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The Effect of Long-Distance Ultramarathon Running on Short and Long Term Podiatry Issues in the Human Body

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Abstract

Ultramarathon running has seen a rapid rise in popularity, yet its impact on podiatric health remains underexplored. Due to the extreme physical and biomechanical demands associated with running distances beyond the standard marathon, ultrarunners frequently experience acute and chronic lower limb injuries. This study systematically reviews existing literature to evaluate the most prevalent podiatric injuries in ultrarunners, categorizing them into acute conditions—such as ankle sprains, ligament tears, and muscular rhabdomyolysis – and chronic conditions – including osteoarthritis, plantar fasciitis, and tendinopathy. By analyzing indexed data from past literature, the results indicate that ankle and knee injuries are most common, with repetitive stress and biomechanical inefficiencies being primary contributing factors. Furthermore, this review explores evidence-based injury prevention strategies, including strength training, footwear modifications, and rehabilitation techniques. These findings provide a foundation for optimizing ultrarunning training protocols and guiding future research toward injury mitigation strategies and long-term musculoskeletal health.

Keywords: Ultramarathon, Ultrarunning, Foot, Muscle, Podiatry, Injury

1. Introduction

In recent decades, ultramarathon running (hereafter referred to as ultrarunning) has gained popularity due to its extreme physical and mental demands. An ultramarathon is conventionally defined as any footrace longer than the standard marathon distance of 42.195 kilometers (km) or 26.219 miles (Costa et al., 2019). Typical ultramarathon distances include 50 km, 50 mi (80 km), 100 km, and 100 mi (161 km), usually completed within a 24-hour (hr) timeframe (Hoffman & Krishnan, 2013). Additionally, multi-day and stage ultramarathons, such as the Cocodona 250 (approximately 250 mi) in Arizona and the Pyrenees Stage Run (220 km over 7 days) in Barcelona, also exist, often exceeding 200 mi with limited sleep between stages.

This surge in ultramarathon participation has brought attention to the unique physiological demands and injury patterns associated with such prolonged endurance events. Notably, ultramarathon runners are susceptible to a range of musculoskeletal injuries, particularly affecting the lower extremities. A study involving 734 ultramarathon runners revealed that 71.2% reported foot or ankle injuries within a 12-month period, with plantar fasciitis (36.3%), Achilles tendinitis (24.0%), nonspecific foot pain (14.0%), and stress fractures (13.4%) being the most prevalent (Jastifer & Hoffman, 2023).

Given the unique challenges posed by ultramarathon running, there is a pressing need for comprehensive research focused on the specific podiatric issues faced by these athletes. While existing literature often addresses running-related injuries in general, targeted studies on ultramarathon-induced podiatric injuries remain limited. Understanding the prevalence, causes, and prevention strategies for these injuries is crucial for promoting the health and performance of ultramarathon runners. This study aims to systematically review the current literature on ultramarathon-related

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podiatric injuries, addressing the following key questions:

1. What are the most common types of chronic injuries that an ultrarunner can experience?
2. What are the most common types of acute injuries that an ultrarunner can experience?
3. With both aims (1.) and (2.) considered, what are the underlying causes behind both types of injuries and what are the best preventative measures to eradicate the effects?

To achieve these objectives, a systematic review methodology is developed in the next section to identify the different types of podiatric issues that ultramarathons can cause.

2. Methodology

To fulfill the aims outlined in Section 1, a strategy for sourcing and organizing literature related to various podiatric issues resulting from ultrarunning will be detailed. Before categorizing injuries into similar groups (such as acute versus chronic or by injury location on the body), it is essential to identify the specific conditions that arise from ultrarunning and demonstrate its effects on the body.

