*Original article (short paper)*

# Exercise performed at hypoxia influences mood state and anxiety symptoms

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**Abstract**—During hypoxia conditions, psychological states can be worsened. However, little information is available regarding the effect of physical exercise performed in hypoxia conditions on mood state and anxiety symptoms. The aim of the present study was to elucidate the acute effect of moderate physical exercise performed at hypoxia on mood states and anxiety symptoms in healthy young subjects. Ten volunteers were subjected to the following conditions: a normoxic condition (NC) and a hypoxic condition (HC). They performed 45 min of physical exercise. Their anxiety symptoms and mood states were evaluated at the initial time point as well as immediately following and 30 and 60 min after the exercise session. Our results showed a significant increase in post-exercise anxiety symptoms and a significant decrease in mood scores immediately after and 30 min after exercise performed in the HC. Moderate physical activity performed at hypoxia condition increased post-exercise anxiety and worsened mood state.

Keywords: physical activity, hypoxia, mood state, anxiety

**Resumo**—"Exercício realizado em hipóxia influencia o estado de humor e sintomas de ansiedade." Em condição de hipóxia o aspecto psicológico pode piorar, porém, ainda há pouca informação sobre a resposta do exercício físico realizado nestas condições sobre o estado de humor e os sintomas de ansiedade. O objetivo deste estudo foi investigar o efeito agudo do exercício físico moderado realizado em condição de hipóxia sobre o estado de humor e sintomas de ansiedade de jovens saudáveis. Dez voluntários foram submetidos a duas condições: Condição Normóxia (CN) e Condição Hipóxia (CH) e realizaram 45' de exercício físico. Os sintomas de ansiedade e humor foram avaliados no momento basal, imediatamente após, 30 e 60 minutos. Observou-se um aumento significativo dos sintomas de ansiedade pós-exercício físico e uma redução significativa dos escores de humor em condição de hipóxia imediatamente e após 30 minutos de exercício. O exercício físico moderado realizado em condição de hipóxia promove uma resposta ansiogênica pós-exercício físico e piora do estado de humor.

Palavras-chave: exercício físico, hipóxia, estado de humor, ansiedade

**Resumen**—" El ejercicio realizado en la hipoxia influencias estado de ánimo y síntomas de ansiedad." En condiciones de hipoxia , los estados psicológicos pueden empeorar . Sin embargo, hay poca información disponible sobre el efecto del ejercicio físico realizado en condiciones de hipoxia en los síntomas del estado de ánimo y de ansiedad. El objetivo del presente estudio fue determinar el efecto agudo del ejercicio físico moderado realizado en hipoxia en los estados de ánimo y los síntomas de ansiedad en los sujetos jóvenes sanos. Diez voluntarios se sometieron a las siguientes condiciones : una condición de normoxia ( NC ) y una condición hipóxica ( HC ). Realizaron 45 min de ejercicio físico. Sus síntomas de ansiedad y los estados de ánimo fueron evaluados en el momento inicial , así como inmediatamente después y 30 y 60 minutos después de la sesión de ejercicio. Nuestros resultados mostraron un aumento significativo en los síntomas de ansiedad después del ejercicio y una disminución significativa en las puntuaciones del estado de ánimo inmediatamente después y 30 minutos después del ejercicio realizado en la HC. El ejercicio físico moderado realizado en condicines de hipóxia aumentó después del ejercicio ansiedad y empeoró el estado de ánimo.

Palabras claves: actividad física, hipoxia, el estado de ánimo, la ansiedad

## Introduction

The number of people exposed to high altitude has increased all over the world. This increase is partially due to increased tourist activity to mountainous regions where the practice of hiking, climbing, skiing and other physical activities is possible (Magalhães Duarte, Ascensão, Oliveira, & Soares, 2002).

In parallel with this growing market, the cumulative number of publications concerning physiological responses (Mazzeo, 2008), human behaviors (Virués-Ortega, Garrido, Javierre, & Kloezeman, 2006) and psychological alterations (Leach & Almond, 1999) after exposure to high altitude has been found, drawing the attention of researchers to the topic.

