

## Anxiety And Acute Mountain Sickness: Comparative Analysis of Active and Passive Ascents To 3600 Meters

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### ABSTRACT

**Objective:** High-altitude exposure is increasingly common due to work and leisure activities. While physical factors contributing to acute mountain sickness (AMS) are well-documented, the role of psychological factors, particularly anxiety, remains underexplored. This study aimed to evaluate anxiety levels and acute mountain sickness during active and passive ascents.

**Methods:** In a cross-sectional, counterbalanced study, 12 healthy male participants aged 20–29 years, underwent both active (hiking) and passive (cable car) ascents to 3600 meters. Each ascent was separated by a two-month washout period. Anxiety levels were assessed using the State-Trait Anxiety Inventory (STAI-Y1), and AMS symptoms were evaluated using the Lake Louise Score (LLS) at multiple time points post-ascent.

**Results:** No significant difference in anxiety levels was observed between active and passive ascents ( $p=0.291$ ). However, during active ascent, significantly higher anxiety levels were exhibited by participants who developed AMS compared to those who did not develop AMS ( $p=0.046$ ). A positive correlation between anxiety scores and LLS was found during both active ( $r=0.681$ ;  $p=0.015$ ) and passive ( $r=0.578$ ;  $p=0.049$ ) ascents. Pre-ascent anxiety levels did not significantly correlate with LLS at altitude after active or passive ascents ( $p=0.389$  and  $p=0.339$ ).

**Conclusions:** Anxiety levels post-ascent are associated with the occurrence of AMS, regardless of ascent method. Monitoring anxiety may aid in identifying individuals at risk for AMS, emphasizing the need for psychological assessments in high-altitude expeditions.

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## Introduction

**I**n High-altitude travel for occupational and recreational purposes has become increasingly common, with an estimated 140 million people residing above 2500 meters (1) and 40 million visiting such elevations annually (2). Such exposure has direct implications for public health, athletic performance, and occupational safety, as even mild altitude-related impairments can reduce efficiency, decision-making, and survival chances in extreme conditions (3). Despite this growing trend, much of the research on high-altitude exposure has focused on physical performance and physiological adaptation, while the psychological aspects, particularly anxiety and mood changes, remain underexplored (4, 5). In sports and performance psychology, theories such as the Yerkes–Dodson Law describe how moderate levels of arousal or anxiety can enhance performance, whereas excessive anxiety can impair it. In high-altitude settings, this relationship may become more pronounced due to the added physiological stress of hypoxia, making theoretical frameworks from psychology directly relevant to altitude physiology (6). Psychological responses to hypoxia can significantly influence the experience and outcomes of altitude exposure. Behavioral disturbances such as anxiety, mood swings, and cognitive impairments affecting decision-making and motor coordination have been observed at high altitudes (7, 8).

Moreover, rapid ascents without adequate acclimatization increase the risk of acute mountain sickness (AMS), which manifests through a constellation of symptoms including headache, gastrointestinal discomfort, dizziness, fatigue, and insomnia (9-12). The development and severity of AMS are influenced by several factors, such as ascent rate, altitude reached, duration of exposure, and individual susceptibility (11). Although the underlying pathophysiology of AMS is not completely understood, current evidence implicates hypoxia-induced cerebral vasodilation, fluid retention, and altered neurotransmitter activity. These physiological changes overlap considerably with symptoms of anxiety disorders (5, 13, 14), complicating clinical differentiation. From a theoretical perspective, hypoxia-induced cerebral vasodilation and increased intracranial pressure provide the biological basis for AMS symptoms. Standardized assessment tools, such as the Lake Louise Scoring System, facilitate symptom evaluation and help differentiate AMS from anxiety-related conditions, thereby improving diagnostic accuracy and guiding targeted interventions (3, 15). At elevations exceeding 3000 meters, symptoms like insomnia, headache, shortness of breath, palpitations, and fatigue can occur due to either AMS or anxiety, making accurate diagnosis challenging (16).

Although previous research has recognized that anxiety might be a precursor or contributing factor to AMS (17-20), the

causal relationship and underlying biological mechanisms remain insufficiently understood. The overlapping symptoms and shared physiological triggers raise questions about whether anxiety should be considered a predisposing condition for AMS or a comorbid outcome. Exposure to low oxygen levels stimulates the sympathetic nervous system, triggering the release of catecholamines and other stress-related neurochemicals. These responses, along with hypoxia-induced hormonal changes such as increased cortisol production (21, 22), have been linked to heightened anxiety and may contribute to the onset or severity of AMS.