While this study follows a systematic approach to reviewing ultrarunning-related podiatric injuries, several limitations must be acknowledged. One key limitation is the potential selection bias in this study, as this study relies on indexed papers primary sourced form Google Scholar, which may exclude relevant but less accessible studies published in specialized medical databases. Additionally, systematic reviews inherently depend on the quality and scope of existing research, meaning that any gaps in the existing literature could influence the findings. Consequently, while this methodology provides a comprehensive synthesis of current knowledge, further research should aim to incorporate prospective studies and controlled experimental designs to enhance the validity and applicability of injury prevention strategies in ultrarunning.

2.1 Indexing Podiatric Injuries Related To Ultrarunning

To effectively demonstrate the impact of ultramarathons on short- and long-term podiatry issues, injuries will be indexed using keywords. For this systematic analysis, two categories of keywords will be used to index podiatric conditions arising from ultrarunning. Since podiatric issues encompass all conditions related to the feet, ankle, lower limb, and knee, the keywords listed in Table 1 will facilitate the indexing and sorting of relevant literature.

The following keywords identified in Table 1 are now assembled into search strings, which involve pairing keywords together in order to index relevant injuries and pair them together in various categories, whether it be between acute and chronic injuries or injuries related to the various parts (ankles, feet, lower limb, and knee). A schematic diagram of how these search strings are created is shown below in Figure 1.

Table 1. Relevant keywords and their justifications are compiled below. These keywords serve as a crucial aspect when indexing literature related to acute and chronic injuries succumbed from ultrarunning.

Keyword 1: “Acute”	This keyword is necessary as various injuries may display similar symptoms, but may be different on the anatomical level
Keyword 2: **“**Chronic”	Similar to Keyword 1 (“acute”), this keyword is necessary in the same logical sense that Keyword 1 is needed to classify various types of injuries.
Keyword 3: “Ultramarathon”	This keyword ensures that all literature indexed is relevant to injuries succumbed from ultrarunning.
Keyword 4: “Ankle”	This keyword is necessary as the ankle joint is one of the areas when discussing podiatry. Injuries of the ankle can both be acute and chronic and shall thus be paired with other keywords to assemble a keyword string used for more efficient indexing.
Keyword 5: “Feet”	This keyword is another area that injury is prevalent, and thus must be included in the indexing process. The justification as to why body parts are isolated is similar to the logic seen for Keyword 4 (“ankle”).
Keyword 6: “Lower” “limb”	Similar justification to Keyword 4 (“ankle”) and Keyword 5 (“feet”). While the lower limb refers to the area of leg between the ankle and knee joints, the word **lower** is isolated and is separated from the keyword “limb” in order to ensure that all ultrarunning injuries to the limb are related to the lower limb and thus match the definition of “podiatric injuries” used in this paper.
Keyword 7: “Knee”	Like the justification of Keyword 4 (“ankle”), Keyword 5 (“feet”), and Keyword 6 (“Lower” “limb”), the knee is a prevalent area in which podiatric injuries may occur.

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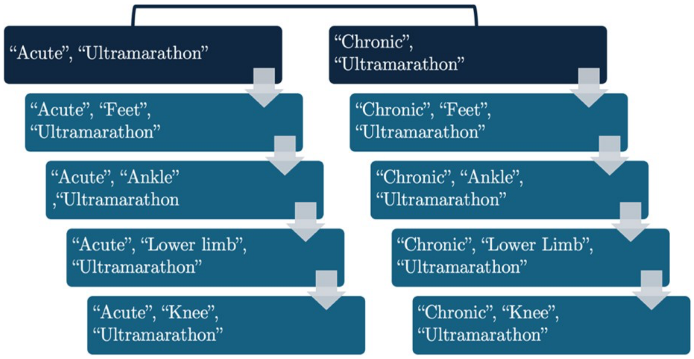

Figure 1. Search strings assembled from the keywords identified in Table 1. By dividing up the injuries by the categories "acute" and "chronic" (seen in dark blue), keywords using the different body parts podiatric injuries encompass (feet, ankle, lower limb, and knee) can be linked together and associated with the keyword "ultramarathon".

