LATOUR, Marianna Ewa and LATOUR, Emilia. Meniscus Tears in Climbing - a Triviality or Serious Concern? Quality in Sport. 2024;19:54328. eISSN 2450-3118.
https://dx.doi.org/10.12775/QS.2024.19.54328
https://apcz.umk.pl/QS/article/view/54328

The journal has had 20 points in Ministry of Higher Education and Science of Poland parametric evaluation. Annex to the announcement of the Minister of Higher Education and Science of 05.01.2024. No. 32553.
Has a Journal's 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 r. Lp. 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 interests regarding the publication of this paper.
Received: 15.07.2024. Revised: 19.08.2024. Accepted: 28.08.2024. Published: 30.08.2024.

Meniscus Tears in Climbing - a Triviality or Serious Concern?

Authors:

Marianna Latour

Pomorski Uniwersytet Medyczny w Szczecinie; Rybacka 1, 70-204, Szczecin

https://orcid.org/0000-0002-2568-5080

mariannalatour@gmail.com

Emilia Latour

Samodzielny Publiczny Wojewódzki Szpital Zespolony; Arkońska 4, 71-455 Szczecin

https://orcid.org/0000-0002-9934-1897

latouremilia@gmail.com

Abstract

Introduction
In the past few years, the popularity of climbing and the number of its new recreational enthusiasts increased. It became clear that there are more types of trauma than finger injuries that should be commonly associated with the sport. This overview focuses on meniscus tears as a prevalent underestimated complaint of climbers.

Aim of the study

We aim to bring attention to meniscus lesions and deal with mechanisms of knee injury in climbing while considering the current views on the structure, function, types of lesions, treatment methods, and results in light of topical literature.

Materials and methods

The methodology for the literature search involved using the keywords: "meniscus tears", "climbing injury", "bouldering", "arthroscopy", and "meniscus repair". The phrases were searched in the PubMed and Google Scholar databases.

Conclusions

We concluded that climbers should recognise acute and chronic meniscus lesions as a concern requiring training breaks, possibly further diagnosis, and adequate treatments. Moreover, awareness of the risk of this type of injury in climbing should be raised, and preventive action should be taken to limit the number of new cases.

Keywords: meniscus tears, climbing injury, bouldering, arthroscopy, meniscus repair

Introduction

Recently, climbing turned from a niche sport performed mainly by professionals into a popular form of physical activity. As it transformed into an indoor activity, it became easily accessible. The sport attracted a wide range of new, inexperienced climbers exposed to the injuries typical for this discipline. Along with that, an increased need for specialised injury characterisation, analysis of their mechanisms and epidemiology appeared, as there has been a noticeable rise in the frequency and severity of trauma [1].

The retrospective cohort study of 114 competitive elite female climbers showed that more than half of them have suffered 1-3 trauma in a year, with the majority in shoulders (37.7%, n = 23) and fingers (34.4%, n = 21) followed by ankle/foot (32.8%, n = 20) and knee (27.9%, n = [2]. Literature generally focuses on traumas in the upper limbs as they are more common in climbing. However, lower limb traumas usually cause climbers to seek first aid during training. Amongst them, ankle injuries are most frequent but not very severe [1]. Apart from that, ACL and meniscus tears are amongst the three most common lower limb injuries caused by climbing. Different kinds of knee injuries are caused mainly by bouldering (46,8% among all types of climbing) and rarely by indoor rope climbing (5,2%)[1].

Frequent falls during jumps from a height, characteristic primarily of bouldering, usually result in ACL tears, which are easily diagnosed and interpreted as cases requiring medical treatment. The second cause of knee damage is trauma related to specific positions executed during climbing, mainly due to medial meniscus damage [1]. These injuries are particularly problematic, as the symptoms may not be very severe and do not always correspond to the severity of the lesion. Consequently, it is easy to underestimate the problem and continue training despite discomfort. This attitude raises the risk of further damage, often more advanced, and suppresses the treatment process [3,4].

Meniscus tears can be part of complex knee damage, especially when coexisting with previously mentioned ACL tears (approximately 17% with ramp lesions of the lateral meniscus) [5,6]. Incompletely healed ligament tears leading to chronic knee instability are cited as the main risk factor for secondary meniscus damage in physically active people, particularly in the medial meniscus [7].

Athletes often avoid taking a break from training, which can, unfortunately, have a decisive impact on treatment. That is why presenting basic information on the anatomical features, diagnostic processes, and treatments of this injury is crucial for limiting the negative consequences of this sport, which offers health benefits when performed with caution.

Methods

The literature search was conducted using a comprehensive approach by utilising the keyword "meniscus" in conjunction with related terms such as "treatment", "mechanism", "function", "anatomy", "diagnosis", and "symptoms." These search phrases were meticulously entered into the PubMed and Google Scholar databases to ensure a thorough search process. Additionally, the review encompassed relevant clinical trials to provide a comprehensive overview of the topic. The research tackles questions on the structure and functions of the meniscus, the kinds of tears and lesions, the mechanism leading to them and the principles of their treatment.

The primary objective of this literature analysis is to provide a comprehensive overview of topics related to meniscus injuries occurring by climbing. Awareness of specific climbing injuries' structure, mechanisms, diagnosis, and treatment is crucial for proper prophylaxis and actions restricting causes of sports trauma.