Hypoxia induced by high altitude impacts the stress response associated with physical exercise (Hsu *et al*., 2006; Niess *et al*., 2003), producing a remarkably unsteady homeostasis (Mazzeo, Wolfel, Butterfield, & Reeves 1994; Mazzeo *et al*., 1995; Mazzeo *et al*., 1998; Mazzeo *et al*., 2000) and hindering physical performance – both maximal and submaximal – during acute or chronic exposure to such environments (Fulco, Rock, & Cymerman, 1998).

Along with the physiological alterations, psychological changes have also been observed during exposure to high altitudes. The most common complaints are often associated with cognition and mood. Regarding cognition, the exposure to altitudes can lead to notable impairments in decision -making ability and arithmetic skills and specific losses in short-term memory and attention span with reflections on visual sensitivity (Lemos *et al*., 2010). The magnitude of these impairments appears to be related to the length of exposure and the altitude increase (Ortega, Buela-Casal, Garrido, & Alcázar, 2004; Paintal, 2004; Pavlicek *et al*., 2005; Qin *et al*., 2001; Vaernes, Owe, & Myking, 1984;), demonstrating the sensitivity of the central nervous system to a partial reduction in $O_2$ levels, triggering cognitive effects (Sharp & Bernaudin, 2004).

With reference to mood states, de Aquino Lemos *et al*., (2012) and Bahrke and Shukitt-Hale (1993) have reported that exposure to altitudes above 4.000 m can influence mood, including increased depressive behavior, anger, fatigue, irritability and transient cognitive impairment. However, the effects of hypoxia similar to such altitudes still require further investigation.

Physical exercise practiced at altitude conditions is believed to promote modifications to both physiological and psychological contexts (Acevedo & Ekkekakis, 2001; Pyne et al., 2000). Thus, considering that high altitudes can influence psychological aspects before affecting physiological aspects (Kobrick & Johnson, 1991), the monitoring of psychological responses could be considered an anticipatory indicator of the deleterious effects of environmental stress, functioning as a predictive indicator for sports performance.

Within this context, the present study aimed to investigate the acute effects of moderate physical exercise at hypoxia on mood state and anxiety symptoms in healthy young volunteers.

## Methods

### *Participants*

The study's sample consisted of 10 male volunteers, whose characteristics are described as the mean ± standard deviation, including age (22.30 ± 2.79 years old), height (176 ± 0.04 cm), weight (72.66 ± 11.86 kg) and BMI (23.37 ± 3.74 kg/m$^2$). All of the volunteers were undergraduate students, were physically active and had no clinically diagnosed diseases. According to self-reports, the volunteers did not use tobacco, alcohol, illegal drugs and/or controlled medications that could interfere with the evaluation of the mood state. All of the volunteers were subjected to 2 conditions: a normoxic condition (NC) and a hypoxic condition (HC) at different time points, including a basal evaluation and immediately, 30 and 60 minutes after physical exercise.

### *Procedures*

Before the beginning of the present study, all of the possible risks involved in the experimental procedures were explained to the volunteers, who participated of their own free will. The study was approved by the Ethics Committee of the Federal University of São Paulo/ Hospital of São Paulo (#0620/09).

The volunteers were blinded to the study procedures. They were maintained in a hypoxic condition at a simulated altitude of 4,500 m for 90 min. A summary of the experimental design is depicted in Figure 1.

Before initiating the protocol, all of the volunteers underwent a clinical evaluation conducted by a specialist doctor during their first visit to the laboratory, including a resting electrocardiogram (ECG) and an ergometric test. After these evaluations, only the subjects considered fit by the doctor participated in the study. All tested subjects were included in the study.

During the second visit, the volunteers underwent a spiroergometric test using a progressive load protocol until maximum voluntary exhaustion. This test was used to determine the intensity of the ventilatory threshold 1 (LV-I), and it consisted of increasing the speed by 1 km/h every minute. The initial warm-up speed was 6 km/h for three minutes. The test was terminated when the volunteer reached maximum voluntary exhaustion. Exhaustion was defined as an inability to follow the speed of the treadmill for 15 seconds or when the volunteer solicited the termination of the test despite being encouraged to continue (Walch *et al*., 2010). As the physical exercise was performed on a treadmill in a controlled laboratory environment, 1% treadmill grade was used to simulate the physical wear of outdoor exercise (Jones & Doust, 1996).

