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THE IMPACT OF STRESS ON DECISION-MAKING AND PERFORMANCE IN ROCK CLIMBING: A LITERATURE REVIEW

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ABSTRACT

Introduction and purpose: Sport climbing, as a high-risk activity, provides a valuable framework for analyzing the impact of stress on decision-making processes. This paper aims to explore specific aspects of climbing that may influence cognitive processes and, consequently, the behavior of individuals engaged in this demanding sport discipline.
Material and methods: A thorough review of the literature available on PubMed and Google Scholar databases was conducted using following keywords: “rock climbing”, “lead climbing”, “top rope climbing”, “bouldering”, “stress”, “decision-making”
Conclusions: Stress significantly affects climbers' cognitive and physical performance, especially among less experienced individuals. However, psychological resilience, experience, and mental training can mitigate its negative impact. When properly managed, stress may even enhance performance and adaptability. Therefore, climbing training should include psychological preparation to improve decision-making, focus, and safety in high-risk conditions.

KEYWORDS

Rock Climbing, Lead Climbing, Top Rope Climbing, Bouldering, Stress, Decision-Making

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Introduction.

In recent years, sport climbing has experienced a significant rise in popularity, with climbing facilities emerging across urban centers to accommodate a wide range of participants, including children and adults, as well as amateur and professional athletes. Despite advancements in accessibility and continuous improvements in safety protocols, climbing remains inherently associated with physical risk. Awareness of these risks – whether explicit or implicit – can significantly influence climbers' psychological states and behavioral responses. For novice climbers, stress may be induced by the height itself, while more experienced individuals may experience heightened stress in response to minimal protection and the increased potential for severe falls. This study aims to synthesize current scientific findings regarding the impact of stress on decision-making processes in climbing, its implications for athletic performance, and evidence-based strategies for mitigating its adverse effects.

Clinical characteristics of stress

Stress is defined as a physiological response of the body to internal or external factors that disrupt homeostasis.[1] It can be broadly categorized into two distinct types: physiological and psychological. *Physiological stress* refers to the body’s innate response to physical challenges, including injury, illness, or intense physical exertion. In contrast, *psychological stress* arises from the body’s reaction to emotionally charged experiences such as anxiety, fear, sadness, or anger.[2] Stress responses, triggered by exposure to stressors, affect numerous aspects of human functioning and, depending on their duration and intensity, may lead to a wide range of adverse outcomes.[3] Exposure to stress can impair the functioning of virtually all bodily systems. It has been shown to disrupt endocrine, cardiovascular, and gastrointestinal functions, and may compromise immune responses.[4-6] Most importantly, in the context of this study, stress also affects memory, learning, and cognitive functions – key components of effective decision-making. In high-risk sports such as climbing, these impairments influence not only performance but also safety.[7]

Types of climbing

Climbing encompasses a variety of forms that differ in movement patterns, route height, required equipment, and setting (indoor vs. outdoor). The two primary categories to distinguish are bouldering and rope climbing. Bouldering involves relatively short routes that emphasize a small number of technically or physically demanding movements. To mitigate injury from falls, crash pads and bouldering mats are used as a form of passive protection. In contrast, rope climbing typically involves higher routes – commonly around 15 meters – and necessitates the use of specialized rope-based protection systems. These systems include *top rope* climbing, in which the rope is anchored at the top of the route, and *lead climbing*, where the climber clips the rope into sequential protection points (quickdraws) while ascending. Lead climbing introduces a greater fall potential, especially when the climber moves above the last secured point, thereby increasing the associated risk. Due to its complexity and exposure, lead climbing generally requires more experience and is more commonly practiced by advanced climbers.

Risks associated with climbing

Given the high incidence of injuries associated with climbing – both from excessive mechanical load on the limbs (e.g., finger tendon injuries, pulley ruptures, shoulder strains)[8,9] and from falls resulting in trauma to the upper or lower extremities (e.g., knee, ankle, or shoulder injuries, fractures)[10,11] – it is essential for climbers to select routes and safety systems that are appropriate for their skill level. Moreover, decisions should be made to balance challenge and safety in order to optimize performance while minimizing the risk of serious injury. The inherent risk of climbing highlights the importance of focusing not only on the development of physical strength – which is undoubtedly crucial for tackling more demanding routes – but also on psychological preparedness. A survey conducted by a panel of coaches from the French Mountaineering Association indicated that psychological traits are the most significant determinant of climbing performance, accounting for 50% of the overall impact. This was followed by physical abilities (27%), tactical skills (15%), and technical skills (8%)[12].