Structure and function

Both Menisci, medial (MM) and lateral (LM), form a fibrocartilaginous, c-shaped structure with a triangular cross-section, covering nearly 60% of the tibial plateau's top surface. Its role is to be a filler, providing a larger contact area at the articular surface between the tibia and femur while stabilising the knee joint and amortising loads transferred by the articular surfaces. It lubricates the articular cartilage while limiting the friction and providing nourishment. The menisci transmit 50% of joint compressive forces in full extension and approximately 85% of the load in 90° of flexion. The presence of nerve endings in the form of the Pacinian corpuscles and Ruffini Cells, especially in meniscus roots, can indicate its proprioceptive function [8,9].

The distribution of meniscus inner collagen fibres plays a deciding role in its function.

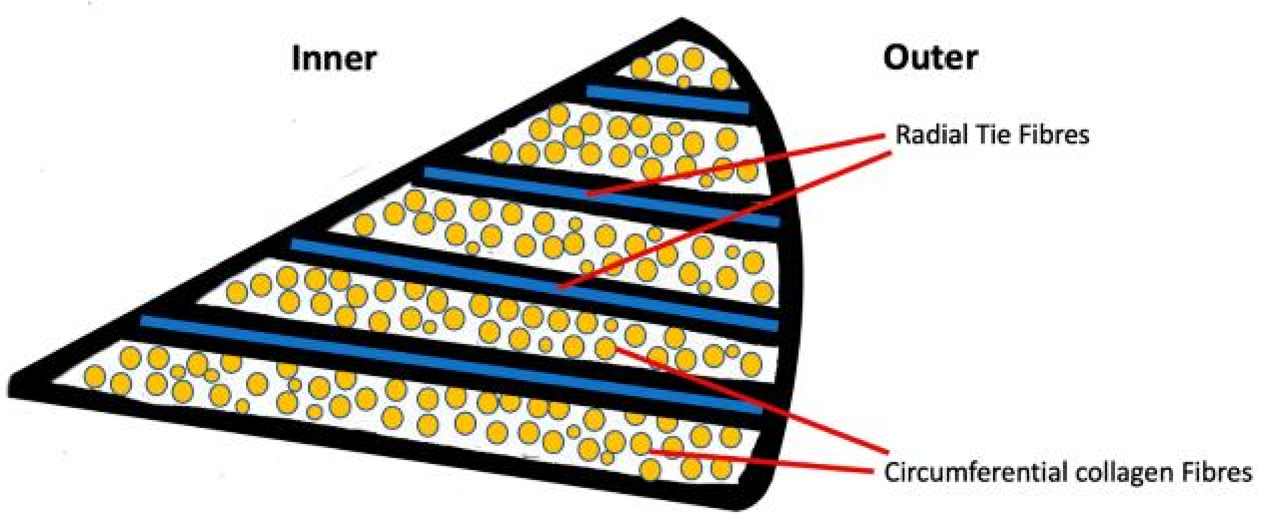

Figure 1. Schematic cross-sectional diagram of the meniscus displaying the circumferential arrangement of collagen fibres and radial tie fibres.

Forces acting in the vertical direction during each standard, i.e. vertical limbs loading, generate tension in circumferential meniscus fibres known as the "hoop stresses". The fibres partially convert the vertical compression forces impacting the articular surfaces into horizontal tensile forces in the meniscus.

On the other hand, radial collagen fibres absorb the shear loads put on the knee. The microcannula inner system, which provides articular fluid circulation during deformations of the meniscus, plays a role in the synovial fluid distribution into the articular cartilage and reduces frictional forces between moving articular surfaces [10].

The vascularisation of the meniscus changes with age. In early childhood, the menisci are fully vascularised, but the amount of blood vessels declines in their inner parts in adulthood. There are three concentric zones: the peripheral most vascularised red-red zone, medial red-white and the central white-white unvascularized zone. The blood supply is fundamental to the success of a meniscus repair. Only tears in the red-red or possibly the red-white zone heal spontaneously [11].
The menisci can be divided into radially arranged zones based on different ligament connections shown in Figure 1.

