DEFINING TYPES AND RISK FACTORS OF OVERUSE INJURIES OF THE FOOT, ANKLE, LEG AND KNEE IN DISTANCE RUNNERS: A SCOPING REVIEW

A thesis submitted to the Unitec Osteopathy Department

In partial fulfilment of the requirements

for the Degree of Masters of Osteopathy

Unitec Institute of Technology

New Zealand

Submitted By

Morgan J Hancock

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Declaration

Name of candidate: Morgan Hancock

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DEFINING TYPES AND RISK FACTORS OF OVERUSE INJURIES OF THE FOOT, ANKLE, LEG AND KNEE IN DISTANCE RUNNERS: A SCOPING REVIEW

is submitted in partial fulfilment for the requirements for the Unitec degree of:

Master of Osteopathy

Principal Supervisor: Micalla Williden

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Finally, I would like to recognise the Unitec Osteopathic lecturers and clinical tutors, without whom my new career could not have come to fruition.
Abstract

Objectives: The objectives of this research were to identify literature involving overuse running injuries and consolidate the diverse material available. Currently it is a broad and extensive field of information crossing multiple modalities providing little amalgamation of its knowledge for clinical practitioners that must treat such injuries. In addition, the risk factors (RF) behind those injuries were identified and thematically categorised to help in the development of strategies for the prevention or treatment of future overuse injuries.

Methods: Arksey and O’Malleys' scoping review design was used as a conceptual framework alongside the PRISMA-ScR extension, recommended by the EQUATOR network.

Results: Incidence rates varied but the most common overuse running injuries identified through the literature were; patellofemoral pain syndrome, Iliotibial friction syndrome, patellar tendinopathy, chronic compartment syndrome, medial tibial stress syndrome, Achilles tendinopathy/paratenonitis, metatarsalgia, plantar fasciitis and bone stress injuries/stress fractures. The RF associated with these injuries were categorised into one of six overall classifications; Demographic, anatomical, physiological, training errors, training surface and footwear. Within those categories, were further subcategories identified as primary avenues of risk in the development of overuse running injuries.

Conclusion: Three themes were developed from the analysis: (1) training errors are frequently cited as being responsible for overuse injuries and could be considered as the root cause behind all overuse injuries. The human body is made to adapt to introduced stressors and can, if given appropriate time and training, build resilience to the repetitive and potentially traumatic forces that running introduces; (2) many of the causes of overuse injuries are interconnected but can also be diametrically opposed, one risk factor that puts a runner at risk of a particular injury may serve as a protective factor for a different injury; (3) there is a potential risk of inappropriate advice from a clinical practitioner that does not understand the interconnected nature of these RF, identified in (2). The anatomical, structural, kinematic, pharmacological, nutritional and training factors that need to be considered when seeking the best outcome for a patient unlikely fall within a single practitioner’s field of expertise and highlights the advantages of greater interprofessional collaboration.

Keywords: running; overuse; injury; foot; ankle; leg; knee
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<th>Description</th>
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<td>ACL:</td>
<td>Anterior cruciate ligament</td>
</tr>
<tr>
<td>ASIS:</td>
<td>Anterior superior iliac spine</td>
</tr>
<tr>
<td>AT:</td>
<td>Achilles tendinopathy</td>
</tr>
<tr>
<td>ATn:</td>
<td>Achilles tendon</td>
</tr>
<tr>
<td>ATL:</td>
<td>Anterior tibiotalar ligament</td>
</tr>
<tr>
<td>ATFL:</td>
<td>Anterior talofibular ligament</td>
</tr>
<tr>
<td>BSI:</td>
<td>Bone stress injuries</td>
</tr>
<tr>
<td>CCS:</td>
<td>Chronic compartment syndrome</td>
</tr>
<tr>
<td>CFL:</td>
<td>Calcaneofibular ligament</td>
</tr>
<tr>
<td>FFS:</td>
<td>Front foot strike</td>
</tr>
<tr>
<td>GFR:</td>
<td>Ground reaction forces</td>
</tr>
<tr>
<td>ITBS:</td>
<td>Iliotibial band friction syndrome</td>
</tr>
<tr>
<td>IdN:</td>
<td>Interdigital nerves</td>
</tr>
<tr>
<td>LCL:</td>
<td>Lateral collateral ligament</td>
</tr>
<tr>
<td>MCL:</td>
<td>Medial collateral ligament</td>
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Definitions

*Anterior thigh:* The anatomical region located between the inguinal ligament and knee joint².

*Abductory twist (during gait):* Rapid abduction of the heel as it leaves the ground during terminal stance/pre-swing phases of the gait cycle creating an abductive whipping motion of the heel as it leaves the ground³.

*Enthesis:* The region in which a tendon, ligament, or joint capsule attaches to bone².

*Foot:* The anatomical region located distal to the ankle joint².

*Ground reaction forces:* Force exerted by the ground on a body in contact with it. Such forces will also contain parallel components during movement, exchanging frictional horizontal forces with the ground to enable such movement³.

*Leg:* The anatomical region located between knee and ankle joint, also referred to as the shank or crus².

*Posterior thigh:* The anatomical region located between the gluteal fold and the knee joint².

