

LIMITS OF ADAPTATION. PAIN THRESHOLDS AND TOLERANCE IN ALPINISTS UNDER ENVIRONMENTAL STRESS – EXPLORATORY ANALYSIS

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Background: Human responses to pain and sensory stimuli are shaped by both biological constitution and long-term exposure to environmental stressors. Extreme environments such as high altitude, cold, heat and intensive physical effort represent strong selective and adaptive pressures. Alpinists constitute a unique group with repeated exposure to hypoxia, thermal stress and sustained physical load, which may influence sensory perception and pain regulation.

Objective: The aim was to examine differences in sensory threshold, pain threshold and pain tolerance between experienced alpinists and non-acclimatized controls across a range of experimentally induced environmental and physiological conditions.

Subjects and methods: The study included 10 alpinists and 35 control participants. Sensory, pain and tolerance thresholds were assessed under five conditions: baseline, simulated altitude (4000 m), heat (42°C), cold (-10°C) and physical exercise. Between-group differences were evaluated using Cohen's d effect sizes (95% bootstrap confidence intervals, 3000 resamples). Effect-size-based inference served as the primary analytical framework.

Results: Alpinists demonstrated consistently higher pain thresholds than controls, particularly at baseline, during heat exposure and following exercise, with large to very large effect sizes. In contrast, group differences in sensory thresholds were generally small and inconsistent across conditions. Notably, pain tolerance showed an opposite pattern: in heat and exercise conditions, controls exhibited substantially higher tolerance than alpinists, despite lower pain thresholds.

Conclusions: The findings indicate that long-term exposure to extreme environments is associated with distinct patterns of pain processing, characterized by elevated pain thresholds but reduced tolerance under prolonged stress. This highlights the complex interplay between biological adaptation, functional specialization and environmental experience, underlining the value of pain-related traits as anthropological markers of human variability and adaptation.

Keywords: Biological anthropology; Pain perception; Environmental stress; Physiological adaptation; Alpinists.

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