Neuroimaging studies have demonstrated that hypoxia can alter activity in brain regions responsible for emotional regulation, such as the amygdala and prefrontal cortex. These changes may lead to impaired emotional processing and increased anxiety (23). Additionally, individuals with heightened anxiety may experience somatosensory amplification, a tendency to perceive normal bodily sensations as intense or distressing. This can lead to an increased perception of AMS symptoms, even in the absence of significant physiological changes (24). However, despite growing awareness of these mechanisms, there is a notable lack of studies directly comparing psychological and physiological responses during different ascent modalities (e.g., active vs. passive). Addressing this gap is critical for refining preventive strategies, guiding psychological screening, and improving safety in high-altitude activities.

This study assessed the relationship between anxiety and AMS during active and passive ascents to 3600m. Using a within-subject design to minimize individual response variability, we aimed to better understand this interaction under different physical stress conditions, addressing a gap in the literature and contributing to improved prediction and prevention strategies. The results of this study could contribute to the development of evidence-based altitude training protocols, facilitate targeted psychological screening of at-risk individuals, and support earlier diagnosis and intervention strategies to improve safety and performance in high-altitude environments.

## Methods

### Participants

Twelve healthy men residing in Tehran (elevation ~1200 m), aged 20–29 years, with a body mass index between 18.5 and 24.9 kg/m<sup>2</sup>, were recruited through convenience sampling based on voluntary participation. Prior to inclusion, participants were fully informed about the study objectives and procedures, completed a demographic questionnaire, provided a medical health certificate from a licensed physician, and signed an informed consent form. The present research employed an experimental approach with a within-subject, counterbalanced design to control for order effects and minimize individual variability. Exclusion criteria included being a mountaineer or having prior high-altitude training experience, which was confirmed for all participants during the eligibility assessment;

any high-altitude activity or sports such as mountaineering; high-altitude exposure above 2500 meters within the past two months; recent blood donation or air travel, which can alter hematological or barometric responses; participation in any altitude-related sports or endurance events within the past 60 days; any acute or chronic illness, including cardiovascular, respiratory, or psychological disorders; failure to participate in any data collection phase; non-compliance with ascent protocols; or voluntary withdrawal. Participants were screened using a comprehensive health questionnaire and a physician-led clinical exam, and they were asked to refrain from taking any medication or supplements during the study period.

### Study Design

This applied research utilized a cross-sectional, counterbalanced design aimed at examining the effects of ascent modality—active vs. passive—on the development of acute mountain sickness (AMS) and the role of anxiety in modulating AMS susceptibility. The counterbalanced design was chosen to minimize order effects and individual physiological variability across testing sessions. By implementing a crossover format with a two-month washout interval, the study controlled for potential acclimatization, residual physiological adaptation, and psychological familiarity with high-altitude conditions, which are known to influence AMS susceptibility and emotional responses.

### Experimental Protocol

After orientation and baseline assessment, participants were randomly assigned into two groups of six. Each group completed two ascent conditions—active and passive—to 3600 meters (Tochal Hotel, Iran). The sequence of ascent modes was reversed for each group after a two-month washout period to mitigate the effects of initial altitude exposure. In both ascent scenarios, participants departed from Tochal Station 1 (1900 m) at 08:00. The active ascent group completed the hike in a structured progression: Station 1 to Station 2 (~1 hour), Station 2 to Station 5 (~2 hours), and Station 5 to the hotel (~3 hours), with a 1-hour rest and meal break at Station 5. The total duration of the active ascent was approximately 7 hours, consistent with recommended non-exertional pacing for non-acclimatized individuals. Participants selected a self-paced, non-competitive tempo to replicate recreational mountaineering conditions while avoiding undue physiological stress. The passive ascent group mimicked the same travel duration using the cable car system. They remained seated or engaged in light ambulation at Stations 2 and 5 to match the rest periods of the hiking group. Lunch was served simultaneously with the active group at Station 5 (11:15–11:45). The passive ascent resumed at 14:30, with arrival at the hotel at 15:00. By matching the ascent timelines, the study controlled for circadian influences on AMS development and hormonal stress markers (25).