Subsequently, physical exercise with a rectangular load was conducted inside a normobaric chamber under both the NC and HC using the same treadmill as the spiroergometric test. The test was performed at a speed below the individual intensity of the LV-I for 45 minutes, thus representing 50% more volume (time) compared to the minimum of 30 minutes of daily exercise recommended by Nelson *et al*., (2007) for a healthy life.

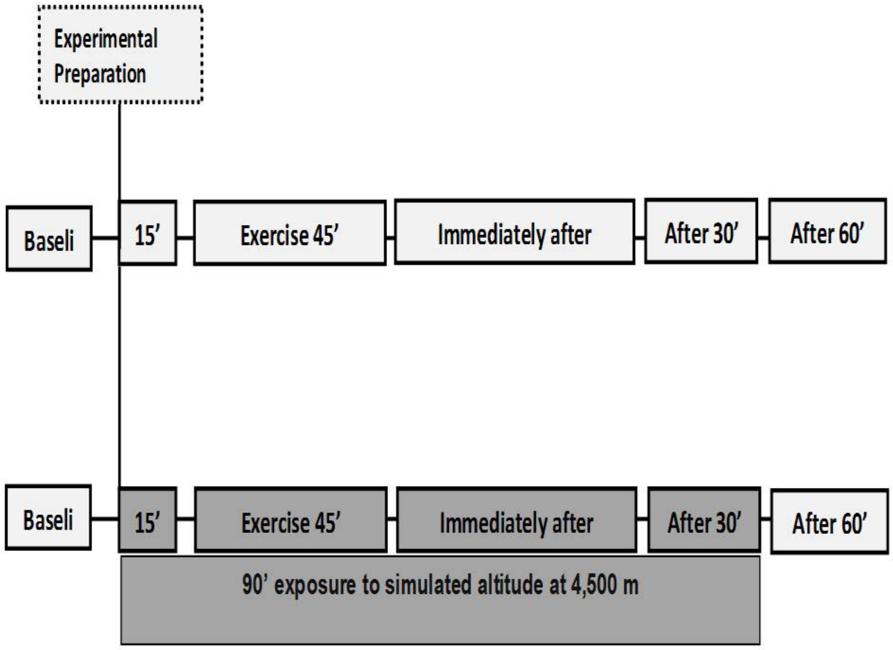


Figure 1. The timeline depicts the experimental design performed by n = 10 volunteers subjected to two conditions: a normoxic condition (NC) and a hypoxic condition (HC) similar to 4,500 m altitude for 90 minutes. For 15 min, the volunteers were allocated to a chamber that simulated altitude. After adjustment, a session of exercise was performed for 45 min. Evaluations of mood state and anxiety symptoms were conducted at four time points: a baseline evaluation outside the chamber in normoxic condition; immediately after 45 min of exercise under the hypoxic condition; after 30 min of exercise under the hypoxic condition; and after 60 min outside the altitude-simulator chamber under a normoxic condition.

The adopted protocol consisted of a 3-min warm-up at 7 km/h, with an immediate adjustment to individual load LV-I. This intensity was unaltered for 45 continuous minutes, except for the hypoxic condition (simulated altitude). In such condition, after 15 minutes of exercise, there was a reduction in the intensity to the warm-up speed, i.e., 7 km/h, which was maintained until the termination of the exercise, representing a decrease of approximately 30% in the effort intensity.

This decrease in the intensity of effort is due to the fact that the volunteers cannot maintain the speed of LV-I as a function of stress generated by exercise and hypoxia. Therefore, for a question of security, the treadmill speed was reduced.

During all of the testing, continuous heart rate monitoring was conducted. The HC experiment was performed one week after the NC experiment. Both tests were begun at 3:00 pm and finished at 4:30 pm.

Evaluations of mood state and anxiety symptoms were conducted at 4 time points: prior to beginning, immediately after, and 30 and 60 minutes after termination of the physical exercise. When the volunteers concluded the experimental protocol, the altitude simulator was turned off, and the volunteers were only dismissed when they did not exhibit any symptom that could prevent their safe leaving.