The Impact of Height

One of the primary factors contributing to stress in climbing is the height of the route, which is inherently linked to the risk of falling and potential injury. A 2016 study conducted on advanced female climbers investigated how potential fall distance during lead climbing influenced catecholamine levels in the blood. Catecholamines – namely adrenaline and noradrenaline – are secreted by the adrenal medulla in response to stress and are responsible for many of the body's physiological changes during stressful situations, such as increased heart rate, elevated blood pressure, and heightened physical readiness. Elevated levels of these hormones can reflect both physical (adrenaline) and psychological (noradrenaline) stress.[13,14]

In the study, climbers ascended two routes: once using all protection points and once skipping every other point, thereby increasing the *runout* – the amount of rope between the climber and the last secured point. This setup heightened the risk of a longer fall and potential injury. In both scenarios, catecholamine levels – especially noradrenaline – increased, but the rise was significantly greater when fewer protection points were used.[15] Interestingly, there were no significant differences in heart rate (HR) or rate of perceived exertion (RPE), suggesting a stronger influence of psychological rather than physical stress under these conditions.

A separate study conducted by Gajdošík in 2020 focused specifically on the physiological response to climbing at different heights and included participants with varying levels of climbing experience. Climbers ascended the same top rope route twice: once several meters above the ground and once on a treadwall approximately one meter high. Importantly, neither scenario presented a risk of long falls. Despite this, all climbers demonstrated higher physiological responses - such as increased HR, ventilation rate, and energy expenditure - during the higher ascent, highlighting the effect of vertical height alone. Notably, less experienced climbers reported significantly higher RPE at greater heights compared to experienced climbers, indicating that psychological stress related to height disproportionately affects novices.[16,17]

Beyond the physiological aspects, researchers have also examined how stress related to height impacts perception and the ability to realize *affordances* - opportunities for action. J.R. Pijpers and colleagues conducted a series of experiments with novice climbers, having them complete lateral traverses at different elevations, with route features kept constant. [18-20] Despite secure conditions, climbing at approximately 5 meters above the ground resulted in increased muscular fatigue, elevated heart rate, and higher blood lactate levels, reflecting increased exertion.[21] Furthermore, climbers spent more time gripping holds and took longer to complete the route when at height. Their movement patterns were also altered, and height-induced anxiety

was found to reduce both perceived and actual maximal reach. Additionally, perceptual capacity declined – participants detected fewer visual cues (e.g., flashing lights used to test attention) – indicating that stress impaired their attentional focus.[20]

Such perceptual and cognitive limitations may have practical consequences in outdoor climbing, where holds are often less visible and require more effective visual scanning and decision-making than those on artificial walls. Understanding the effects of height-induced stress is therefore critical not only for performance but also for climber safety.

The impact of climbing style on climbers

The type of protection used during rope climbing significantly influences the climber's perception and experience of a route. Lead climbing, which provides fewer opportunities for protection than top rope climbing, has been shown to affect both psychological and physiological performance. Research indicates that lead climbing places greater physiological demands on the body compared to top rope climbing, with the additional energy expenditure being primarily met through anaerobic metabolic pathways. Although no significant differences in anxiety levels were observed between the two styles, lead climbing was perceived as substantially more mentally and physically taxing. Climbers reported exerting more effort and experiencing greater frustration with their performance during lead ascents.[22]

However, this pattern does not appear to extend to advanced climbers. In experienced individuals, no significant differences were found in either physiological or psychological variables in response to changes in climbing style, suggesting a greater adaptability and resilience to the demands of lead climbing.[23]

Another factor influencing stress in climbing is whether the route is familiar to the climber (redpoint) or attempted for the first time (on-sight). In a study conducted by Draper and colleagues, significant differences were observed in self-reported pre-climb somatic and cognitive anxiety, climb duration, and post-climb blood lactate levels depending on the climbing style.[24] These findings highlight the interplay of psychological and physiological stress in climbing. Specifically, the heightened anxiety associated with on-sight lead climbing appears to contribute to increased physiological load, particularly among intermediate-level climbers.