## Psychological and Physiological Assessments

Acute Mountain Sickness (AMS) was evaluated using the Lake Louise Score (LLS), a validated self-report instrument assessing five symptom domains: headache, gastrointestinal discomfort (e.g., nausea), fatigue or weakness, dizziness or lightheadedness, and sleep disturbance. Each item is rated on a scale from 0 (none) to 3 (severe), yielding a score between 0 and 15. AMS was diagnosed when participants reported a total score  $\geq 3$  and a headache score  $\geq 1$ , following international consensus criteria (20).

State Anxiety was measured using the State-Trait Anxiety Inventory, Form Y-1 (STAI-Y1), a widely used psychometric tool for transient anxiety levels. It comprises 20 items scored on a 4-point Likert scale (1 = almost never to 4 = almost always), with total scores ranging from 20 to 80. Higher scores indicate greater anxiety. The STAI-Y1 has demonstrated strong internal consistency (Cronbach's  $\alpha > 0.90$ ) and sensitivity to situational stressors, including environmental and physiological challenges (17).

All participants completed the STAI-Y1 one day before each ascent to establish a baseline measure of state anxiety. Trait anxiety was measured once at low altitude in Tehran (STAI-Y2) prior to the first ascent to provide baseline descriptive information on participants' general anxiety disposition. Following arrival at the high-altitude destination (3600 m), AMS and anxiety

assessments were repeated at three intervals: 2 hours post-arrival (17:00), 6 hours post-arrival (21:00), and the following morning (~08:00). To accommodate for variability in symptom latency, the highest LLS and STAI-Y1 scores across the three post-arrival time points were used in the final analysis (14,26-27).

## Environmental and Dietary Controls

To reduce confounding variables, all participants consumed standardized meals and were instructed to avoid caffeine, alcohol, and other stimulants for at least 24 hours before each ascent. Fluid intake was encouraged but not regulated to mimic real-world conditions. Ambient temperature, barometric pressure, and humidity were monitored at each altitude station, though environmental data were not analyzed as outcome variables. None of the ascents occurred during adverse weather events.

## Statistical Analysis

The Shapiro–Wilk test confirmed the normal distribution of variables. Descriptive statistics were expressed as mean  $\pm$  standard deviation. Paired sample t-tests compared mean anxiety scores between the active and passive ascent conditions. Independent sample t-tests compared anxiety levels between participants with and without AMS. A  $2 \times 4$  repeated-measures ANOVA (ascent mode  $\times$  time points) was conducted on STAI-Y1 scores to examine changes in anxiety across ascent modes and measurement times. Pearson's correlation coefficient tested the association between LLS and STAI-Y1

scores. Simple linear regression analyses were performed separately for active and passive ascents to evaluate the predictive relationship between post-ascent anxiety scores and AMS severity (LLS). The significance threshold was set at  $p < 0.05$  for all analyses. Data were analyzed using IBM SPSS Statistics for Windows, Version 26.0. Sample size adequacy was evaluated using Eng's formula (28), which indicated that 12 participants in a within-subject crossover design would be sufficient to detect a 40% effect with 80% power at a 0.05 significance level.

## Results

All 12 participants successfully completed both active and passive ascent conditions without any adverse medical events. In Tehran, participants' mean trait anxiety scores (STAI-Y2) prior to the active and passive ascent conditions were 30.3 and 33.6, respectively (Table 1). A  $2 \times 4$  repeated-measures ANOVA (ascent mode: active vs. passive; and 4 time points) on STAI-Y1 scores showed no significant main effect of ascent mode ( $F_{(1,11)} = 0.102$ ,  $p = 0.756$ ,  $\eta^2 = 0.009$ ) and no significant main effect of time ( $F_{(3,33)} = 1.096$ ,  $p = 0.365$ ,  $\eta^2 = 0.091$ ). The ascent mode  $\times$  time interaction was also not statistically significant ( $F_{(3,33)} = 2.739$ ,  $p = 0.059$ ,  $\eta^2 = 0.199$ ).

Table 1- Descriptive Statistics for STAI-Y1 and LLS Across Ascent Modes and Time Points

Variable	Ascent Mode	Tehran	17:00 pm	12:00 pm	08:00 am
STAI-Y1 (State anxiety)	Active	28.6 $\pm$ 6.9	35.7 $\pm$ 13.5	33.4 $\pm$ 12.8	27.7 $\pm$ 9.5
	Passive	32.5 $\pm$ 8.0	30.0 $\pm$ 9.3	29.1 $\pm$ 9.3	30.1 $\pm$ 9.5
LLS (AMS severity)	Active	-	3.2 $\pm$ 1.9	2.9 $\pm$ 3.2	1.4 $\pm$ 1.3
	Passive	-	1.8 $\pm$ 1.9	1.8 $\pm$ 2.1	2.0 $\pm$ 1.8

Values are presented as mean  $\pm$  standard deviation. STAI-Y1: State-Trait Anxiety Score. LLS: Lake Louise Score. Times correspond to measurements at baseline (Tehran) and three post-arrival time points at 3,600 m. A dash (-) indicates measurements not applicable at baseline.