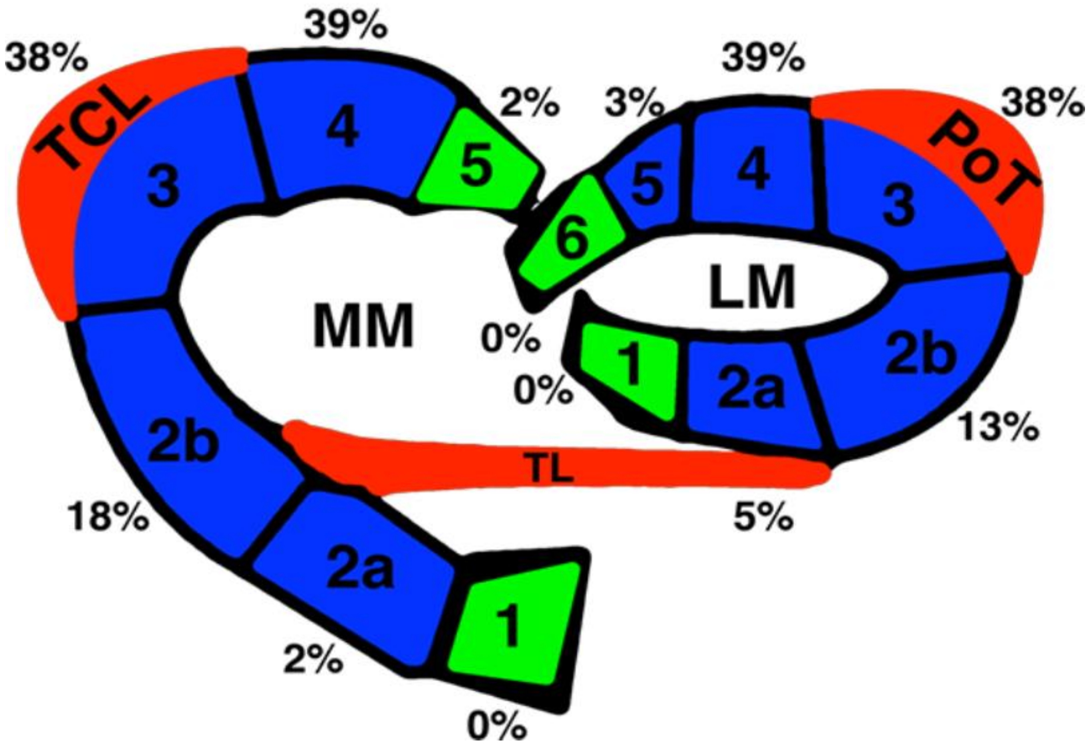

Figure 2: Schematic image of the medial meniscus (MM) and lateral meniscus (ML) zones. In the MM, zone 3 attaches to the tibia collateral ligament (TCL). In the LM, the transverse ligament (TL) delineates zone 2 into two sub-zones: 2a and 2b; zone 3 attaches to the popliteal tendon (PoT). The percentages represent the meniscus injuries. Adapted from [12].

Medial meniscus (MM)

Larger in size than the LM. The MM has a stronger connection to the bone than the LM. The c-shape is less curved out of the two menisci. The posterior horn is significantly larger than the anterior one. The MM is attached to the tibial plateau by its anterior and posterior roots. Tibiofemoral and capsulofemoral ligaments provide additional stabilisation of MM, especially in zones 3 and 4 in Figure 1. By the intermeniscal ligament, its anterior horn connects with the anterior horn of the LM.

Lateral meniscus (LM)

LM is smaller and more mobile than the MM. Its c-shape is more closed than that of MM so that the equally sized corners are close to each other. Beyond the roots attached to the plateau, ligaments stabilise the ML. Some of the most significant ligaments are meniscotibial lateral and posterior (also known as coronal) [13] and meniscocapsular (also known as retinaculi). They connect the ML with the tibia and capsule, except for the area of the anterior horn and most of the posterior horn within the hiatus of the popliteus muscle. Further ligaments that play a significant role in connecting the posterior horn with the lateral surface of the lateral condyle of the femur, running on the anterior and posterior surfaces of the posterior cruciate ligament (PCL), are meniscofemoral anterior (Humphrey) and posterior (Wrisberg).

In zone 3 in Figure 1, the lateral meniscus has intricate attachments, including the lateral meniscotibial ligament (LMTL), the popliteo-fibular ligament (PFL) and the popliteo-meniscal ligament (PML). This combination of the three can be described as the menisco-tibio-popliteus-fibular complex (MTPFC) [14].

Mechanism of injury

Only four injury mechanisms were identified in a study of 71 patients, competitive and recreational climbers with acute knee injuries, subjected to four years of retrospective multicenter analysis. Those mechanisms can, therefore, be considered typical of climbing. Injuries to the medial meniscus dominated over those to the lateral meniscus (28.6% and 5.2% of all knee injuries)[1].

Apart from a fall to the ground, three body positions commonly used in climbing techniques were identified as causes of meniscus injury [1].
The heel hook technique is the most common cause of knee injuries and medial meniscus tears.

Falls to the ground: *typical for bouldering, are the main triggers for ACL lesions, often with concomitant meniscus lesions.*

Heel hook position: *The heel applies pressure to the hold. Meanwhile, the foot is pulled by flexing the knee via a strong hamstring contraction. In addition, the whole limb is in major external rotation in the hip joint, applying variation and rotational load to the knee.*

High step position: *The affected leg is in a squat position and carries the entirety of the athlete's weight by a fully flexed knee. The limb is externally rotated, flexed and obducted in the hip joint.*

Drop knee position: *The flexed knee is the lowest-positioned part of the affected limb, with its foot attached higher to the holder, while the hip joint is aligned in a strong internal rotation. As the body position is altered, the climber loads the affected limb, causing a strong overload of the medial meniscus.*

The research found that high-step and drop knee injuries were more common during rope climbing, while heel hook and fall injuries were more often caused by bouldering.

All the above-mentioned positions load the knee with torsional forces in the main bends while minimising rotational stability based on the cruciate and cystic ligaments. They generate shearing stresses in the menisci, whose free movement is limited by the ligament connections. When the limit values are exceeded, the stresses lead to meniscus tears.

