OBCOWSKA, Alicja, DUDA, Joanna, KĘDZIA, Jakub, WALENDZIK, Aleksandra, RACISZ, Pawel, OBCOWSKA, Kinga and RACISZ, Kinga. Sport Climbing and Bouldering - Injury Patterns with Focus on the Lower Extremities. Quality in Sport. 2025;47:66722. eISSN 2450-3118.
https://doi.org/10.12775/QS.2025.47.66722
https://apcz.umk.pl/QS/article/view/66722

The journal has been awarded 20 points in the parametric evaluation by the Ministry of Higher Education and Science of Poland. This is according to the Annex to the announcement of the Minister of Higher Education and Science dated 05.01.2024, No. 32553. The journal has a Unique Identifier: 201398. Scientific disciplines assigned: Economics and Finance (Field of Social Sciences); Management and Quality Sciences (Field of Social Sciences).
Punkty Ministerialne z 2019 - aktualny rok 20 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 l.p. 32553. Posiada Unikatowy Identyfikator Czasopisma: 201398. Przypisane dyscypliny naukowe: Ekonomia i finanse (Dziedzina nauk społecznych); Nauki o zarządzaniu i jakości (Dziedzina nauk społecznych).
The authors declare that there is no conflict of interest regarding the publication of this paper.
Received: 18.11.2025. Revised: 29.11.2025. Accepted: 29.11.2025. Published: 30.11.2025.

Sport Climbing and Bouldering - Injury Patterns with Focus on the Lower Extremities

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Abstract

Introduction

Climbing has grown significantly in popularity and includes various sub-disciplines that differ in environment, equipment, and injury patterns. A key distinction lies between sport climbing, which uses ropes, and bouldering, where only crash pads are used. That leads to different injury risks. While lead climbing injuries often affect the upper limbs, bouldering more commonly

results in lower limb injuries like sprains and strains. Given the specificity and potential long-term consequences of these injuries, raising awareness and developing targeted prevention and rehabilitation strategies is crucial.

Aim of study

This study aims to review the current literature on climbing-related injuries with a focus on lower limb injuries, especially knee injuries, and provide an overview of potential prevention and treatment strategies.

Materials and methods

The literature was sourced from databases like PubMed, Google Scholar, and other relevant platforms using search terms such as ‘bouldering’, ‘sport climbing’, ‘injuries’, ‘lower limb injuries’, and ‘strategies’. The review focused on English-language articles published from 2015 onward.

Conclusion

Climbing-related injuries are becoming increasingly common, yet research on lower limb injuries remains limited. This makes it difficult to define clear prevention and rehabilitation strategies. Raising awareness of injury risks and applying standard treatment approaches based on accurate diagnosis is essential.

Keywords

Climbing injuries, Bouldering, Sport climbing, Lower extremities, Injury prevention, Rehabilitation

Introduction

Climbing as a sport has seen a significant rise in popularity in recent years, particularly since its inclusion in the Olympics [1, 2, 3].

It is important to note that climbing is not a homogeneous discipline—it comprises several sub-disciplines that differ in terms of location (indoor vs. outdoor), equipment used, and training objectives [4].

One key distinction worth emphasizing is the difference between bouldering and other sub-disciplines. In sport climbing, a rope is used to secure the climber, which helps to prevent traumatic falls in most cases. In contrast, in bouldering, the climber's only protection is a crash pad placed beneath the climbing area (indoors) or on the ground (outdoors), which allows for relatively safe falls from lower heights [5].

These various forms and distinctions contribute to the different types of injuries sustained during climbing.

In outdoor climbing, most injuries are fall-related (traumatic injuries), whereas in indoor climbing, the causes are more varied [5, 6, 7]. In the case of lead climbing, the majority of injuries, regardless of their nature, typically affect the upper limbs. In bouldering, however, injuries most commonly involve the lower limbs, especially sprains and strains.