Paired sample t-tests revealed no statistically significant difference in state anxiety levels between active and passive ascent conditions ( $t_{(11)} = 1.109$ ,  $p = 0.291$ ,  $d = 0.32$ ). When comparing anxiety levels between participants with and without AMS, the results showed that during active ascent, anxiety levels were significantly higher in participants with AMS than in those without ( $t_{(6,864)} = 2.435$ ,  $p = 0.046$ ,  $d = 1.41$ ). However, during passive ascent, the difference in anxiety scores between AMS and non-AMS participants was not statistically significant ( $t_{(10)} = -1.200$ ,  $p > 0.05$ ,  $d = 0.70$ ) (Figure 1).

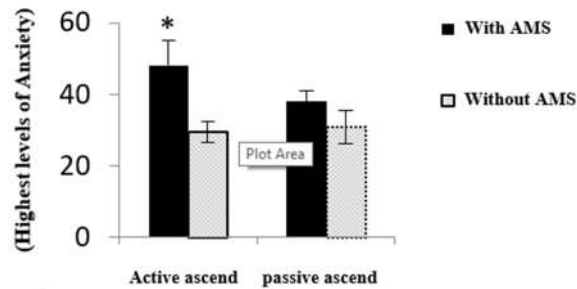


Figure 1- Comparison of state anxiety scores (STAI-Y1) between participants with and without AMS during active and passive ascent conditions. Error bars represent standard deviations of the mean. (\*: significant difference compared to participants without AMS ( $p=0.046$ )).

Further analysis using Pearson correlation coefficients demonstrated a significant positive association between state anxiety scores and AMS severity, as measured by the Lake Louise Score (LLS), during both ascent conditions. Specifically, during active ascent,

there was a strong correlation between anxiety and LLS ( $r = 0.681$ ,  $p = 0.015$ ), while a moderate yet still statistically significant correlation was observed during passive ascent ( $r = 0.578$ ,  $p = 0.049$ ) (Figure 2).

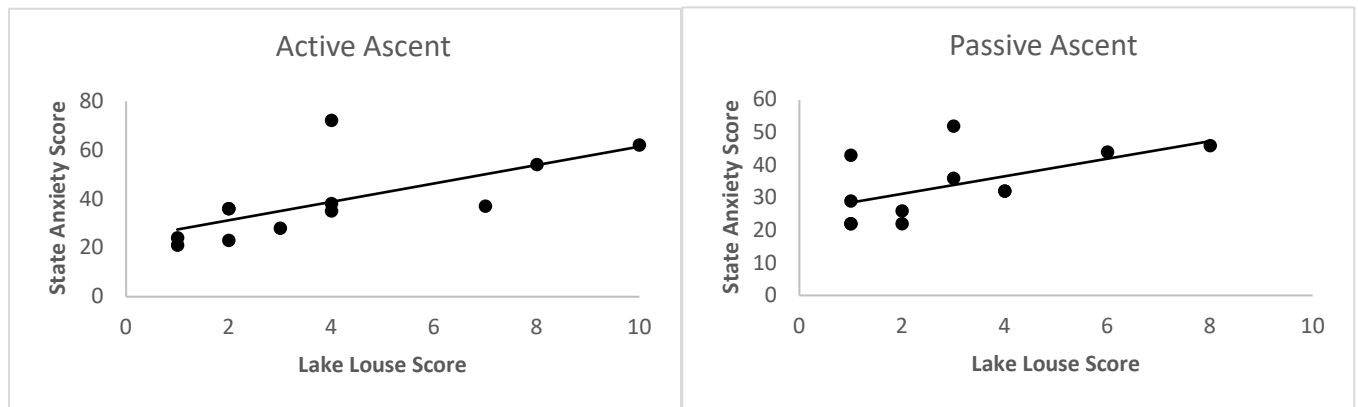


Figure 2- Scatterplots showing the relationship between STAI-Y1 (state anxiety score) and AMS severity (Lake Louise Score) for active and passive ascent conditions. Solid lines indicate regression fit.