2.2 Analyzing Indexed Podiatric Injuries

Upon indexing and compiling a list of various podiatric injuries related to ultrarunning, they must be analyzed and discussed as per the aims listed in section 1. To do this, the injuries shall first be categorized into the categories of chronic injuries and acute injuries based on the duration the injury can affect an ultrarunner for simplicity and organization. Then, they will be sub-categorized based on the parts of the body they may occur in.

To achieve aim 3 listed in section 1, the underlying causes is best understood anatomically. Thus, the types of symptoms shall be described as well as the best/typical methods for recovery when such injury takes place in an ultrarunner, citing literature on the matter.

3. Literature Selection

In order to follow the conceptual framework methodology outlined in Section 2, existing literature from Google Scholar (https://scholar.google.com/) was compiled using the keywords displayed in Table 1.

While it can be useful to limit the time frame for each search on Google Scholar, especially for relevant and recent topics that may have become relevant after a certain year, ultrarunning still remains relatively new and has only significantly increased in popularity over the last decade; thus, all the literature available on it is useful. Thus, when using the following search string key words to index papers, no constraint on timeframe shall be selected which allows the largest search query to be produced.

- "acute", "feet", "ultramarathon"
- "acute", "ankle", "ultramarathon"
- "acute", "lower" "limb", "ultramarathon"
- "acute", "knee", "ultramarathon"
- "chronic", "feet", "ultramarathon"
- "chronic", "ankle", "ultramarathon"
- "chronic", "lower "limb", "ultramarathon"
- "chronic", "knee", "ultramarathon"

After indexing and compiling a list of podiatric injuries related to ultrarunning, these injuries must be analyzed and discussed according to the aims outlined in section 1. To facilitate this, injuries will first be categorized into chronic and acute types based on the duration they may affect an ultrarunner, ensuring simplicity and organization. Subsequently, they will be sub-categorized according to the specific body parts involved.

First, using the keywords, the following number of papers (n) was indexed as shown in Table 2 below.

Table 2. The keywords identified in Table 1 are first indexed in order to gather all literature related to the keyword. All keywords are associated with the keyword "ultramarathon" (except the key word "ultramarathon") to ensure that all papers are related to ultrarunning. Similarly, the publication year setting on Google Scholar remains untouched (Any Time), meaning that old and new papers – relative to the current year this systematic analysis was conducted, 2024 – are all indexed regardless of their publishing date.

Keyword(s)	Year of Publication	Number of results (n)
"Acute" "Ultramarathon"	Any time	8240
"Chronic" "Ultramarathon"	Any time	6670
"Ankle" "Ultramarathon"	Any time	1770
"Feet" "Ultramarathon"	Any time	1990
"Lower""limb" "Ultramarathon"	Any time	2200
"Knee" "Ultramarathon"	Any time	3060
		Total n = 23930

While a large number of literature has been gathered based on indexing the keywords, these keywords are highly unspecific when used individually (as seen by the large number of indexed results, *n* = 23930). Thus, to gather only relevant literature that allows for the aims identified in section 1 to be achieved, search strings capable of being indexed in google scholar are now used. These strings, as well as the number of indexed results, *n*, are shown in Table 3 below.

Table 3. The keywords, assembled into search strings that are used to index literature on Google Scholar, are used to filter out irrelevant literature indexed from Table 2. Thus, this reduces the number of papers un- or semi-related to ultrarunning and the effects on podiatry and ensures that the literature is fully relevant to the keywords.

Search String	Year of Publication	Number of results (*n*)
"Acute" AND "Feet", "Ultramarathon"	Any time	334
"Acute" AND "Ankle", "Ultramarathon"	Any time	210
"Acute" AND "Lower" "limb", "Ultramarathon"	Any time	1000
"Acute" AND "Knee", "Ultramarathon"	Any time	801
"Chronic" AND "Feet", "Ultramarathon"	Any time	443
"Chronic" AND "Ankle", "Ultramarathon"	Any time	282
"Chronic" AND "Lower" "limb", "Ultramarathon"	Any time	270
"Chronic" AND "Knee", "Ultramarathon"	Any time	710
		Total *n* = 4050

Now, using the abstracts of the *n* = 4050 papers indexed using the search strings, papers were manually filtered based on a selection criteria developed to ensure that all papers used are fully relevant to the topic.

