0.05$ (C), no significant results were obtained for the maximum blood pressure (B), for the minimum blood pressure (D) and the breath rate (E). Vertical bars denote a standard errors of mean (SEM).*

Discussion

The present study represents one of the few reports about the effect of moderate altitude, i.e., less than 5000 m a.s.l., on the psychological and physiological status.

Our results showed a significant effect of altitude-hypoxia on the subjective somatic state of climbers, as given by the significant results of somatization subscale. Although the altitude-hypoxia affects the subjective somatic state of climbers, it is not a sufficient condition to generate psychiatric transitory status, confirming our initial hypothesis. Numerous report suggest the negative effects of altitude on the mood. Indeed, after experiencing euphoria, climbers may also become irritable, anxious and apathetic [22]. In our study, we observed an increase in the positive emotions. This effect may be due to the initial euphoric stage after arriving at the Base Camp, given that we did not observe significant effects on the NA. This result, can be explained at light of the relationship between physical activity and the mood. Several studies Pasco and [23] found a positive correlation between the Positive Affect and the physical activity. It is possible that the physical effort perceived during the climb could have influenced the experience of well-being and the positive emotions in general.

Although the physical effort perceived during climbing, our study showed an increase of mental fatigue in a hypoxic environment, in agreement with our assumption. Previous studies have investigated the physiological effects of fatigue in a controlled condition [7,24] but there are no studies describing the time-course of mental fatigue in a natural altitude setting. Mental fatigue is an unusual parameter investigated, due to the difficulty in quantification. Several physiological aspects seems to condition mental fatigue. Hunger and dehydration are the principal aspects that may induce tiredness. For this reason, we tested the volunteers after food and water consumption. Volunteers underwent psychological and psychophysiological tests after adequate rest at Base Camp. The RPE scores display the principal effects of hypoxia on mental fatigue at Base Camp and persistent tiredness after returning to sea-level. The correlation between the SOM and the RPE scores prove the close relationship between two common aspects of tiredness. The higher scores of the SOM at Base Camp were the indirect evidence of the imbalance of physiological parameters. We found a significant correlation between the SOM and the BPmax at Base Camp. Furthermore, we found increased PA scores at Base Camp, with a dramatic decrease after returning to sea-level. These findings are unexpected and in contrast with our assumptions and with previous studies. The nega-

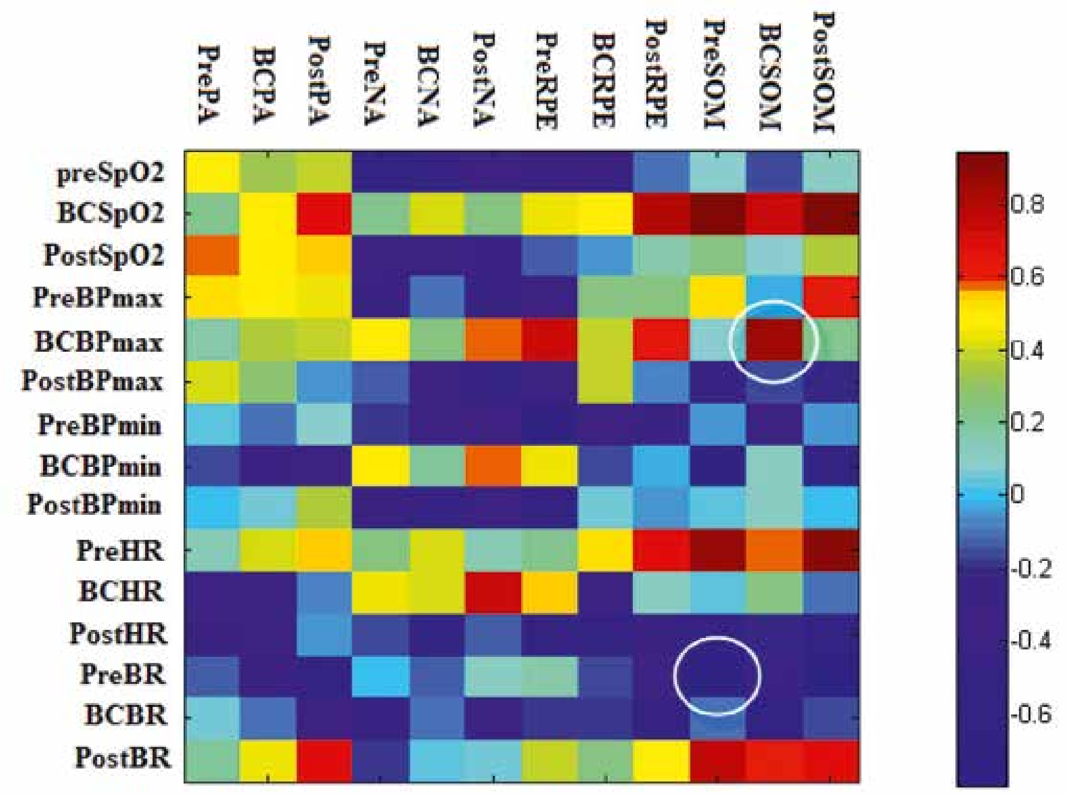

FIGURE 3. *The coloured map depict the Spearman's rank correlation results. Spearman's rank correlation showed a significant positive correlation between the SOM and the BPmax at hypoxic station ($p < 0.05$), a significant negative correlation between the SOM and the BR at hypoxic station ($p < 0.05$).*

tive mood states are very common at mountain altitude and previous studies have shown an higher incidence of AMS (Acute Mountain Sickness) with typical negative symptoms of headache, dizziness, nausea, loss of appetite and insomnia [15,25,26]. It is important to note that climbers were exposed at sub-acute hypoxia (3 days of trekking and 1 day at 4150 m a.s.l.).

Sub-acute hypoxia exposure provokes a temporary neurotransmitting imbalance. The hypoxic environment can cause the alteration in the neurotransmitters utilization and concentrations [27]. The cholinergic system appears to be the most vulnerable to hypoxia, but it is possible that the rate of synthesis of neurotransmitters, like, dopamine, serotonin and amino acids, are affected by acute hypoxia [28].

In future studies emotional processing will be important to investigate the psychological adaptation at altitude exposure, especially in an emergency context. In conclusion, our findings suggest that exposure to high altitude could put a strain on the physical endurance of mountaineers, without affecting the emotional state.

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