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Therapeutic Potential of Indoor Climbing from Physical Fitness to Neurorehabilitation and Mental Health

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Abstract

Background. Rock climbing is currently experiencing a global surge in popularity and represents a unique model of physical activity that integrates resistance and isometric training with high neurological stimulation. It challenges the traditional dichotomy between cardiovascular and strength sports by offering a complex, interval-based form of exertion where movement precision is as vital as the power generated.

Aim. The aim of this review is to explore the multi-dimensional landscape of rock climbing as a health intervention, focusing on its impact on physiological adaptations, musculoskeletal health, and its specific therapeutic efficacy in psychiatry and neurorehabilitation.

Material and methods. This paper reviews recent literature, including meta-analyses and randomized controlled trials, regarding the effects of climbing. The analysis covers physiological parameters (VO2max, bone density, core strength), Bouldering Psychotherapy (BPT) for depression, and neurorehabilitative protocols for Parkinson's disease, Multiple Sclerosis, and Autism Spectrum Disorder (ASD), alongside an assessment of injury risks.

Results. Climbing significantly improves VO2max, grip strength, and core stability, and serves as an effective intervention for chronic low back pain. In mental health, Bouldering Psychotherapy reduces symptoms of moderate depression (average decrease of 8.3 points on MADRS), achieving outcomes comparable to Cognitive Behavioral Therapy with long-term sustainability. In neurorehabilitation, climbing leads to significant reductions in Parkinson's motor symptoms (tremor by 51%, rigidity by 30%), aids fatigue management in multiple sclerosis, and enhances selective attention in children with autism spectrum disorder. Overuse injuries, particularly to the finger pulley system, constitute the primary risk factor (up to 68% of adult injuries).

Conclusions. Rock climbing is a relatively safe, multi-modal intervention that offers significant clinical benefits across physiological, psychological, and neurological domains. It facilitates a vital shift in patient identity from focusing on limitations to recognizing capabilities and warrants broader integration into standard healthcare systems and insurance-covered rehabilitation programs. However, clinicians must remain vigilant regarding specific overuse injuries and skeletal maturity, particularly in adolescent populations.

Key words: rock climbing, bouldering, psychotherapy, neurorehabilitation, depression, physical fitness

1. Introduction

Sport climbing is currently undergoing a "golden age." The inclusion of bouldering, lead climbing, and speed climbing in the Olympic programs of Tokyo (2020) and Paris (2024), alongside its confirmed presence in Los Angeles (2028), has fundamentally shifted the global perception of this discipline. From a medical perspective, climbing represents a unique model of physical exertion that integrates elements of resistance and isometric training with high levels of neurological stimulation (Michael et al., 2019).

Traditional approaches to physical activity often categorize sports into those promoting cardiovascular endurance such as running and those focused on building strength like

bodybuilding. Climbing defies this dichotomy by offering an interval-based form of exertion where movement precision is as vital as the power generated (Bertuzzi et al., 2007; Limonta et al., 2018). This review explores how this synergy impacts the prevention and treatment of non-communicable lifestyle diseases.

2. Physiological Adaptations and Musculoskeletal Health

2.1. Musculoskeletal System and Pain Prevention

Climbing is a physical activity that necessitates the utilization of multiple muscle groups, including both lower and upper limbs, the feet and hands, abdominal muscles, and the back. Furthermore, mobility in the hip joints and the spine is of critical importance. To overcome a bouldering problem or complete a climbing route, it is necessary to perform a variety of movements loaded by one's own body weight (Mermier et al., 2000; Michael et al., 2019; Muehlbauer et al., 2012).

A 2018 meta-analysis conducted on a group of students provides significant insight into this subject, evaluating the impact of climbing on key aspects of physical fitness: body fat percentage, body function, muscle power, muscle endurance, and flexibility. The results of the analysis showed no significant effect of climbing training on body fat reduction, however significant progress was noted in other areas of physical health.