1. Unrelated to the topic: While specific keywords and search strings generally filter out irrelevant papers unrelated to podiatric injuries from ultrarunning, some mildly related but not fully relevant papers may still pass through. During a manual scan of the *n* = 4050 papers, the abstracts of *n* = 716 papers were identified as semi- related or unrelated to the topic. These 716 papers were subsequently discarded, leaving *n* = 3334 papers in Table 3.
2. Foreign Language: As the search string consists of English words and the search query was conducted from an IP address in North America, the indexed papers are primarily written in English. However, some papers have English titles but are written in foreign languages, which do not contribute to this systematic review. Consequently, the *n* = 84 papers written in a language other than English, or containing sections in different languages, are discarded from the *n* = 3334 papers, resulting in *n* = 3250 papers remaining for filtering.
3. Corrupt files: While most of the literature on Google Scholar consist of papers – in PDF format – published in credible journals, some results lead to websites or files that are corrupt or do not open due to technical issues. As *n* = 579 results consisted of corrupted files or random links, *n* = 2671 papers remain.
4. Duplicated files: As seen in Table 3, many of the search strings consist of many similar keywords (for example, "Acute" AND "Knee", "Ultramarathon" and "Chronic" AND "Knee", "Ultramarathon" only differ by the keyword "Chronic") and thus may index many overlapping papers. Out of the *n* = 2671 papers left, many papers yielded the same results from the same search strings (*n* = 1094), leaving 1577 papers left for indexing.
5. Unfamiliar journal/Authors absent: While reviewing the abstracts to assess duplication or relevance, the source of each paper (including the journal and author) was also examined to ensure the scientific accuracy of the information presented. This involved verifying that the journal in which the paper was published is credible and peer-reviewed, thereby ensuring content accuracy. Additionally, all papers without listed authors were excluded for citation purposes. As a result, *n* = 428 papers were removed, leaving *n* = 1149 papers available for information extraction.

From the n = 1149 papers remaining after criteria selection, relevant information to meet the aims is gathered and discussed in section 4. Section 5 then expands on the effects of ultrarunning on podiatry, incorporating medical imaging and scientific research from the n = 1149 papers to thoroughly identify ultrarunning's impact on the body.

4. Results

From the *n* = 23930 papers, by assembling search strings from the keywords identified in Table 2 reduced, the total amount of papers indexed was reduced to *n* = 4050. Then, to satisfy the criteria in section 3, a total of *n* = 2901

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papers were removed, leaving n = 1149 papers to be fully analyzed for this systematic review.

Of the 1,149 papers reviewed, most focused on ankle and knee joints (n = 269 and n = 402 papers, respectively), with foot injuries (n = 288) following closely. This distribution aligns with expectations, as ankle and knee issues are common sources of pain for runners, including ultrarunners, making them highly relevant topics in the literature. Although some papers discussed general lower limb injuries, duplicates were removed, meaning "lower limb" papers largely concentrated on ankle, foot, or knee injuries.

In reviewing the criteria for identifying the most common injuries in the literature, it is essential to acknowledge that many acute injuries are prevalent not only in ultrarunning but also in trail running and long-distance running. As a result, sources used in Section 4 may not specifically address these injuries in the context of ultrarunning. This paper aims to contextualize the identified injuries from the literature within an ultrarunning framework, so some sources may not contain the keyword "ultramarathon." However, references discussing chronic injuries will generally include "ultrarunning," as most chronic injuries are specific to long-distance ultrarunning.

With all aspects considered, the following injuries have been identified into the categories of acute and chronic injuries; this is seen in Figure 2 below.