Dual tasks and fear words

While the effects of divided attention on task performance have been widely studied, a particularly novel approach was presented by A.L. Green and W.S. Helton in the context of climbing. In a 2011 experiment, the researchers examined how dual-tasking influences performance during a complex motor activity such as climbing. They compared the performance of intermediate-level climbers while completing a single task (either climbing or word memorization alone) with that during a dual-task condition (climbing while memorizing words). The results showed that engaging in both tasks simultaneously impaired both climbing performance and word recall, highlighting the cognitive cost of adding a secondary task to an already physically and mentally demanding activity.[25]

In a follow-up study conducted in 2014, the authors introduced a key modification: the memorized words were divided into emotionally neutral and fear-related categories. Once again, the dual-task condition led to reduced climbing distance, lower performance, and decreased memory recall. Notably, climbing performance declined further when climbers were tasked with memorizing fear-related words compared to neutral ones, indicating that the emotional content of words alone can negatively affect physical performance.[26]

Interestingly, when asked to evaluate their own performance, climbers were aware of the general decline associated with dual-tasking but remained unaware of the additional performance drop caused by the emotional valence of the words. This suggests that emotional distractions may exert a subtle yet significant influence on performance, even when individuals are not consciously aware of their effects.

Can fear be overcome?

Height-related stress and the fear of falling are among the primary psychological factors that limit a climber's ability to effectively tackle challenging routes. This form of stress can manifest in altered behavior, including stiff or inefficient movements, which increase energy expenditure and reduce overall endurance. Consequently, climbers may experience greater hesitation, more tentative movement patterns, and impaired decision-making regarding subsequent actions.[27] These effects can ultimately compromise performance and reduce the likelihood of a successful ascent.

However, the emotional response to such stressors can be trained and regulated, much like physical skills in climbing. As noted by Gajdošík, stress induced by height predominantly affects less experienced

climbers.[16] Experience plays a critical role in managing psychological demands, as more advanced climbers typically exhibit lower heart rates both before and during climbing, along with reduced ratings of perceived exertion (RPE) when compared to non-climbers—factors that directly contribute to enhanced performance.[17]

Targeted psychological training has also been shown to improve climbing outcomes and reduce fear of falling.[28] Such training should focus on anxiety reduction, enhancement of concentration, and building self-confidence, as well as the incorporation of mindfulness techniques to help climbers regulate their mental state independently.[29] This integrative approach not only supports psychological resilience but also promotes safer and more effective climbing performance.

The role of experience and mental attitude in climbing decision-making

Experience is a key factor enabling climbers to make accurate decisions and enhances their problem-solving abilities. Advanced climbers tend to spend less time previewing bouldering problems, complete them more quickly, and make fewer movement errors compared to less experienced individuals.[30] Climbing expertise also influences neurocognitive functioning. A 2018 study showed that climbers outperform non-climbers in tactile and spatial perception, as well as movement memory.[31] This advantage may stem from the nature of climbing, which often requires selecting appropriate holds based primarily on touch rather than vision – especially when holds are located above the climber's line of sight.

Both experience and confidence prior to an ascent have been shown to positively influence performance in lead and top rope climbing. These traits are associated with faster navigation through critical sections of a route and lower heart rates among climbers who successfully complete climbs.[32] Confidence in one's ability also plays a vital role in risk-taking behavior. According to Llewellyn, climbers who are more self-assured are more likely to engage in higher-risk climbs, take calculated risks, and attempt more difficult routes, effectively managing the fear associated with such challenges.[33]

Gender-related differences in risk perception were highlighted in a 2021 study focused on outdoor climbing. While male climbers demonstrated higher confidence levels and a greater tendency to take risks, the study did not find significant differences between men and women in how much stress they experienced from the risk itself.[34]

The Role of Route-Setting Experience in Climbing Performance

Another crucial skill supporting decision-making in climbing is route reading – the ability to mentally simulate the required movements before initiating the ascent. This includes assessing hold shape, texture, orientation, and size, which, when combined with prior experience, helps climbers predict the positions and movements needed to overcome specific challenges.[35] The broader a climber's movement repertoire, the more efficient their climbing becomes. Given that stress can narrow attentional focus, impair perception, and reduce both perceived and actual reach during climbing,[20,36] it is essential that climbers assess the route beforehand, when not yet affected by physical exertion or height-induced anxiety.