## Instruments

*Altitude simulator.* A normobaric chamber (CAT - Colorado Altitude Training™/CAT-12 Air Unit) was used. The study was conducted in a chamber equipped for altitude simulation of up to 4,500 m. This altitude is equivalent to a barometric pressure of 433 mmHg and a fraction of inspired oxygen ($FiO_2$) of 13.5%.

## Objective measures

*Physical exercise.* The physical exercise testing was performed on a treadmill (*Lifefitness*® 9700HR, Schiller Park, IL, USA).

*Ergospirometry.* The ergospirometric evaluation was performed using Quark (PFT – Pulmonary Function Testing – FRC & DLCO – 4Ergo, Cosmed, Italy). The system was calibrated before each protocol using an established concentration of gases. The volume and flow calibrations were performed with the aid of a three-liter syringe. A flow-by silicone facemask (Hans Rudolph® Kansas City, MO, USA) was used to increase the volunteers' comfort.

*Heart rate monitoring.* Heart rate monitoring was performed using a cardiofrequencymeter (Polar®, model FS1, Kempele, Finland).

## Subjective measures

*Mood states.* Visual Analogues of Mood Scales (VAMS): This scale evaluates mood state and consists of 16 analogues composed of two adjectives of opposite feelings separated by a 100-cm straight line. Each individual was asked to vertically mark the point that best described his/her feeling at that moment during the test. These scales combined four factors: anxiety, i.e., calm-agitated, tranquil-concerned, relaxed-tense; physical sedation, i.e., insightful-unperceptive, capable-incapable, dynamic-apathetic, confident-tangled, sociable-retiring, graceful-awkward, strong -weak; mental sedation, i.e., awake-lethargic, attentive-distracted; and other feelings and attitudes, i.e., interested-indifferent; friendly-hostile, cheerful-melancholic, satisfied-unsatisfied. This scale was developed by Bond and Lader (1974) and was validated by Guimarães (1998) for a Brazilian population.

*Anxiety symptoms*. Trait-State Inventory of Anxiety (STAI): This scale evaluated anxiety symptoms distributed between two facets: anxiety-trait (referring to personality aspects) and anxiety-state (referring to systemic aspects of the context). Each part of the scale comprised 20 phrases. The anxiety-state facet measured how the individual felt at the moment of the evaluation, and the anxiety-trait facet measured how the individual commonly feels on a day-to-day basis. On each part, the scores range from 20 to 80 points to indicate low (0-30 points), medium (from 31 to 49) or high (50 points or more) anxiety levels. The lower the scores are, the lower the anxiety levels are (Spielberger, Gorshusch and Lushene, 1970; Biaggio and Natalicio, 1979). In the present study, the evaluation of the trait part was not conducted because it refers to personality. However, the state anxiety was measured at the abovementioned time points.

### *Statistics*

The data are presented as the mean ± standard deviation (SD). Normality was verified using the Shapiro Wilk test. Comparisons of parametric data were performed using ANOVA with repeated measures and Duncan's *post hoc* test. The adopted level of significance was $p< .05$. All of the analyses were performed using the software Statistica®, version 12.0 (http://www.statsoft.com).

## Results

### *Assessment ergospirometric*

Table 1 shows the descriptive analyses of the results from the spiroergometric testing performed until maximum voluntary exhaustion at the initial time point. The parameters related to oxygen consumption are presented as absolute values (liters/minute) as well as relative to the total body mass. Additionally, the parameters concerning ventilation behavior, peak oxygen consumption at the first and second ventilatory thresholds, time and heart rate are also presented.