Climbing-related injuries are quite specific and require specialist knowledge from orthopedic surgeons, physiotherapists, and other healthcare professionals involved in their management. Moreover, it has been reported that up to 44% of climbers who have sustained an injury experience chronic pain and functional limitations related to that injury [7]. For these reasons, raising awareness about the risks, prevention strategies, treatment, and rehabilitation of such injuries is of utmost importance [7, 8]. There is still a lack of sufficient research on this topic to provide reliable data or conclusions.

Aim of study

This paper aims to review the current literature on climbing-related injuries, with particular focus on lower limb injuries, especially knee injuries, and to provide an overview of potential

prevention, treatment, and rehabilitation strategies that will enable better management by doctors and physiotherapists.

Materials and methods:

Articles were retrieved from databases such as PubMed and Google Scholar, as well as other resources. Search phrases including 'bouldering', AND/OR 'sport climbing', AND 'injuries', AND/OR 'lower limb injuries', AND 'strategies' were used to identify relevant literature. Selected articles were published from 2015 onwards and included case reports, reviews, and other study types. Only articles published in English were included.

Main Body

1. Injury Epidemiology in Rock Climbing: A Focus on Lower Extremity Injuries

In recent years, several studies have emerged addressing the epidemiology of climbing-related injuries. The majority of these studies consistently show that most injuries, especially overuse injuries, affect the upper extremities and are most prevalent among climbers training indoors [5, 7, 9]. With regard to lower extremity injuries, the ankle appears to be the most frequently affected anatomical site [7, 9]. It is noteworthy that lower extremity injuries are commonly associated with outdoor climbing and are more often acute, including fractures and dislocations [7].

A study by Lutter et al. [8] indicated that overuse injuries account for approximately 68% of climbing-related injuries, while acute injuries represent only 32%. However, this finding should be interpreted with caution, as the study population consisted exclusively of climbers over the age of 35.

In a 2017 study conducted by McDonald et al. [7], which analysed 1.251 documented climbing injuries, the majority (71.4%) involved the upper limbs, while 21.3% affected the lower limbs, and 7.3% were related to other body regions, including the head, spine, and torso. The findings also indicated that indoor climbers reported a higher incidence of injuries compared to those climbing outdoors.

A study conducted by Grønhaug et al. [10] on elite competitive female climbers found that 53.5% of the athletes reported at least one injury within the past year, with the shoulder and fingers being the most commonly affected sites. However, the results are difficult to compare with other studies, as this was a sex-specific investigation.

Other studies highlight that lower extremity injuries may account for anywhere from 12.7% to 27.6% of all climbing injuries [4]. Another previously mentioned study showed that 35.6% of all reported injuries involved the lower extremities (including toes, ankle, knee, thigh, and hip), while 12.9% of all injuries specifically affected the knee, encompassing both acute and chronic conditions [10]. In contrast, the previously mentioned study by Lutter et al. [8] (focused on climbers over 35 years of age) reported a much lower incidence; only 6% of injuries involved the lower extremities.

A cohort study by Lum et al. [9] revealed that 30.1% of climbers sustained lower extremity injuries, with the knee being affected in 7.4% of cases. Importantly, the study distinguished between injuries that required surgical intervention and those that did not - 27 out of 32 reported knee injuries required surgery. In total, 11% of all reported injuries in the study required surgical treatment, with the majority of surgical cases involving the lower extremities. The most common knee procedures were anterior cruciate ligament (ACL) reconstruction, meniscectomy, and interventions involving the patellar tendon [9].

According to Chang et al. [11] the most commonly observed lower limb injuries involve contusions or fractures of the calcaneus and ankle, ligamentous ankle sprains, as well as tears of the anterior and posterior cruciate ligaments and collateral ligaments of the knee. Patellar dislocations were also frequently noted.

There is also a growing body of literature addressing injury epidemiology in children and adolescents. The physiology of the paediatric musculoskeletal system differs significantly from that of adults, highlighting the need for specific knowledge and injury prevention strategies tailored to younger populations [12]. Increasing awareness and research in this area is essential for improving safety in youth climbing [13].