Baseline anxiety levels measured in Tehran prior to ascent were not significantly correlated with AMS severity in either ascent mode. This finding differs from some prior studies reporting that higher pre-ascent anxiety predicts AMS development (11,19,29). A likely explanation is that, in our

study, STAI-Y1 scores were collected one day before ascent, at a time when participants had not yet encountered altitude-related physiological stressors. These scores may have primarily reflected anticipatory anxiety rather than the acute anxiety that emerges under hypoxic conditions. Furthermore,

participants were non-mountaineers but were uniformly briefed on the study procedures, ascent profiles, and expected conditions, potentially reducing uncertainty and anxiety before departure. The standardized pre-ascent environment, including rest, meals, and group support, may also have minimized individual variability. Collectively, these factors could have attenuated any baseline anxiety differences and weakened its association with subsequent AMS in our sample.

During active ascent, the correlation between pre-ascent anxiety and LLS was weak and not significant ( $r = 0.274$ ,  $p = 0.389$ ), and a similar non-significant pattern was found during passive ascent ( $r = 0.303$ ,  $p = 0.339$ ). Simple linear regression analyses further examined the predictive relationship between post-ascent state anxiety and AMS severity. In the active ascent condition, anxiety scores explained 46.3% of the variance in LLS scores ( $R^2 = 0.463$ ,  $F_{(1,10)} = 8.64$ ,  $p = 0.015$ ), with each one-point increase in STAI-Y1 associated with a 0.123-point increase in LLS. In the passive ascent condition, anxiety scores explained 33.4% of the variance in LLS scores ( $R^2 = 0.334$ ,  $F_{(1,10)} = 5.02$ ,  $p = 0.049$ ), with each one-point increase in STAI-Y1 associated with a 0.124-point increase in LLS.

## Discussion

Anxiety is a prevalent psychological condition characterized by persistent worry or fear in anticipation of potential challenges, significantly impacting occupational performance, daily functioning, and overall quality of life (29). Exposure to high-altitude

environments has been documented to induce or exacerbate anxiety symptoms, which are frequently associated with the onset of acute mountain sickness (AMS) (5, 18-20, 30). Kious et al. (2019) conducted a comprehensive study involving medical interns and found that transitioning from low to high altitudes was significantly associated with increased symptoms of depression, anxiety, and suicidal ideation compared to remaining at low altitudes (17). These findings align with reports of new-onset anxiety disorders in individuals traveling to high altitudes (20). The overlapping symptoms of AMS and anxiety, such as headache and insomnia, suggest a potential bidirectional relationship, where each condition may influence the severity and manifestation of the other (19).

The present study aimed to investigate the differential effects of active versus passive ascent on anxiety and AMS, as well as the relationship between pre-ascent anxiety and AMS development. Our repeated-measures ANOVA results indicated that anxiety levels increased at altitude regardless of the ascent method, with no significant difference between active and passive ascents. Participants who developed AMS exhibited higher anxiety levels than those who did not, irrespective of the ascent method. Furthermore, both Pearson correlation and simple linear regression analyses showed that post-ascent anxiety was positively correlated with AMS severity, while pre-ascent anxiety measured at low altitude was not.

These associations can be interpreted through both theoretical and physiological frameworks. On a physiological level, exposure to low oxygen levels stimulates the sympathetic nervous system, increasing the release of catecholamines such as norepinephrine and epinephrine. These neurotransmitters drive the "fight-or-flight" response, elevating heart rate, blood pressure, and alertness, all of which can heighten anxiety. Hypoxia also alters serotonin and dopamine pathways, which regulate mood, and activates the hypothalamic–pituitary–adrenal axis, increasing cortisol production. While cortisol aids in stress management, sustained elevation under hypoxia can impair cognition and exacerbate anxiety symptoms. Consistent with these mechanisms, our findings also resonate with the Yerkes–Dodson law, which suggests that moderate levels of arousal can enhance functioning, whereas excessive arousal becomes detrimental. In the present context, the elevated anxiety observed after ascent may have driven participants beyond the optimal zone, thereby worsening AMS symptoms. The somatosensory amplification framework provides additional insight, suggesting that individuals with elevated anxiety are more likely to perceive ordinary bodily sensations as unusually intense or distressing, leading to higher AMS reports even under comparable physiological stress.