Menisci lesion

The reported annual incidence of meniscus injury is about 61 per 100,000 people. Medial meniscus injuries are generally seen more frequently than injuries of the lateral meniscus, to a ratio of approximately 2:1.4 [15]

Traumatic tears

Tears connected to the explicit injury. The complaints arise during typical overstraining activities, such as body rotation around a weight-bearing limb with additional valgisating force at the knee and less often standing up from a low position. the 2019 ESSKA meniscus consensus defined it as:" a meniscus tear associated with a sufficient knee injury and a sudden onset of knee pain."[6]

Degenerative lesions

Lesion type is often related to no underlying injury, an injury of low energy in the elderly, or patients with permanently overloaded knee joints due to physical activity, reoccurring micro-injuries, improper limb axes and obesity.

Types of lesions according to their shape:

Longitudinal

The tear runs along the meniscus's long axis. The ramp lesion is one kind of longitudinal lesion involving a torn posterior horn of the MM in the area of the menisco-capsular ligament.

Radial

Characterised by a tear stretching from the free inner margin of the meniscus towards the external pericapsular zone.

Horizontal
Primarily degenerative tears of the horizontal meniscus plane.

Complex
A complex lesion is a combination of multiple tears running in different directions.

Flap tear or tongue-shaped
Oblique or longitudinal-shaped tears dissevering a movable but partially pedunculated meniscus fragment.

Bucket-handle tear
Encountered when a torn pedunculated fragment is connected to the remaining part of the meniscus at both ends.

In the last two types of lesions, displacement of the damaged fragment may result in blocking of the joint, i.e. limiting its full extension or its uncomfortable clicking.

Diagnosis

Symptoms

The most common symptoms of a meniscus tear are locking and/or popping, decreased range of motion, stiffness, swelling, and pain, which follow the knee's significant and typical distortion injury. Symptoms of chronic-overuse-based meniscus lesions are less specific and relatively not so severe. The dominant ailment is pain in the the joint line region, especially evident at the end of the flexion range of motion and during loading of a partially flexed knee in a weight-bearing limb.

Diagnostic tests
The most common meniscus tests are Appley's compression and distraction, McMurray's, Thessaly's, and joint line tenderness tests. All but the last one reproduce the torsional nature of the most common traumatic displacement of articular ends, which most often leads to meniscus tears.
Their diagnostic value in clinical practice is debatable. Some authors emphasise the limited accuracy of the tests and indicate the need to confirm the diagnosis based on NMR [16]. Therefore, the combination of several positive tests has a clearly greater diagnostic significance than each of them alone [17].

MRI

Although meniscus lesions used to be identified mainly through diagnostic arthroscopy, due to the development in terms of accuracy of results interpretation and construction of high-field-strength devices, magnetic resonance imaging (MRI) became the gold standard. MRI's universality allows for differentiation between different types, extensions, cyst associations, and meniscus extrusions of lesions [18]. The MRI outcomes can be ascribed to adequate operative treatments with the help of the Stroller and Crues 3-grade classification [18,19] presented in Table 1.

Table 1. The meniscus injuries grading system (Stroller and Crues).

grade 1	small focal or diffuse area of hyperintensity, no extension to the articular surface,
grade 2	linear areas of hyperintensity could extend to the articular surfaces one or both bun without involving it,
	2a) linear abnormal hyperintensity with no extension to the articular surface,
	2b) abnormal hyperintensity reaches the articular surface on a single image,
	2c) abnormal hyperintensity reaches the articular surface on a single image,
grade 3	abnormal hyperintensity extends to at least one articular surface (superior or/ and inferior) in two or more consecutive images and is referred to as a definite meniscus tear.