2. Risk factors and mechanisms of injury

Between 2008 and 2017, Buzzacott et al. [6] analysed epidemiological data regarding emergency department (ED) presentations attributed to climbing-related trauma and observed a progressive increase in the number of reported cases over this period. Nonetheless, the authors noted that it remains uncertain whether this trend reflects a genuine rise in injury incidence or is primarily attributable to the expanding participation rates in climbing during recent years.

In response to this observed trajectory, several studies have sought to delineate modifiable and non-modifiable risk factors contributing to injury occurrence in climbers. Woollings et al. [14]

performed a systematic review of the available literature on this topic. A synthesized overview of their conclusions is provided in Table 1.

Table 1. Potential Risk Factors of Injury classified by modifiable, potentially modifiable and non-modifiable [14]

Risk Factor	Category	Number of Studies	Conclusions/Limitations
Sex	**Non-modifiable**	**12**	**Results conflicted**
Age	**Non-modifiable**	**9**	**Results conflicted**
Years of experience	**Potentially Modifiable**	**7**	**Results conflicted**
Climbing skill level / maximum difficulty	**Potentially Modifiable**	**8**	**Results conflicted; in favor of the higher difficulty of the climb, the more injuries.**
BMI (Body Mass Index)	**Modifiable**	**3**	**In favor of this being a risk factor**
Body weight	**Modifiable / Confounded**	**2**	**Results conflicted**
Grip strength	**Modifiable**	**2**	**Results conflicted**
Climbing volume	**Modifiable (tentative)**	**3**	**Results conflicted**

Climbing Intensity Score (CIS)	**Modifiable**	**2**	**Both showed higher CIS = higher risk**
Alcohol consumption	**Modifiable**	**2**	**Results conflicted**

The most frequently reported cause of climbing-related injuries in the literature is overuse, resulting from repetitive movements. Only subsequently are specific climbing techniques and falls mentioned as additional causes [5]. Overuse injuries typically affect the upper limbs, while fall-related injuries are more commonly associated with the lower limbs [5, 7]. Bouldering, due to its specific nature—short, yet highly intense and technically demanding exertion—appears to place particular strain on the lower extremities [15]. This theory is supported by Lutter et al. [16] as bouldering-related activities accounted for 69% of all knee injuries in their study, which strengthens the hypothesis that it is more likely to cause knee injuries than rope climbing.

Lower limb injuries are often linked to specific climbing techniques such as the heel hook, drop knee, and high step, as well as to falls, as previously mentioned [16].

The heel hook technique involves hooking the heel over a rock or hold to generate pulling force through the lower limb—this movement creates substantial friction between the climber's heel and the climbing surface, allowing the climber to lift the body [4, 15]. This biomechanical pattern results in significant stress and loading on the lateral and posterior structures of the knee. Due to the external rotation of the knee characteristic of this movement, the following anatomical structures are particularly susceptible to overuse and injury: lateral collateral ligament (LCL), lateral meniscus, posterior cruciate ligament (PCL), popliteus tendon, posterior joint capsule, iliotibial band (tractus iliotibialis), and hamstring muscles and tendons, especially the biceps femoris muscle [15, 17].

The drop knee technique involves full internal rotation of the hip joint combined with deep flexion of the knee joint (sometimes reaching maximal flexion), which increases the risk of meniscal injuries and medial collateral ligament injury [4].

The high step technique refers to placing one lower limb onto a hold in a deep squat position, with maximal knee flexion and external rotation at the hip joint, bearing weight on this leg while the contralateral leg is often completely unloaded. This position predisposes the climber to medial meniscal tears [16].

Falls, as a mechanism of knee injury, are most commonly associated with uncontrolled descent, particularly when combined with rotational forces, insufficient surface protection, or fatigue leading to loss of body control. This injury mechanism is more frequently observed in less experienced climbers [16].