These results are in line with previous studies that have established an association between anxiety and AMS (4, 17-19, 29, 31). Tang et al. (2023) reported increased anxiety

levels in both AMS and non-AMS groups following a 58-hour bus ascent from 500 m to 3800 m, with significantly higher anxiety observed in the AMS group (16). Similarly, Bian et al. (2015) found that individuals who developed AMS exhibited higher anxiety levels compared to those who did not after a two-hour flight to 3700 m, indicating a potential role of anxiety in AMS onset (31). In a subsequent study, Bian et al. (2016) assessed 285 Chinese men during a four-day hiking ascent from 400 m to 3450 m and found that individuals with AMS scored higher on somatization, depression, and anxiety scales (29). Their earlier research also indicated that higher baseline somatization scores at sea level were independent predictors of AMS, emphasizing the importance of psychological factors in AMS susceptibility (19). Missoum et al. (1992) reported that pre-ascent anxiety served as a reliable psychological predictor of AMS (11). High pre-exposure anxiety levels have been associated with an increased incidence of AMS (17, 18). Dong et al. (2013) found that anxiety levels were significantly higher in individuals who developed AMS compared to those who did not (19). Oliver et al. (2012) observed that total AMS scores were associated with increased anxiety, although these scores could not predict AMS onset the following day (20). Boos et al. (2018) reported that STAI scores independently predicted AMS at subsequent altitudes (12). Conversely, Niedermeier et al. (2017) found no association between anxiety and AMS in a simulated altitude environment (30). The relatively low to moderate baseline trait

anxiety observed in our participants may help explain why pre-ascent anxiety did not predict AMS development. It is possible that dispositional anxiety was not sufficiently elevated to act as a vulnerability factor, whereas situational stress under hypoxia more strongly influenced AMS severity.

While cognitive tests in simulated altitude settings have shown the impact of hypoxia, noticeable differences exist when comparing results from simulated environments to those from natural high-altitude conditions, even when using the same cognitive assessments (32, 33). Field experiments are considered to provide a more accurate reflection of the real effects of altitude exposure (33). Most previous studies have relied on simulated environments because conducting research at high altitude poses significant logistical challenges. Variations in ascent protocols, hypoxia type (simulated vs. natural), and participant demographics may account for these discrepancies. Importantly, this is the first field study to directly compare active and passive ascents to the same altitude in the same participants under matched timelines, standardized rest and meals, and a counterbalanced within-subject design. This methodological rigor minimizes inter-individual variability and strengthens the ecological validity of our findings compared to simulated-environment studies.

The present study also has several limitations that should be considered. First, AMS symptoms were monitored only up to the morning after arrival. Although the literature indicates that most symptoms

emerge within 6–12 hours after reaching high altitude, delayed-onset cases cannot be fully excluded. Second, while our statistical justification indicated that a sample of 12 participants was adequate for detecting the targeted effect size, the small cohort limits external validity. Accordingly, the findings should be interpreted as exploratory and in need of confirmation in larger and more diverse populations. Third, the sample consisted exclusively of young, healthy males, which restricts applicability to females, older adults, or individuals with pre-existing medical conditions.

Future research can be conducted with larger and more diverse samples, including women and older adults, at higher altitudes and for longer durations, incorporating objective biomarkers alongside self-report measures.

In conclusion, this counterbalanced within-subject field study at 3,600 m found that post-ascent anxiety was positively associated with AMS severity across both ascent modes, whereas pre-ascent anxiety was not predictive.

These findings highlight the importance of repeated post-arrival anxiety monitoring for AMS risk assessment and suggest that integrating simple screening tools such as the STAI-Y1 could improve safety in high-altitude expeditions, occupational deployments, and athletic contexts. Individuals with elevated anxiety scores should be closely monitored for AMS symptoms to enable timely intervention,

including rapid evacuation or descent when necessary.

### Author Contributions

All authors contributed equally to the conceptualization of the article and writing of the original and subsequent drafts.

### Data Availability Statement

Data available on request from the authors.

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### Ethical considerations

This article is based on a doctoral dissertation from the exercise physiology department at Razi University, which received ethical approval (code IR.RAZI.REC.1400.076) from the university's research deputy and ethics committee. Additionally, the study is registered with the Iranian Registry of Clinical Trials (code IRCT20211223053495N1).

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### Conflict of interest

The authors declare no conflict of interest.

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