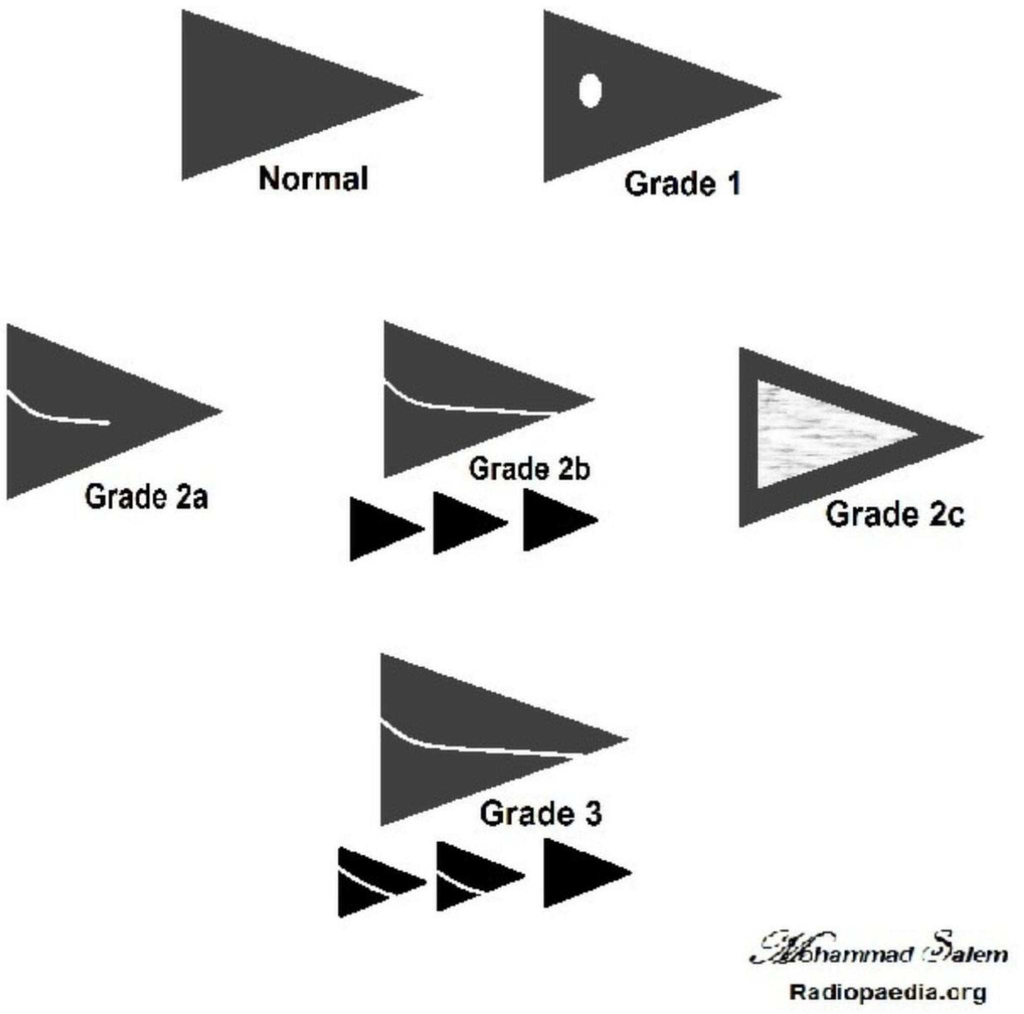

Figure 3: Meniscus injuries grading system (Stroller and Crues) adapted from[20]

This grading ignores paracapsular meniscus injuries including the menisco-capsular and menisco-tibial ligaments, also assessed in MRI.

Artro CT

An alternative to the MRI in case of contraindications, offering considerably high sensitivity and specificity for diagnosing meniscus pathologies, is CT arthrography (Artro CT). Despite its assets, its role in detecting changes in the meniscus remains complementary to MRI primarily due to the invasive nature of the examination (the need to inject a contrast agent into the joint) and exposure to ionising radiation. The only field in which the Artro CT is superior to the MRI in terms of sensitivity and specificity is the pericapsular lesions.

Ultrasonography (USG)

Ultrasound examination, widely used in diagnosing post-traumatic knee conditions due to its safety, does not accurately depict the centrally located structures of the joint cavity. In terms of the meniscus, USG may help assess the extrusion signs (protrusion of the meniscus beyond the outline of the edges of the articular surfaces), presence of fluid in the joint-hematoma or effusion accompanying meniscus pathologies. These signs are, however, not specific to meniscus pathologies. USG helps detect peripatellar cysts accompanying chronic damage to the meniscus and in ultrasound-guided injections into the cysts. Assessment of internal meniscus structure and its ligament connections with the tibia and joint capsule requires excellent experience from the diagnostician. The measure of accuracy of the USG diagnosis is subjective and cannot be the basis for the decision to implement invasive surgery.

Plain radiography

Plain radiography has no significance in detecting meniscus tears.
It only helps to differentiate meniscus damage from diseases affecting bones, particularly with gonarthrosis and fracture-dislocations.

Treatment

The approach to treating meniscus tears has evolved over recent decades. The British Association for Surgery of the Knee (BASK) formulated the current operative guidelines in 2018 [21].

Nonoperative

Adequate in degenerative lesions without symptoms of joint locking with a flipping (displacing) torn meniscus fragment or in small lesions located in a vascular zone. It incorporates periods of rest, immobilisation, NSAIDs, corticosteroid injections, physical therapy, and supervised exercise. The exercises are performed to strengthen the muscles of the limbs, increase flexibility and improve proprioception.
There are numerous reports of the lack of benefit of partial meniscectomy in degenerative damage to the meniscus in older people. In randomised multicenter controlled studies, better results have not been confirmed regarding knee pain, overall knee function, and health-related quality of life in patients treated by arthroscopic partial meniscectomy compared to patients treated conservatively [11,22,23]

Arthroscopy, meniscectomy

Historically, subtotal meniscectomy has been the standard of care in meniscus lesions. As knowledge about the role of the meniscus progressed, a view emerged that it is necessary to preserve as much of the meniscus as possible.
It was confirmed that removal of the damaged posterior horn of the medial meniscus or segmental resection of the meniscus body with a break in the continuity of the pericapsular zone has a similar effect on the cartilage contact pressure (growth) between the tibia and femur to total meniscectomy. Comparisons of patients after total and partial meniscectomy clearly show better results for the second group[24]. Thus, the total meniscectomy gave way

to meniscus-preserving techniques: partial meniscectomy and meniscus repair or transplantation [23,25]. The opinion that there are no indications for meniscectomy in the course of degenerative changes was established as all benefits are short-term and do not offset the risk of complications associated with the surgery.[26]. Routine meniscectomy is no longer advocated for in patients with standard overload degenerations.