Regarding body function, resting heart rate and maximal oxygen uptake (VO2max) were analyzed. Although the resting heart rate did not decrease, which the authors attribute to the relatively short duration of the study, a positive effect was observed on the VO2max parameter, which is a reliable reflection of the body's aerobic capacity. Muscular power assessment included handgrip strength, lower limb pedaling power, and vertical jump, with the most pronounced improvement observed in grip strength. Significant progress was also shown in muscular endurance, defined as the ability to continue work under increasing fatigue. Measurements based on the number of pull-ups, push-ups, and squats showed improvement in each of these exercises. The final element studied was flexibility, measured by the sit-and-reach test. Although this tool may not fully reflect the specific mobility required in climbing, the analysis confirmed a progression of results in this parameter as well (LI et al., 2018).

Therapeutic climbing (TC) constitutes a valuable method supporting the rehabilitation of patients with chronic low back pain, demonstrating effectiveness comparable to, and in certain aspects superior to, standard therapeutic exercises. Randomized clinical trials have shown that while both forms of activity significantly improve patients' vitality, mental health, and social functioning, therapeutic climbing brings additional benefits in terms of subjectively perceived physical functioning and general health perception. In these two areas, TC effects statistically exceeded the results achieved in traditional exercise programs.

The advantage of climbing in certain aspects of perceived health stems from the specificity of this training, which forces the patient to concentrate on precise movements, subtle changes in body posture, balance, and breathing. This form of cognitive engagement allows for the redirection of attention away from pain and limitations toward a positive experience of the body, facilitating a modification of associations between movement, pain, and avoidance behaviors. Although muscular strength was not measured directly in this study, as subjectively perceived health and disability were found to be better predictors of return to work than

physical parameters, it is suggested that the interaction of coordination and concentration, rather than muscle strengthening per se, crucially influences the improvement of quality of life. The results provide a scientific rationale for recommending climbing as an effective intervention in the treatment of chronic back pain (Engbert & Weber, 2011).

Analysis of the impact of climbing on bone mineral density (BMD) provides significant conclusions regarding the specificity of mechanical loading in this sport. Studies have shown that areal bone mineral density and mineral content in the axial skeleton, specifically in the femoral neck and lumbar spine, among climbers are similar to those of untrained individuals but significantly lower than in resistance-trained men. This suggests that climbing alone may not constitute a sufficient stimulus to trigger osteogenesis in central skeletal sites, which the authors associate with high climbing economy and techniques that limit the generation of muscular forces necessary for bone remodelling.

In contrast, markedly different results were observed regarding the peripheral skeleton. Parameters for the tibia and forearm in climbers were comparable to the resistance-trained group, indicating that the specific loading of the limbs during climbing may have an osteogenic potential similar to traditional resistance training. In the context of osteoporosis prevention and skeletal health, these findings point to the need for supplementing climbing with resistance training, which more effectively loads critical areas such as the hips and spine without negatively affecting the low body fat levels advantageous to climbers (Sherk et al., 2010).

Another important aspect of analyzing the health-promoting impact of climbing is its effect on core muscle strength, grip strength, and spinal mobility in previously sedentary young adults. Studies have shown that an 8-week training program leads to a significant improvement in maximal isometric strength of the trunk in both the sagittal and coronal planes, as well as a significant increase in handgrip strength. Concurrently, progression in trunk mobility was observed in both analyzed planes. Furthermore, a 9–10% increase in grip strength after 8 weeks of training was also confirmed in a population of children and adolescents (Balas et al., 2009).

2.2. Impact of climbing on the cardiometabolic profile

Climbing, although traditionally perceived as a resistance-based activity, exerts substantial cardiorespiratory demands that exceed simple anaerobic frameworks. Research conducted during simulated bouldering competitions demonstrates that this exertion engages a significant fraction of maximal oxygen uptake, with peak VO2 values reaching approximately 75% of VO2max and heart rates ascending to 88% of the age-predicted maximum. A key physiological aspect involves specific respiratory mechanics: thoracic loading and the necessity of trunk stabilization during climbing constrain tidal volume expansion, forcing the body to maintain minute ventilation primarily through a significant increase in respiratory frequency. Furthermore, periodic breath-holding or Valsalva-like maneuvers are frequently observed as a means to stiffen the spine and provide postural support for strenuous movements, which further modifies respiratory patterns. Although cardiorespiratory parameters return to baseline relatively quickly (within 2–4 minutes post-climb), perceived exertion and blood lactate concentrations remain elevated for a significantly longer duration, suggesting a dominance of peripheral neuromuscular fatigue over central cardiorespiratory limitations.