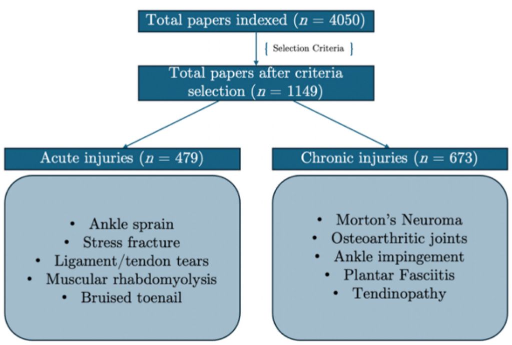

Figure 2. A schematic diagram of the number of papers sorted for acute injuries and chronic injuries and the noteworthy conditions/injuries that are related to ultrarunning. Some injuries have been generalized but apply to the ankle and knee (such as osteoarthritic joints). Similarly, some conditions may happen in various body parts (such as a stress fracture, ganglion cyst, or ligament tears) but have been generalized for simplicity.

5. Discussion

What follows is a thorough discussion of these injuries and how ultrarunning can create symptoms and tears due to the high-impact nature of the sport. Section 5 is divided into acute and chronic injuries as seen in Figure 2.

5.1 Acute Ultrarunning Injuries

Ankle Sprains

Ankle sprains are common acute injuries in ultrarunners, particularly among ultra-trail runners who contend with rugged terrain filled with roots, rocks, and other irregularities. The most frequent type is the lateral ankle sprain, occurring when the ankle inverts (Scheer and Krabak, 2021). Key factors contributing to lateral sprains in ultrarunning include: (1) ankle joint fatigue, increasing susceptibility to sprain, (2) uneven terrain, especially in trail races, and (3) previous ankle injuries, which may weaken ligament tissue. Although less common, lateral sprains can also happen in track ultramarathons due to improper footing.

Three main ligaments support the lateral ankle: the anterior talofibular ligament, the calcaneofibular ligament, and the posterior talofibular ligament (Hertel, 2002). In a lateral sprain, the anterior talofibular ligament, which connects the talus to the fibula, is commonly injured. Medial ankle sprains, caused by eversion, can also occur, though they are less prevalent. These affect the deltoid ligament complex, which stabilizes the ankle in an everted position (Hertel, 2002).

While ankle sprains cannot be entirely prevented on technical trails, flat-footed individuals may be more susceptible due to reduced kinematic stability. Preventive strategies include strength training for muscles around the ankle (such as the fibularis and tibialis anterior), proprioceptive exercises (e.g., balance training on unstable surfaces), and supportive footwear. For treatment, the RICE protocol (rest, ice, compression, elevation) should be applied initially to control inflammation, followed by a rehabilitation program incorporating gradual activity, strength, and proprioceptive training to aid recovery and reduce recurrence (Kemler et al., 2011). By implementing these strategies, ultrarunners can reduce the risk of ankle sprains and enhance recovery when injuries occur.

Ligament & Tendon Tears

Acute injuries to lower leg ligaments and tendons in ultrarunners often result from the high biomechanical

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demands on muscles like the tibialis anterior, gastrocnemius, and soleus. The tibialis anterior, responsible for dorsiflexion, stabilizes the foot and absorbs shock during initial ground contact. Prolonged fatigue may impair this function, increasing the risk of anterior talofibular ligament overstretching or tearing as plantarflexion-dorsiflexion balance is disrupted (Fallon, 1996). Meanwhile, repetitive downhill running places high tensile forces on the Achilles tendon through eccentric loading of the gastrocnemius and soleus, potentially leading to microtrauma or rupture if the forces surpass the tendon's limit.

The gastrocnemius, a two-joint muscle heavily involved in plantarflexion, is particularly vulnerable to acute injury during intense activities like sprinting or hill running. Fatigue from rapid contraction transitions delays stretch response, straining the Achilles tendon (Maganaris, 2003). The soleus, a postural muscle engaged in prolonged activity, can become overworked in ultramarathons, leading to chronic overload and, eventually, acute tendon injuries if sudden demands exceed its capacity (Maganaris, 2003).