Table 1. Descriptive analyses of the results from the ergospirometric test performed at maximum voluntary exhaustion.

| Variables | Mean ± SD | Minimum Values | Maximum Values |
|---|---|---|---|
| VO2 peak (L•min-1) | 3.53 ± 0.45 | 2.88 | 4.14 |
| VO2 peak (mL•kg•min-1) | 49.84 ± 6.01 | 40.91 | 58.83 |
| HR max (bpm) | 190.90 ± 8.49 | 179 | 204 |
| VE max (L) | 143.97 ± 20.62 | 102.5 | 173.4 |
| Max speed (km•h-1) | 15.80 ± 1.40 | 13 | 17 |
| LV-I speed (km•h-1) | 10.08 ± 1.00 | 9 | 12 |
| LV-II speed (km•h-1) | 13.30 ± 1.25 | 11 | 15 |
| VO2 LV-I (L•min-1) | 2.55 ± 0.23 | 2.09 | 2.89 |
| VO2 LV-I (mL•kg•min-1) | 36.12 ± 3.89 | 31.1 | 41.29 |
| HR LV-I (bpm) | 156.70 ± 10.17 | 145 | 173 |
| VO2 LV-II (L•min-1) | 3.11 ± 0.38 | 2.5 | 3.8 |
| VO2 LV-II (mL•kg•min-1) | 43.87 ± 5.10 | 35.2 | 49.32 |
| HR LV-II (bpm) | 177.00 ± 12.06 | 157 | 194 |

Data are presented as the mean ± standard deviation from 10 volunteers. Abbreviations: VO2 - oxygen consumption; HR - heart rate; VE - ventilation; LV-I - ventilatory threshold I; LV-II - ventilatory threshold II.

### *Assessment of mood state*

Table 2 illustrates the results from the Visual Analogues of Mood Scales, including anxiety, physical and mental sedation and other feelings and attitudes. The scores on the Visual Analogues of Mood Scales were not significantly different at the evaluated time points ($F_{1,18}$= 0.33; $p$ = .57). The *Physical Sedation* scores in the HC showed a significant decrease compared with the initial measurement ($p$<0.05).

Table 2. Mood state scores.

| | Dimensions | NC | | | | HC | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **Baseline** | **Immediately after** | **30 min** | **60 min** | **Baseline** | **Immediately after** | **30 min** | **60 min** |
| **VAMS** | **Anxiety** | 46.24 ± 13.40 | 43.04 ± 14.69 | 45.72 ± 13.95 | 48.06 ± 14.47 | 44.95 ± 15.26 | 42.00 ± 16.16 | 44.71 ± 14.86 | 41.74 ± 13.84 |
| | **Physical sedation** | 43.44 ± 9.06 | 40.51 ± 11.38 | 39.89 ± 11.66 | 39.45 ± 10.44 | 44.51 ± 8.54 | 33.61 ± 14.18a | 33.91 ± 14.51a | 40.23 ± 11.43b,c |
| | **Mental sedation** | 39.44 ± 17.81 | 39.59 ± 12.13 | 39.95 ± 11.94 | 37.31 ± 11.70 | 41.94 ± 10.62 | 32.78 ± 16.03 | 34.05 ± 15.27 | 37.14 ± 11.33 |
| | **OFA** | 47.34 ± 7.80 | 43.92 ± 12.07 | 45.11 ± 10.70 | 44.89 ± 9.32 | 47.48 ± 6.05 | 40.56 ± 10.03a | 41.44 ± 10.36a | 42.29 ± 10.74 |

Two-way ANOVA with repeated measures and Duncan's post hoc test. a – compared with the baseline in the same condition; b – compared with the immediately after time point in the same condition; c – compared with 30 min in the same condition. Results were significant at $p \leq .05$. Data are presented as the mean ± standard deviation from 10 volunteers. Abbreviation: OFA - Other feelings and attitudes.