Climbing also induces a pronounced exercise pressor response, characterized by drastic increases in arterial blood pressure (BP). Intra-arterial measurements have revealed that during

high-intensity climbing exercises, such as campus board training, BP can increase by 40–67%, with some athletes reaching peak values as high as 273/189 mmHg. These extreme spikes result from a combination of high-intensity isometric contractions of large muscle groups, the muscle metaboreflex, and elevated intrathoracic pressures associated with breath-holding. Chronic exposure to such extreme BP values may lead to adaptive cardiovascular remodelling, including myocardial hypertrophy and changes in vascular reactivity, which necessitates further clinical investigation to determine long-term health implications.

Analysis of performance determinants confirms that aerobic capacity, both systemic and local forearm oxidative capacity, is a crucial predictor of red-point climbing ability, explaining approximately 67% of the total variance in performance. Elite climbers exhibit unique microvascular adaptations, such as enhanced capillary filtration and higher vascular conductance in the finger flexor muscles, allowing for superior oxygen utilization during exertion. Notably, sport-specific assessments, such as treadwall tests, serve as more valid predictors of climbing ability than traditional treadmill-based exercise. This suggests that climbing itself acts as a potent cardiovascular stimulus that promotes aerobic metabolic efficiency, which is fundamental not only for athletic success but also for the overall metabolic and circulatory health of practitioners.

(Callender et al., 2020, 2021; Fryer et al., 2018)

3. A Breakthrough in Psychiatry: Climbing as a Psychotherapeutic Intervention

The field of mental health is currently the most dynamically developing branch of research concerning climbing. The term "Bouldering Psychotherapy" (BPT) has entered the mainstream of medical literature due to ground-breaking studies in Germany and Austria (Luttenberger et al., 2015, 2022).

3.1. Depression and Mood Disorders

The latest systematic review from 2025, involving an analysis of seven clinical trials with 471 participants, provides strong evidence that indoor climbing, and specifically bouldering combined with mindfulness exercises (BPT), constitutes an effective and clinically significant intervention in the treatment of moderate depression in adults. High-certainty evidence (GRADE) indicates that an 8–10 week training program allows for the reduction of depressive symptoms from moderate to mild, with an average decrease of 8.3 points on the MADRS scale, which significantly exceeds the minimal clinically important difference (MCID) of 5 points. Notably, in a therapeutic context, these effects are sustained long-term, lasting from 6 to 12 months after the intervention ends. Comparative analysis has shown that therapeutic bouldering is more effective than no intervention or home-based exercise, demonstrating effectiveness similar to group cognitive-behavioral therapy (CBT). The authors highlight the high safety profile of this method, as none of the analyzed studies reported adverse events or injuries, making it a safe alternative or supplement to pharmacotherapy, which is potentially burdened by side effects. The uniqueness of climbing as a tool supporting mental health stems from the synergy of high-intensity physical effort, the necessity of solving motor problems, and exposure to height, which fosters the building of trust and a sense of self-efficacy. Furthermore, climbing, unlike verbal therapies, directly contributes to the improvement of overall physical fitness, which has additional value in preventing comorbidities and reducing overall mortality (Larsson et al., 2025).

The evidence obtained in meta-analyses is directly reflected in the results of clinical trials, such as the work of Stelzer et al. It was observed that during an eight-week BPT intervention cycle, depression scores decreased by 6.74 points on the SCL-90-R scale and by 8.26 points on the BDI-II scale, representing a transition from highly clinical levels to a range close to normal. Most importantly, the BPT program proved to be a significant predictor of symptom reduction even after controlling for the participants' general physical activity. This is significant as the participants represented a lifestyle defined as "low active," averaging 6,515 steps per day, which is typical for individuals not engaging in regular sports. Despite this low baseline activity level, regression analysis showed that the specific climbing intervention was the key to clinical improvement (Stelzer et al., 2018). The positive impact of Bouldering Psychotherapy is not limited to the reduction of depressive mood but also includes significant improvement in areas such as phobic anxiety, active and passive coping with stress, and interpersonal sensitivity. Such a broad spectrum of impact results from the fact that BPT combines cognitive, emotional, and social components. A key element of this therapy is mindfulness training forced by the nature of climbing itself, requiring full presence in the "here and now" to master a motor problem. Scientific literature clearly supports the effectiveness of mindfulness in treating depressive disorders, and climbing acts here as a form of exposure to subjectively threatening situations requiring focused attention, the mastery of which is associated with an increase in self-efficacy and internal locus of control. The reported effect sizes fall within the moderate range, making BPT comparable to other short-term group therapies and to the effects reported in meta-analyses concerning the impact of physical exercise on depression (Gürer et al., 2024).