After initial treatment with the RICE protocol (48-72 hours), progressive loading exercises are key for rehabilitation (White, 2009). Controlled eccentric movements, such as gradually intensified calf raises, build tensile strength in the gastrocnemius and soleus, while specific exercises target tibialis anterior dorsiflexion strength. Ultrasound therapy or electrical stimulation can further aid blood flow and healing in the affected tissues, promoting effective recovery (White, 2009).

Muscular Rhabdomyolysis

Acute muscle rhabdomyolysis is a type of muscle damage caused by prolonged intense activities, resulting in the release of muscle proteins into the bloodstream (Bezuglov et al., 2023). The combination of repetitive eccentric contractions and high-intensity terrain can lead to microtrauma. Eccentric loading, particularly during downhill running, places excessive strain on muscle fibers, disrupting sarcomeres—the basic contractile units of muscle tissue. This damage can trigger an inflammatory response, causing intracellular components, such as myoglobin, to enter the bloodstream, which is characteristic of rhabdomyolysis (Bezuglov et al., 2023).

Specific characteristics of the lower leg muscles may increase their susceptibility to rhabdomyolysis during ultrarunning. The gastrocnemius, a powerful two-joint muscle, is particularly vulnerable due to its dual role in knee flexion and ankle plantarflexion (Maganaris, 2003). This dual function can lead to muscle overload, especially during runs lasting more than 6 hours. Additionally, prolonged exertion can deplete glycogen stores in the legs, resulting in an energy crisis as the body breaks down muscle tissue for energy. This breakdown releases damaging enzymes and proteins, further heightening the risk of rhabdomyolysis (Bezuglov et al., 2023).

Since extreme rhabdomyolysis can be fatal, prompt treatment is essential. Key interventions include hydration and electrolyte replacement to support renal function and prevent acute kidney injury. Intravenous (IV) fluids, usually isotonic saline, are administered to quickly expand blood volume and dilute myoglobin in the bloodstream. The volume and rate of IV fluids should be customized based on the runner's condition and urine output, with a goal of at least 200 mL/hour, reflecting adequate kidney function. Laboratory tests for creatine kinase (CK) and myoglobin levels are crucial to gauge muscle injury severity and guide treatment (Torres et al., 2015).

5.2 Chronic Ultrarunning Injuries

Osteoarthritis

The prolonged mechanical stress and repetitive loading in ultrarunning can increase the risk of osteoarthritis in the ankle and knee. Key factors include cartilage degradation, subchondral bone remodeling, and synovial inflammation, all exacerbated by age, body mass index, and biomechanical misalignments (Hunter and Bierma-Zeinstra, 2019). Research shows that cumulative microtrauma from joint loading disrupts cartilage balance, potentially leading to early osteoarthritis (Shakoor et al., 2010). Additionally, repetitive strain triggers inflammation through pro-inflammatory cytokines and matrix metalloproteinases, accelerating joint degeneration.

Changes in gait mechanics, often used to manage fatigue and discomfort in ultrarunners, can place added stress on knee and ankle joints, heightening the risk of chronic overuse injuries. Foot strike variations and inadequate footwear may further amplify joint stress, increasing osteoarthritic risk (Shakoor et al., 2010).