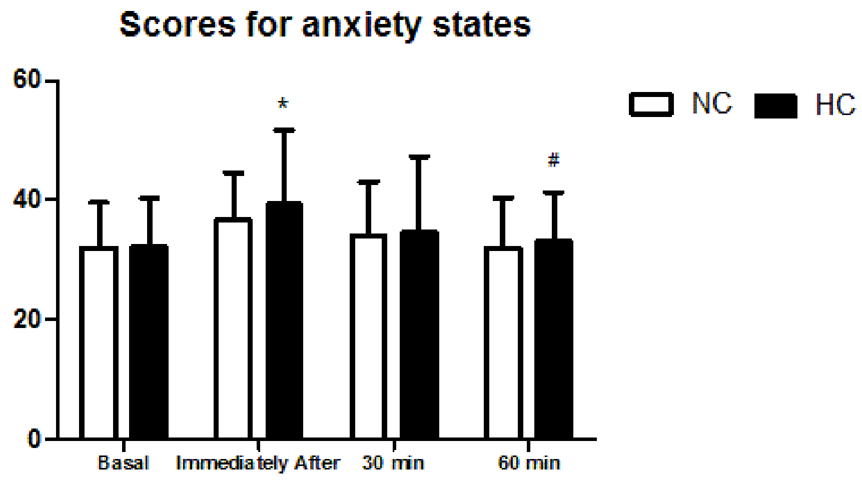


Figure 2. Two-way ANOVA with repeated measures followed by Duncan's *post hoc* test was performed. *compared with the same baseline condition; #compared with the same condition immediately after exercise. Results were considered significant for $p \leq .05$. The data are expressed as the mean ± standard deviation.

The *Physical Sedation* score measured 60 minutes after termination of the physical exercise was significantly higher compared with the same parameter immediately after or 30 minutes after exercise ($p< .05$). Furthermore, there was a significant decrease in the *Other Feelings and Attitudes* score in the HC immediately after and 30 minutes after termination of exercise compared with the initial measurement ($p< .05$).

## *Assessment of anxiety symptoms*

Figure 2 depicts the results from the STAI-State, which measured the anxiety state displayed by the volunteers at the moment of the evaluation. Anxiety scores in the HC showed a significant increased immediately after termination of the physical exercise compared with the initial measurement ($F_{3,54}$=5.24; $p$ = .02).

## *Assessment of heart rate*

Figure 3 details the heart rate patterns during the physical exercise performed in the HC or NC. Upon beginning the exercise, as expected, there was an increase in the heart rate (transition from rest to activity), followed by stabilization after 5 minutes. Subsequently, there was a reduction in the heart rate after the termination of the exercise (recovery). After 15 minutes of physical exercise under the HC, there was a subtle reduction in this parameter compared with the NC.

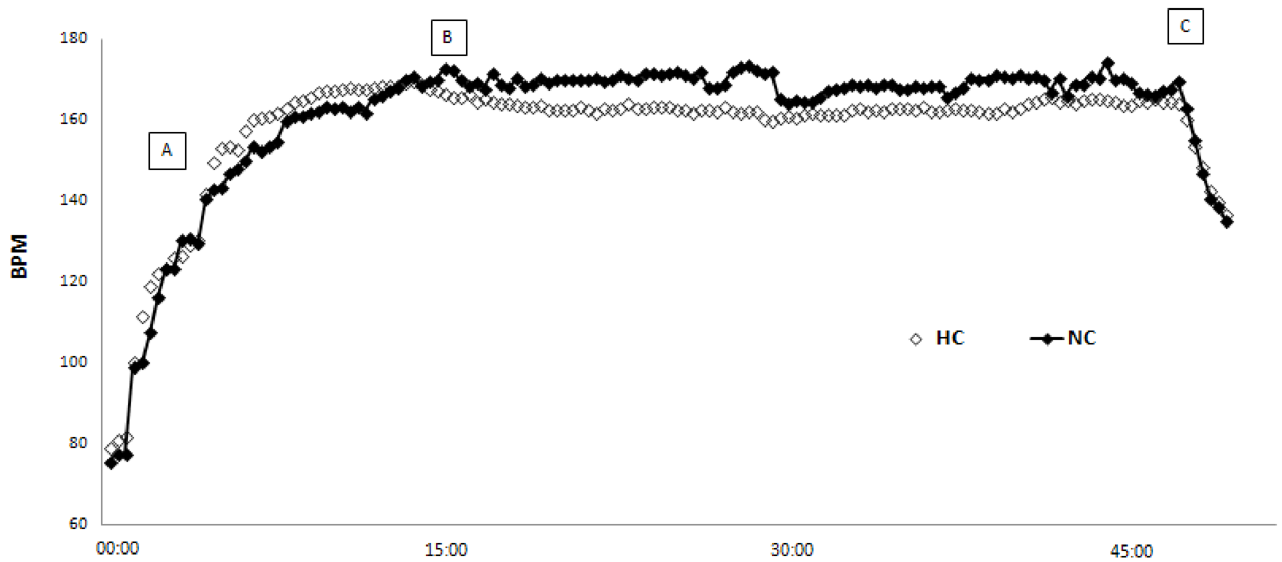


Figure 3. Pattern of the heart rate in beats per minute (BPM); the data are represented by means. Caption: A- Transition from rest to activity; B- Adjustment to exercise intensity for the hypoxia group (reduction to warm-up speed, approximately 30% of the LV-I); C- Termination of the exercise training.