An important supplement to these analyses are the results of the StudyKuS, which was the first in the literature to directly compare the impact of therapeutic climbing on perceived self-efficacy in people with depression against a home-based exercise program (EP) and modern cognitive-behavioral therapy (CBT). At the baseline, participants in all groups rated their self-efficacy as below average. Following the intervention, improvement was noted in all groups, but only in the BPT and CBT groups did patients achieve scores classified as normal or healthy. Statistical analysis showed that therapeutic climbing is significantly more effective in building perceived self-efficacy than independent physical activity (EP), achieving a moderate but clinically significant effect size of d=0.39. At the same time, no significant differences were found between the effectiveness of BPT and CBT, suggesting that a 10-hour climbing program in a group setting can provide benefits comparable to professional psychotherapy in the area of strengthening belief in one's own capabilities. Particularly interesting from a clinical perspective is the analysis of mediators of patient improvement; while in the CBT group, the decrease in depression severity was at least partially mediated by an increase in perceived self-efficacy, this effect did not occur in the climbing group (BPT). This suggests that the therapeutic power of bouldering rests on other factors specific to this discipline that do not depend directly on changes in perceived self-efficacy. These results provide a strong argument for the broader inclusion of BPT into healthcare systems as a valuable supplement to traditional treatment methods, especially in cases where the priority is the rapid restoration of mental well-being and cognitive function (Kratzer et al., 2021).

4. Neurorehabilitation and Brain Plasticity.

4.1. Parkinson's Disease

Sport climbing occupies a special place in modern neurological rehabilitation as a multi-modal intervention supporting the treatment of Parkinson's disease (PD). Randomized controlled trial results indicate that a 12-week climbing program leads to significant and lasting improvement in motor symptoms, measured by the MDS-UPDRS-III scale, which showed an average decrease of 12.9 points (where a change of 3.5 points is considered clinically significant). Climbing proved more effective than unsupervised physical training, which only stabilized disease progression, and its effects exceeded results obtained from other forms of activity, such as Tai Chi, Nordic walking, or LSVT-BIG. The greatest responsiveness to the intervention was shown by tremor (a 51% improvement), followed by muscular rigidity (30%) and bradykinesia (28%), the reduction of which was measurable after only 6 weeks of training. This improvement translates directly into greater patient independence in daily life and a reduction in fall risk through better postural control and the ability to perform faster compensatory movements.

An important biomechanical aspect is the impact of climbing on the stooped posture characteristic of PD progression. It has been shown that regular climbing sessions effectively reduce forward cervical spine flexion, regardless of the patient's age or BMI. The mechanism of this impact is complex and involves strengthening the back extensors and shoulder girdle muscles, increasing trunk and spinal flexibility, and intensive training of proprioception and spatial body awareness. Climbing, by requiring precise movement planning and execution, engages cognitive functions and neuromotor mechanisms, allowing for posture correction through visual and tactile biofeedback. Crucially for quality of life, despite its image as an extreme sport, top-rope climbing proved to be a safe, feasible, and highly motivating form of activity for individuals without prior experience, characterized by excellent therapeutic adherence (Langer et al., 2021, 2023).

4.2. Multiple Sclerosis

Parallel to the successes in Parkinson's therapy, therapeutic climbing (TC) is gaining recognition as an effective supportive intervention in multiple sclerosis (MS). The application of this discipline in MS is based on the fact that climbing constitutes one of the most primordial forms of movement, for which regulatory programs are evolutionarily encoded in the central nervous system. During therapeutic sessions, three-dimensional motor patterns combining alternating static and dynamic muscle activity are activated, allowing for the holistic engagement of many functional systems simultaneously. Studies indicate that regular training can lead to the reduction of key MS symptoms, such as fatigue, spasticity, and cognitive deficits. Furthermore, climbing directly counteracts balance and trunk stability disorders, and the increase in muscle strength plays a vital role in limiting the progression of functional disability.