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While arthritis is generally irreversible, its progression can be managed. Cross-training methods like cycling and swimming help maintain cardiovascular fitness with less joint impact (Drummer et al., 2021). Similarly, strength training improves muscular support around joints, enhancing stability and reducing abnormal loading. Proper footwear with cushioning can help alleviate stress on knee and ankle joints. Nutritionally, incorporating anti-inflammatory foods and supplements like glucosamine and chondroitin sulfate can support joint health, allowing ultrarunners to continue training with a reduced risk of worsening osteoarthritis (Reginster et al., 2012)

Plantar Fasciitis

Plantar fasciitis, characterized by inflammation and degeneration of the plantar fascia, poses a significant concern for ultrarunners due to the biomechanical demands and repetitive loading of long-distance running (Kakouris and Fong, 2021). The condition's pathogenesis involves microtrauma to the plantar fascia, worsened by factors like excessive pronation, inadequate footwear, and training errors, such as sudden mileage increases. Histological examinations of affected tissues show a shift from normal collagen structure to a disorganized and degenerated matrix, indicating a failed healing response. Additionally, the buildup of inflammatory mediators in the tendon contributes to pain and discomfort, which can impair performance and lead to compensatory movement patterns that increase the risk of secondary injuries (Rabadi et al., 2022).

Effective management of plantar fasciitis in ultrarunners involves strategies to alleviate symptoms while allowing for continued training. Conservative treatments, such as targeted stretching and strengthening exercises for the gastrocnemius and soleus muscles, enhance flexibility and resilience, reducing strain on the plantar fascia. Foot orthotics are also beneficial for evenly distributing load across the foot, addressing excessive pronation, and improving biomechanical alignment, particularly for individuals with flat feet or high arches (Goff and Crawford, 2011). Additional therapies, including cryotherapy and shockwave therapy, can promote tissue repair and reduce inflammation by directly targeting microtears, supporting faster recovery (Rupareliya and Shukla, 2021).

Tendinopathy

Tendinopathy, a common overuse injury in ultramarathon runners, is the breakdown of tendon tissue due to chronic mechanical loading and insufficient recovery time (Kakouris and Fong, 2021). The pathophysiology of tendinopathy involves a series of cellular and molecular changes within the tendon matrix, including increased collagen disorganization, degeneration of the extracellular matrix, and alterations in tenocyte function. This condition often arises in response to repetitive, high-intensity training, where the cumulative effects of tensile and compressive forces exceed the tendon's adaptive capacity; this is usually seen in the build-up stages of an ultramarathon (Drigny et al., 2024). Notably, the tendons most susceptible to these changes, such as the Achilles and patellar tendons, exhibit a marked reduction in tensile strength, rendering them vulnerable to injury. Biomechanical factors, including foot strike patterns and lower extremity alignment, further contribute to the exacerbation of tendinopathy, emphasizing the complex interplay between intrinsic and extrinsic factors in its development (Drigny et al., 2024).

When managing tendinopathy, rehabilitation protocols should employ strategies such as activity modification and cross-training can facilitate recovery while maintaining cardiovascular fitness (Irby et al., 2020). Recent evidence supports the use of adjunctive therapies, including ultrasound and platelet-rich plasma (PRP) injections, which may accelerate the healing process by enhancing vascularization and modulating inflammatory pathways (Zhou and Wang, 2016).

6. **Conclusion**

This study underscores the significant impact of ultramarathon running on podiatric health, identifying ankle sprains, ligament tears, and muscular rhabdomyolysis as the most prevalent acute injuries, while osteoarthritis, plantar fasciitis, and tendinopathy dominate chronic conditions. The findings highlight the necessity of proactive injury prevention strategies, as prolonged exposure to extreme endurance running can lead to long-term musculoskeletal complications.

To mitigate these risks, ultrarunners should adopt evidence-based prevention methods, including structured strength training, progressive load management, and footwear tailored to individual biomechanics. Injury rehabilitation should emphasize eccentric strengthening and cross-training alternatives to reduce excessive stress on the lower limbs while maintaining fitness.

While this study provides a comprehensive review of ultrarunning-related podiatric injuries, further research is necessary to refine injury prevention protocols. Future studies should focus on longitudinal assessments and biomechanical analyses to better understand the progression of ultrarunning injuries over time. By integrating these insights into training practices, ultrarunners can optimize performance while minimizing injury risk, ensuring longevity in the sport.

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