This result may have been due to the reduced exercise speed (10 *vs.* 7 km/h) because the volunteers complained about the difficulty of performing the exercise at the LV-I intensity.

## Discussion

In the present study, we found that physical exercise performed for 45 minutes at the HC or at an altitude equivalent to 4,500 m for 90 min may influence, at least in part, mood state and anxiety symptoms in healthy physically active young volunteers.

These results establish a relevant connection between the exposure to high altitudes and physiological and psychological processes, which are ultimately related to the acclimation capacity of the human body. The effects on acclimation vary according to the exposure altitude and biological individuality (Araújo, 2009). At high altitudes, the human body initiates a myriad of physiological adjustments to adapt itself to the environment, including classical changes in acid-base metabolism as well as physiological adjustments that exert effects on the cardiovascular, respiratory, immune and endocrine systems, ultimately affecting the brain (Lemos *et al.*, 2010; Mazzeo, 2008; Virués-Ortega *et al*., 2006;). As indicated by Kobrick and Johnson (1991), these physiological adjustments can be elicited by mood estate changes promoted by exposure to altitude, thus characterizing an anticipatory indicator of the adverse effects induced by the environment. Perhaps psychological these changes may be mediated by changes in the concentration of neurotransmitters and change in the cerebral blood flow (Querido *et al.,* 2007; Weicker & Strüder, 2001).

Although the condition of hypoxia does not appear to influence the supply of oxygen to the brain (Wolff, 2000), the major portion of that oxygen is used for producing energy. This may result in impairment of certain brain enzymes, among which we can highlight the tryptophan hydroxylase, whose main function is to participate in the synthesis of serotonin (Katz, 1980, Young, 2013). Thus, the hypoxia condition can decrease in serotonin production, resulting in in worsening to the mood of those who are exposed to this condition, which may be an explanation for the decrease in the mood of subjects in our study.

Within this context, altitude may exert a remarkable amount of psychobiological influence, and mood and cognition are the most critically affected aspects in addition to motor, perceptual and behavioral impairments (Virués-Ortega *et al.*, 2006).

However, the literature has been emphatic in reporting that physical exercise promotes beneficial responses in mood state, especially predominately aerobic exercises. These exercises should provide a pleasant, non-competitive activity for 20 to 40 minutes at moderate intensity that are performed in predictable environments and are spatially fixed (Berger & Owen, 1998). According to Ekkekakis and Petruzzello (1999), physical exercise performed below the ventilatory threshold promotes sufficient adjustments to alter body homeostasis, splitting psychological and physiological responses. When performed at the ventilatory threshold, responses can vary according to each individual and are influenced, at least partially, by physiological adjustments and by the cognitive factors involved in dealing with the situation.

In our study in particular, altitude simulation was conducted using a normobaric chamber; in other words, there was no alteration of the barometric pressure. Conversely, to simulate the target altitude of 4.500 m (equivalent to 433 mmHg), the oxygen supply was reduced to a $FiO_2$ of 13% compared with the $FiO_2$ of 21% observed in normoxic conditions, likely explaining the results reported herein.

In a study performed with 11 volunteers who ran at intensities equal to their ventilatory thresholds under two distinct conditions (normoxia and hypoxia), Friedmann Bauer, Menold, and Bärtsch (2004) did not find any differences in the relative intensities or in the physiological parameters such as heart rate and blood lactate concentrations. These results suggested that psychological factors determined the performance of an individual in hypoxic conditions.