3. Therapeutic and Preventive Strategies in Climbing-Related Lower Limb Injuries

Overall, one of the key elements in minimizing the risk of climbing-related injuries is an understanding of the biomechanics of specific techniques (e.g., the heel hook) [15, 17]. Equally important is the climber's self-awareness regarding muscular imbalances and working actively to correct them [7].

It should be underlined that the approach to managing acute injuries differs significantly from that of injuries caused by overuse [7]. In general, conservative (non-operative) treatment allows for an earlier return to sport [9].

The treatment (whether surgical or non-surgical) and rehabilitation approach will vary depending on the specific injury. However, it seems reasonable to follow general evidence-based guidelines after an accurate diagnosis.

Considering the specific biomechanical demands of the heel hook technique, Schöffl et al. [17] suggest that developing dedicated screening and monitoring protocols may be beneficial. However, they also emphasize that it is currently unclear what exactly such assessments should focus on.

Ehiogu et al. [15] focused their research on the treatment and rehabilitation of hamstring injuries associated with the heel hook technique. They emphasized that in the early stages of treatment, pain control is crucial. However, they warned that excessive use of non-steroidal anti-inflammatory drugs may delay tissue healing. They also underline the important role of manual therapy to activate and support tissue remodelling. Once pain subsides, they recommend initiating concentric muscle activation within a pain-free range of motion.

It must be remembered, however, that in the case of complete tendon rupture, full immobilization or surgical intervention may be required [7].

Menisci play a variety of essential roles in the knee joint, including load distribution, shock absorption, reduction of joint friction, cartilage nutrition, and joint stabilization — all of which contribute to preservation of joint function [18]. As a result, treatment strategies for meniscal tears remain complex and somewhat controversial [19].

Eberbach et al. [19] examined whether partial meniscectomy or meniscal repair is more effective. Their findings showed that while partial removal allows for a faster return to sport, it also alters knee biomechanics and may contribute to long-term degeneration of cartliages and other structures in the knee joint. In contrast, meniscal repair requires a longer rehabilitation period but is associated with less cartilage wear in the long term, making it the preferred choice for younger athletes [19].

Calanna et al. [18] emphasized that treatment strategies for meniscus should be tailored to the specific type of tear (medial vs. lateral meniscus), the presence of associated injuries, and the individual needs of the patient.

In the case of injuries involving the anterior cruciate ligament (ACL), the decision between operative and non-operative management should be individualized, taking into account the patient's expectations and level of physical activity, as some patients can function well without an ACL [20].

Rehabilitation protocols increasingly favor a patient-centered approach. Techniques such as neuromuscular electrical stimulation (NMES), blood flow restriction training, psychosocial support, and early conditioning of the contralateral lower extremity are gaining popularity [20]. However, Culvenor et al. [21] have highlighted that most rehabilitation recommendations for ACL injuries are based on low to very low-certainty evidence.

Furthermore, individuals who have experienced an ACL injury are at a significantly higher risk of reinjury upon returning to sport compared to the general population [21]. Barber-Westin, et al. [22] reported that approximately one in five athletes sustains a recurrent knee injury after returning to high-risk sports.

Conclusion

As climbing continues to grow in popularity, climbing-related injuries are also becoming more common. However, there is a limited number of articles and studies reviewing lower extremity injuries among climbers, making it difficult to establish definitive prevention and rehabilitation strategies. Raising awareness about the risks and specific movement patterns associated with climbing—and their impact on the types of injuries sustained—appears to be crucial. After an appropriate diagnosis, it seems that commonly used treatment strategies for each specific injury of the lower extremity should be applied.

Disclosure

Author's contribution

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Funding Statement

This research has not received any special funding.

Institutional Review Board Statement

Not Applicable.

Informed Consent Statement

Not Applicable.

Data Availability Statement

Not Applicable.

Acknowledgements

This research has not received any administrative or technical support.

Conflict Of Interest

The authors declare no conflict of interest.

All authors have read and agreed with the published version of the manuscript

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