Arthroscopic repair

With improvements in surgical techniques, the increasing availability of implants allowing all-inside repair, and supportive biological engineering methods, meniscus repair has become the primary surgical treatment option. The treatments aim to restore the continuity of the circular bundles of meniscus fibres and the roots of the meniscus, which restores proper stress load distribution across articular surfaces and normalises symptoms related to meniscus damage, improving scores in clinical assessment scales at least in short and medium-term follow-up [27, 28]

The table below shows that indications for surgical treatment depend on many biological and mechanical factors influencing the healing processes.

Table 2: Indications for surgical repair of meniscus tear[29]

Indications
Tear size larger than 1cm Active patient Meniscus tissue amenable to repair
Most favourable conditions
Young patients Location in the peripheral third of meniscus (red-red zone: within 3-4 mm of capsule) Vertical tear pattern In conjunction with ACL reconstruction
Less favourable conditions
Radial and flap tears Location in the middle and central third of meniscus (red-white zone: within 3-6 mm of capsule and white-white zone: central 3-4 mm of capsule)

Various methods of meniscus stitch are used depending on the operator's experience and the type of damage. Classic surgical threads and anchors paired with inside-outside, outside-inside, and all-inside techniques are used.

Replacement

In a long-term assessment after five years, cohorts of patients after meniscus repair presented worse clinical results than in the short and middle-term follow-ups.
When the results of partial meniscectomy and meniscus repair were compared, the former had a clear advantage in the first years of treatment; however, the results of these two groups were getting closer to each other in quality in the long-term follow-up [27].
Meniscus repair failure rate in six years after meniscectomy reaches 25%, regardless of the suture technique [27,30].

Both partial and total meniscectomy are linked to the development of knee arthrosis in cases of primarily unrepaired meniscus injuries and failed repairs. Hence, meniscus transplants enter clinical practice in younger patients with higher expectations regarding sports activity.

Indications to the meniscus implant include age under 50, total or segmental non repairable damage, damage to the meniscus with a decline in its biomechanical functions, demands regarding physical activity, and lack of gonarthrosis.

Essential techniques, similar to those stabilising a torn meniscus during its repair, are used to stabilise transplants. Replacement can involve the whole meniscus with its roots or only a missing segment. Transplants are fixed with various types of root stabilisation.

Some allografts have bone blocks attached to the anterior and posterior roots, making biointegration with the recipient's tibia easier. Other transplants require intact native roots of the damaged meniscus or use a stabilisation technique in the bone canals. There are three types of meniscus transplants in clinical practice.

Allotransplants:

Its essential advantages are the ability to choose a suitable shape and size previously determined with imaging tests and the possibility of stabilising meniscus roots bone-to-bone.

The main disadvantage is having to source from cadavers, as the host's humoral and cell-mediated immune systems are sensitised.

Methods of freezing, freeze drying, irradiation of allografts could reduce the immunogenicity, however there is a risk of transplant weakening, and increasing the rate of procedure failures [31]. Another threat is the possibility of transmitting infectious agents between the recipient and the donor. What is more ethical doubts in some patients may constitute an obstacle in carrying out the procedure.

Autotransplants:

Various donor sides are used for autotransplantation of damaged meniscus: fascia lata, peroneus longus muscle tendon [32], hamstring tendons, and quadriceps tendon.

The advantage of an autograft is usually some excess tissue and its splendid immunological compatibility.

The main inconveniences are additional traumatisation by extending the procedure through sourcing an autograft and the difference between its shape, structure, and mechanical features and those of the native meniscus.

Artificial meniscus implants:

Two types of meniscus substitutes can be distinguished: porous, resorbable implants that are the matrix for the regeneration of the meniscus and are replaced during healing by the patient's tissue, and solid ones, non-resorbable implants that are integrated with the remnants of the meniscus [33]

The advantage of artificial meniscus implants is their availability, without the need for patient traumatisation with graft collection or the risk associated with allografts.

On the other hand, implantation is difficult due to the delicacy of the implant and the rough healing process.

Current research aims to use bioengineering achievements, mainly in the fields of stem cells and growth factors, to create innovative implants.

Studies on meniscus reconstruction are being conducted on animal models using various modifications of polycaprolactone (PCL) scaffolds conjugated to autologous stem cells, like the synovium-derived mesenchymal stem cells (SMSC), to achieve the optimal biomechanical properties and biocompatibility [34,35].

Prevention

It was stated that rope climbing should be preferred to bouldering as it allows for the "avoidance of falls and direct impact on the knee" in reinjury prevention.

It is also suggested that in bouldering, "down climbing" (a cautious descent) or a "top-out" (an alternative easy descent) should be chosen over jumping down [1].

The dependence of meniscus damage on specific movement is so distinct that it has recently been postulated to record the type of routes on which damage occurred so that the layout of climbing paths can be modified and cause fewer accidents, as has already been achieved in skiing [2].

Reports of higher trauma rates and greater injury severity in recreational climbers compared to elite competitors point to the importance of training and paying particular attention to the most challenging techniques that generate a heightened risk of damage to the meniscus.

Conclusions

Meniscus tears are commonly diagnosed as position-based injuries in climbers.