It is well documented that strenuous physical exercise performed in external environments such as altitude, heat and cold impose increased psychological and physiological stress (Acevedo & Ekkekakis, 2001; Bolmont, Thullier, & Abraini, 2000; Gleeson, 2000; Pyne, Gleeson, & Mcdonald, 2000). Environmental changes can influence psychological functioning before affecting physiological factors (Kobrick & Johnson, 1991). Thus, monitoring the psychological conditions can indicate the adverse effects of environmental stress. Among the innumerable variables that might be relevant within this context, mood responses are known to reflect environmental changes (Bahrke, & Shukitt-Hale, 1993).

From this perspective, when we compared both of the experimental conditions using the chosen instruments (STAI and VAMS), the results concerning the mood state and the anxiety symptoms were unexpected. In fact, we had hypothesized that the simulated altitude condition in association with physical exercise-induced stress would negatively impact the mood and anxiety scores, thus presenting differences from the scores verified in the normoxic condition. However, we must also consider the effect of the magnitude of the hypoxia-induced adjustments. These adjustments are conditioned to alterations such as oxygen saturation fluctuation, exposure time to the condition, effort intensity and load as well as to the inter-individual variability (Mazzeo, 2008).

The STAI-State survey indicated that there were no changes in the volunteers' behavior in the experimental condition at sea level; namely, individuals did not display alterations in their typical patterns of anxiety. In contrast, at the simulated altitude condition, the immediate termination of the physical exercise was anxiogenic. The values returned to baseline 60 min after the termination of the activity.

In normoxia, Petruzzello, Landers, Hatfield, Kubitz, and Salazar, (1991) have postulated that physical exercise only induces anxiolytic effects when performed at a predominantly aerobic level and with a minimum duration of 21 minutes. However, other studies have reported that both high- and low -intensity exercise induces decreased anxiety levels (Berger & Owen, 1998; Cox, Thomas, & Davis, 2000; Steptoe, Kearsley & Walters, 1993).

According to the Visual Analogues of Mood Scales (VAMS), a normoxic condition did not induce alterations in any of the examined variables. Thus, physical exercise in normoxia did not affect the study volunteers' anxiety, mental or physical sedation or other feelings and attitudes. Conversely, at the simulated altitude, exercising induced decreased physical sedation and other feelings and attitudes in the volunteers. This effect lasted until 30 minutes after the termination of the activity. In contrast to our findings, Bonnon, Noel-Jorand, and Therme (1999) investigated a rising program to find the ideal psychological adaptation to high altitudes in a group of alpinists. These participants were subjected to tasks that evaluated cognitive aspects and mood state in normoxic or hypoxic conditions at 3,500 and 5,400 meters. The cited authors failed to find robust effects on cognition or emotion, suggesting that the majority of the participants experienced successful acclimation. The interesting topic was that the authors proposed that the mechanisms of psychological adaptation may better respond to a gradual acclimation process involving a progressive rising speed and some time spent at each phase of altitude increment.

Another study at lower altitudes also showed results that contrasted with our results. In the study from Piehl Aulin, Svedenhag, Wide, Berglund, and Saltin (1998), 15 volunteers were exposed to 2,000 or 2,700 m above sea level. The authors found that living in a hypoxic environment for 12 hours/day and maintaining a training load in normoxic conditions did not negatively affect mood state (Lane, Terry, Stevens, Barney, & Dinsdale, 2004). This discrepancy may be explained by the fact that our study was performed at a higher altitude (equivalent to 4,500 m).

The anxiety measured by STAI and the VAMS are conceptually different. While IDATE stratifies the score of anxiety, VAMS is an analog scale that assesses the emotional state considering the subjective perception of the mood and determines a subjective anxiety that contains high cognitive component. Due to the different nature of the scales, the use in conjunction research is desirable. While VAMS allows freedom of choice for the evaluated, STAI don't.

The limitation of this study is that the effects on the dependent variables were not randomized to the HC and NC groups. Thus, the effects on the dependent variables may be even greater if the conditions were randomized.

In summary, moderate physical exercise at a simulated altitude of 4,500 m can induce mood alterations, namely, a post-exercise anxiogenic effect and worsening mood. Hence, it is possible that mood states and anxiety symptoms can be manifested prior to physiological responses. In addition, knowledge of these alterations may contribute to the development of strategies that minimize wear and maintain physical performance in hypoxic environments.

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