A key asset of climbing in the context of MS is its extraordinary plasticity and the possibility of individualizing loads. For patients with balance disorders, a firmer pull of the climbing rope can be used, which partially offloads body weight and stabilizes the climber. Individuals with paresis or visual impairments can use specially selected routes where densely placed and texturally varied holds allow for the compensation of visual deficits through the sensory and tactile systems. Beyond the physical dimension, climbing offers patients a unique opportunity

to explore their own possibilities and limits, which drastically increases the sense of self-efficacy and self-confidence. Although climbing is sometimes distorted in the media as a risky extreme sport, in therapeutic settings, it is a safe, multidimensional training method. It counteracts the effects of a sedentary lifestyle and obesity, which often accompany neurological diseases, thereby improving the metabolic and oxidative status of the organism, which may have additional neuroprotective effects (Steimer & Weissert, 2017).

4.3. Autism Spectrum Disorder

Another important area of neurorehabilitation where indoor climbing achieves measurable success is the therapy for children on the autism spectrum (ASD), particularly regarding the improvement of selective attention. Research has shown that a 10-week structured climbing program allows for a significant improvement in attention parameters, manifested by shortened times in cognitive tests along with a significant reduction in the number of errors made. This mechanism is based on the cognitive-motor engagement hypothesis, according to which climbing requires the child to constantly scan visually, plan movement sequences, and make real-time decisions. This combination of physical effort with intense cognitive engagement forces the nervous system to filter out distractors and concentrate on a specific goal, which is crucial for the development of attentional control.

Climbing is a discipline exceptionally well-suited to the cognitive profile of individuals with ASD, as it utilizes their natural preference for focusing attention on non-social stimuli, such as uniquely shaped holds or color-coded climbing routes. The use of visual supports (e.g., color-coding routes) helps children with ASD limit the excess of irrelevant external stimulation and trains the brain to identify the most important visual cues. Beyond the purely cognitive aspect, indoor climbing serves as a tool for sensory regulation, teaching children to plan actions and solve problems in a safe, predictable environment. It also offers a unique, non-verbal form of expression and achievement, fostering a sense of success and competence, which are of fundamental importance in the educational process and daily social functioning of patients with autism (Broupi et al., 2025).

5. Injury Risk

Analysis of risk factors highlights the dominance of overuse injuries, which comprise up to 68% of adult climbing traumas, particularly affecting the finger pulley system. While beginners and younger climbers are susceptible due to physical immaturity and technical errors, experienced and older athletes face risks associated with age-related physiological decline and extreme route intensity. Notably, adolescents (15–19 years) represent a high-risk group for periphyseal stress injuries, which are frequently misdiagnosed as soft tissue damage, such as A2 pulley ruptures.

Regarding prevention, the efficacy of prophylactic taping remains controversial; it may provide a false sense of security, leading to premature returns to activity or increased risk-taking. Conversely, contemporary literature emphasizes structured, high-resistance strength training like fingerboard sessions to build tissue resilience against climbing-specific loads. (Zieliński et al., 2025).

6. Summary and conclusion

In conclusion, rock climbing is a rather safe and multi-modal intervention that offers significant clinical benefits across various health domains. It has proven to be an effective tool in mental health by reducing moderate depression and building long-term self-efficacy that remains sustained for up to twelve months. In the field of neuromotor disorders, it significantly improves motor symptoms such as posture and rigidity in Parkinson's disease while enhancing functional stability in patients with multiple sclerosis. Furthermore, climbing serves as a superior method for building core strength and aerobic capacity, while in pediatric populations, it specifically enhances selective attention and emotional regulation for children with ASD. Although indoor top-rope climbing is generally safe, clinicians must remain vigilant regarding finger overuse and skeletal maturity in younger athletes. Ultimately, rock climbing facilitates a vital shift in patient identity from focusing on limitations to recognizing capabilities, and its high adherence rates and holistic impact warrant its broader integration into standard healthcare systems and insurance-covered rehabilitation programs.

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