The rise in meniscus tears in the last two decades is attributed to the continued expansion and popularity of the climbing. The high step, drop knee, and heel-hook poses are highly risky due to the extreme forces they generate on knee joints. Understanding the mechanisms of these injuries, along with effective diagnostic and treatment strategies, is essential for managing and preventing meniscus injuries. Acute knee injuries require an immediate break in sports activity, implementation of diagnostics, and treatment. Training renewal should only be considered after the full function of the damaged limb has been restored. Climbers should remember that they are at risk of repeated knee strain, which could lead to overload damage of the menisci with milder and more chronic symptoms than in acute sports injuries. Such subacute and chronic knee complaints should also motivate climbers to undertake effective diagnostics (MRI) and subject themselves to adequate treatments to protect them from the propagation of meniscus damage. Further climbing development could involve changes in the techniques and construction of routes, reducing the risk of meniscus injuries - a significant problem for people practising this discipline.

Author Contribution Statement

Conceptualization, ML, and EL; methodology, ML, EL; software, not applicable; check, EL, and ML; formal analysis, EL; investigation, ML; resources, ML, EL; data curation, EL; writing - rough preparation, ML, EL; writing - review and editing, ML, EL; visualisation, ML, EL ; supervision, not applicable ; project administration, not applicable; receiving funding, not applicable.

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

Funding Statement

This research received no external funding.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

Not applicable.

Conflict of interest Statement

The authors deny any conflict of interest.

References

1. Lutter C, Tischer T, Cooper C, et al. Mechanisms of Acute Knee Injuries in Bouldering and Rock Climbing Athletes. Am J Sports Med. 2020;48(3):730-738. doi:10.1177/0363546519899931
2. Grønhaug G, Joubert LM, Saeterbakken AH, Drum SN, Nelson MC. Top of the podium, at what cost? injuries in female international elite climbers. Front Sports Act Living. 2023;5:1121831. Published 2023 Jun 16. doi:10.3389/fspor.2023.1121831

3. Quarmby A, Zhang M, Geisler M, et al. Risk factors and injury prevention strategies for overuse injuries in adult climbers: a systematic review. Front Sports Act Living. 2023;5:1269870. Published 2023 Dec 12. doi:10.3389/fspor.2023.1269870

4. Kovářová M, Pyszko P, Kikalová K. Analyzing Injury Patterns in Climbing: A Comprehensive Study of Risk Factors. Sports (Basel). 2024;12(2):61. Published 2024 Feb 19. doi:10.3390/sports12020061

5. Rodriguez AN, LaPrade RF, Geeslin AG. Combined Meniscus Repair and Anterior Cruciate Ligament Reconstruction. Arthroscopy. 2022;38(3):670-672. doi:10.1016/j.arthro.2022.01.003

6. Kopf S, Beaufils P, Hirschmann MT, et al. Management of traumatic meniscus tears: the 2019 ESSKA meniscus consensus. Knee Surg Sports Traumatol Arthrosc. 2020;28(4):1177-1194. doi:10.1007/s00167-020-05847-3

7. Snoeker BA, Bakker EW, Kegel CA, Lucas C. Risk factors for meniscal tears: a systematic review including meta-analysis. J Orthop Sports Phys Ther. 2013;43(6):352-367. doi:10.2519/jospt.2013.4295

8. Skinner HB, Barrack RL, Cook SD. Age-related decline in proprioception. Clin Orthop Relat Res. 1984;(184):208-211.

9. Reider B, Arcand MA, Diehl LH, et al. Proprioception of the knee before and after anterior cruciate ligament reconstruction. Arthroscopy. 2003;19(1):2-12. doi:10.1053/jars.2003.50006

10. Jacob G, Shimomura K, Krych AJ, Nakamura N. The Meniscus Tear: A Review of Stem Cell Therapies. Cells. 2019;9(1):92. Published 2019 Dec 30. doi:10.3390/cells9010092

11. Mordecai SC, Al-Hadithy N, Ware HE, Gupte CM. Treatment of meniscal tears: An evidence based approach. World J Orthop. 2014;5(3):233-241. Published 2014 Jul 18. doi:10.5312/wjo.v5.i3.233

12. Astur D. Arthroscopic Assessment of meniscal injuries using an anatomical zone classification system. Artroscopia [Internet]. 2020Dec.23 [cited 2024Aug.5];27(4). Available from: https://revistaartroscopia.com.ar/index.php/revista/article/view/112

13. Gilat R, Mitchnik IY, Mimouni T, Agar G, Lindner D, Beer Y. The meniscotibial ligament role in meniscal extrusion: a systematic review and meta-analysis. Arch Orthop Trauma Surg. 2023;143(9):5777-5786. doi:10.1007/s00402-023-04934-7

14. Perelli S, Morales Avalos R, Masferrer-Pino A, Monllau JC. Anatomy of lateral meniscus. Ann Jt. 2022;7:16. Published 2022 Apr 15. doi:10.21037/aoj-20-118

15. Müller M, Heck J, Pflüger P, Greve F, Biberthaler P, Crönlein M. Characteristics of bouldering injuries based on 430 patients presented to an urban emergency department. Injury. 2022;53(4):1394-1400. doi:10.1016/j.injury.2022.02.003

16. Smith BE, Thacker D, Crewesmith A, Hall M. Special tests for assessing meniscal tears within the knee: a systematic review and meta-analysis. Evid Based Med. 2015;20(3):88-97. doi:10.1136/ebmed-2014-110160