Experienced routesetters—individuals responsible for designing climbing routes in indoor climbing facilities—possess highly developed skills in visualizing movement sequences and problem-solving under climbing-specific conditions. A recent study investigated how such expertise influences climbing performance. The participants included professional climbers, some of whom had prior experience in route setting. Each participant was asked to complete two bouldering problems under time constraints (four minutes and two minutes, respectively), which simulated a climbing competition and further increased psychological stress.

The results indicated that climbers with route-setting experience demonstrated superior decision-making abilities, as evidenced by shorter preview times, more efficient movement strategies, and fewer tactical corrections during the climbs. Additionally, they achieved better performance outcomes, including higher top-out rates, fewer attempts, and greater progress (higher holds reached) in their best attempts. Notably, this group was less adversely affected by time pressure compared to climbers without route-setting experience.[37]

These findings suggest that route-setting experience provides climbers with an expanded repertoire of practiced movement patterns and enhances their ability to rapidly and accurately interpret climbing challenges. This allows for more effective decision-making, improved performance, and greater resilience under pressure.

Positive Stress and Adaptive Functioning

For many individuals, stress is predominantly associated with negative emotional and physiological responses. However, research increasingly supports the notion that stress, in accordance with the "fight, flight, or freeze" response model, may not only provoke avoidance or paralysis but can also activate motivational and adaptive processes. Under certain conditions, stress can serve as a catalyst for action, enhancing the individual's capacity to engage effectively with challenging tasks.

A specific form of beneficial stress, referred to as *eustress*, has been shown to exert energizing and performance-enhancing effects. Eustress can contribute to physiological regulation, including restoration of energy balance, support for cardiovascular health, increased physical endurance, and improved cognitive functioning. It facilitates attentional focus and strengthens intrinsic motivation. In contrast, *distress* – a maladaptive and prolonged form of stress – has been linked to a broad range of negative outcomes affecting both physical and psychological health.[38]

Empirical studies have demonstrated that stress influences decision-making processes. Whether this influence is advantageous or detrimental depends largely on the context in which the decision is made and the cognitive demands of the task.[39] Evidence from portable EEG recordings in competitive climbers suggests that individuals who successfully completed outdoor climbing routes – particularly those characterized by greater technical difficulty – exhibited increased alpha wave activity (indicative of physiological relaxation) and elevated theta wave activity (associated with deep internal concentration) during the most stressful portions of the climb, known as the crux.[40]

These findings align with performance efficiency theory and attentional control theory, which posit that increased frontal alpha and theta activity serves as a neural mechanism to inhibit irrelevant stimuli and reduce cognitive interference under pressure. Such modulation of neural activity not only enhances acute task performance but may also facilitate long-term motor and cognitive skill development.

Thus, climbing – despite its inherent risk – can elicit beneficial psychophysiological outcomes. The ability of the human organism to not only tolerate but also adapt and grow in response to controlled exposure to stress is consistent with the concept of *antifragility*.[41] In order to elicit the positive effects of stress, it is essential to maintain its intensity within an optimal range – sufficiently high to stimulate adaptive responses, yet below the threshold that might lead to maladaptive consequences or system overload.

Conclusions

Climbing, as a high-risk sport, requires not only physical strength and technical proficiency but also advanced psychological resilience and decision-making capabilities. The reviewed literature clearly demonstrates that stress – whether stemming from height, potential falls, or the mental load of dual tasks – can significantly impair cognitive function, perception, and motor performance. These effects are particularly pronounced among novice climbers, who exhibit greater physiological and psychological responses under stress, including elevated anxiety, reduced movement efficiency, and impaired attentional control.

Importantly, experience and psychological training emerge as key modulators of stress impact. More experienced climbers demonstrate lower physiological arousal, enhanced route-reading skills, and greater confidence, all of which contribute to improved performance and safer decision-making. Techniques such as mindfulness, visualization, and anxiety regulation can further support climbers in mitigating the negative effects of stress.

While stress is often perceived as a performance-limiting factor, it can also act as a catalyst for growth and adaptation when properly managed – a concept aligned with the theory of antifragility. Recognizing the dual role of stress, future training programs for climbers should incorporate psychological components aimed at enhancing mental resilience, improving focus under pressure, and fostering adaptive responses to high-risk environments. This integrative approach may optimize both performance and safety in climbing practice.

Disclosures

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