17. Mahnik A, Mahnik S, Hrabac P, Bojanic I. Using a combination of three clinical tests for detecting meniscal tears increases the accuracy of the clinical examination. J Sports Med Phys Fitness. 2024;64(7):661-667. doi:10.23736/S0022-4707.24.15584-3

18. Lefevre N, Naouri JF, Herman S, Gerometta A, Klouche S, Bohu Y. A Current Review of the Meniscus Imaging: Proposition of a Useful Tool for Its Radiologic Analysis. Radiol Res Pract. 2016;2016:8329296. doi:10.1155/2016/8329296

19. Stoller DW, Martin C, Crues JV 3rd, Kaplan L, Mink JH. Meniscal tears: pathologic correlation with MR imaging. Radiology. 1987;163(3):731-735. doi:10.1148/radiology.163.3.3575724

20. Amer M, Knipe H, Roberts D, et al. MRI grading system for abnormal meniscal signal intensity. Reference article, Radiopaedia.org (Accessed on 05 Aug 2024) https://doi.org/10.53347/rID-36617

21. Abram SGF, Beard DJ, Price AJ; BASK Meniscal Working Group. Arthroscopic meniscal surgery: a national society treatment guideline and consensus statement. Bone Joint J. 2019;101-B(6):652-659. doi:10.1302/0301-620X.101B6.BJJ-2019-0126.R1

22. Wijn SRW, Hannink G, Østerås H, et al. Arthroscopic partial meniscectomy vs non-surgical or sham treatment in patients with MRI-confirmed degenerative meniscus tears: a systematic review and meta-analysis with individual participant data from 605 randomised patients. Osteoarthritis Cartilage. 2023;31(5):557-566. doi:10.1016/j.joca.2023.01.002

23. Abram SGF, Hopewell S, Monk AP, Bayliss LE, Beard DJ, Price AJ. Arthroscopic partial meniscectomy for meniscal tears of the knee: a systematic review and meta-analysis. Br J Sports Med. 2020;54(11):652-663. doi:10.1136/bjsports-2018-100223

24. Hede A, Larsen E, Sandberg H. Partial versus total meniscectomy. A prospective, randomised study with long-term follow-up. J Bone Joint Surg Br. 1992;74(1):118-121. doi:10.1302/0301-620X.74B1.1732238

25. Lee W, Lee J, Hong M, et al. Mechanical alterations in the avascular region of the meniscus following partial meniscectomy: A cadaveric porcine longitudinal meniscal tear model. Clin Biomech (Bristol, Avon). 2020;75:105005. doi:10.1016/j.clinbiomech.2020.105005

26. Siemieniuk RAC, Harris IA, Agoritsas T, et al. Arthroscopic surgery for degenerative knee arthritis and meniscal tears: a clinical practice guideline. BMJ. 2017;357:j1982. Published 2017 May 10. doi:10.1136/bmj.j1982

27. Jeong HJ, Lee SH, Ko CS. Meniscectomy. Knee Surg Relat Res. 2012;24(3):129-136. doi:10.5792/ksrr.2012.24.3.129

28. Bottomley J, Al-Dadah O. Arthroscopic Meniscectomy vs Meniscal Repair: Comparison of Clinical Outcomes. Cureus. 2023;15(8):e44122. Published 2023 Aug 25. doi:10.7759/cureus.44122

29. Burns TC, Giuliani JR, Svoboda SJ, Owens BD. Meniscus repair and transplantation techniques. J Knee Surg. 2011;24(3):167-174. doi:10.1055/s-0031-1286051

30. Nepple JJ, Dunn WR, Wright RW. Meniscal repair outcomes at greater than five years: a systematic literature review and meta-analysis. J Bone Joint Surg Am. 2012;94(24):2222-2227. doi:10.2106/JBJS.K.01584

31. Goble EM, Kohn D, Verdonk R, Kane SM. Meniscal substitutes--human experience. Scand J Med Sci Sports. 1999;9(3):146-157. doi:10.1111/j.1600-0838.1999.tb00445.x

32. Milenin O, Strafun S, Sergienko R, Baranov K. Lateral Meniscus Replacement Using Peroneus Longus Tendon Autograft. Arthrosc Tech. 2020;9(8):e1163-e1169. Published 2020 Jul 22. doi:10.1016/j.eats.2020.04.016

33. Vrancken AC, Buma P, van Tienen TG. Synthetic meniscus replacement: a review. Int Orthop. 2013;37(2):291-299. doi:10.1007/s00264-012-1682-7

34. Abpeikar Z, Javdani M, Alizadeh A, Khosravian P, Tayebi L, Asadpour S. Development of meniscus cartilage using polycaprolactone and decellularized meniscus surface modified by gelatin, hyaluronic acid biomacromolecules: A rabbit model. Int J Biol Macromol. 2022;213:498-515. doi:10.1016/j.ijbiomac.2022.05.140

35. Li Z, Wu N, Cheng J, et al. Biomechanically, structurally and functionally meticulously tailored polycaprolactone/silk fibroin scaffold for meniscus regeneration. Theranostics. 2020;10(11):5090-5106. Published 2020 Apr 6. doi:10.7150/thno.44270