*Q-Angle:* An angle formed by a line created from the ASIS to the mid patella intersecting with a line created from the mid patella to the tibial tubercle, with the knee in full extension³.
1 Introduction

1.1 Thesis overview

The format of this thesis is paper-based chapters structured to provide an overview of overuse running injuries and their associated RF. Section one introduces the thesis and provides an abstract of the problem reviewed throughout. Section two reviews the relevant literature providing a brief anatomical overview of relevant anatomical structures included within the research, a discussion of runner categorisations and a brief overview of the recent uptake in barefoot vs shod running debate. Section three provides the methodology of the research and section four presents the results of the categorisation and the injuries identified for the review. Section five synthesizes those findings and provides a discussion on the specifics of the identified RF and the application of the findings in professional practice. Finally, limitations are discussed, and reflections on the process are provided.

1.2 Conceptual design and approach

Reviews of research have become more widespread as evidence-based practice gains recognition as a benchmark for better patient outcomes\(^4\). Various review types have developed in response to this and one such methodology is the “scoping review”. Scoping reviews emerged due to a need for a synthesis of existing research data that was too complex or heterogenous to fall within the definitions of a precise systematic review process\(^4\). Furthermore, scoping reviews are considered useful to help clarify working definitions and define conceptual boundaries in a field. When deciding on an approach of a systematic or scoping review, Munn et al.\(^5\) propose that the most important consideration for an author to consider is if the results of the review are intended to answer a clinically meaningful question or to provide evidence to inform practice. In the case of the former, a systematic review is best practice while in the latter, a scoping review will be of greater relevance\(^5\).

Unlike a systematic review, scoping reviews trend away from assessments of methodological limitations or risk of bias within the evidence\(^5\). This is due to the nature of the findings of a scoping review, that do not seek to provide definitive guidance from a clinical or policy position\(^5\). They instead provide a summary of the wider evidence available, even if portions of such evidence may still be inconclusive\(^5\). For the purposes of the investigation around the types and causes of overuse running injuries, it was the identification of characteristics or models within individual papers, and the mapping and thematic categorisation of these concepts that was the priority, due to the existing literatures heterogenous nature.
2 Literature review

Lower limb injuries account for approximately 10% of total injuries to athletes and, running is the most common activity associated specifically with knee, leg, ankle and foot injuries. The high incidence of runner injuries is unsurprising considering that during running ground reaction forces (GFR) acting on the lower limbs effectively triple the body weight of a runner in relation to the body's centre of mass. Due to their proximity to the point of application of force, impact absorption at the heel, plantar ligaments and fascia are of even greater magnitude, reaching up to 12 times the body weight of the runner. Previous studies and reviews on the proportion of running injuries by anatomical site agree that most running injuries occur at or below the knee (~70%) and is the reason for the regional anatomical range of this scoping review.

Injury prevention and reduction are important goals for clinicians, trainers, and individuals involved in regular physical activity. There is an array of research on sports injuries that is prevention-based and describes models or frameworks that aid in the design of prevention strategies. Current research specific to running leans heavily towards incidence rates, RF or investigations on the epidemiological and aetiological factors of overuse running injuries. This specificity of the research has created a wide span of information, spread among an equally wide span of publications creating difficulties for health practitioners to standardise frameworks in developing diagnostic and treatment plans. Without any consolidation of the currently published material it is left to the individual to research and track down relevant studies involving running injuries, and then partake in further research to ensure the validity of recommendations based on the identified causes or RF of those injuries.

This literature review provides an overview of the anatomical locations included in this scoping review with specific consideration to individual structures that are more frequently injured in running. It discusses the biomechanical process of the gait cycle and the differences in a runner's gait to that of walking. The division of runners is defined with an explanation on why distance runners were exclusively selected for this analysis. The literature review concludes with a brief summary of the relatively recent debate on barefoot running and the overall goals of this scoping review.

2.1 Anatomical overview

2.1.1 Elements of the knee

The knee is one of the larger and more complex joints of the human body. It is also the most commonly injured structure for runners.

The femur, tibia and patella create the main articular surfaces of the knee via the tibiofemoral and patellofemoral joints. Alongside the tibia runs the fibula, while it is not directly involved in the
knee joint, it’s attachment to the main structure via the superior tibiofibular joint creates surfaces for major muscles of the leg and thigh to attach to.

The medial and lateral menisci contribute to the congruence between the articular surfaces of the femur and tibia. The ‘C’ shape of the medial meniscus and ‘O’ shape of the lateral meniscus increase the area of contact between the femoral condyles and tibial plateau, improving weight distribution and shock absorption. The meniscus must withstand a range of shear, compression and tension forces generated through a variety of movement. If injured the vascularization of the tissue is highly relevant as its healing capacity is directly related to blood supplied to the tissue. While the menisci are fully vascularized shortly after birth, by adulthood they contain only blood vessels and nerves in the peripheral 10-25% of the tissue. This lack of vascularization to the interior of the menisci makes it susceptible to permanent acute and degenerative injury.

Unique to the knee is an arthrokinematics movement known as the “screw-home” mechanism which plays a key role in knee stability. During terminal range knee extension (0°), external rotation of the tibia creates a torsion of the anterior cruciate ligament and posterior cruciate ligament tightening both ligaments and locking the knee into position. This creates an optimal angle of stability between the tibia and femur.

The extensor apparatus is a title given to the combination of muscle, tendon and bone that act as a unit to provide extension of the knee. It consists of the quadriceps muscles that initially converge to form the quadriceps tendon, shortly above the patella and the patella itself. The quadriceps tendon becomes classified as the central patellar tendon as it invests the patella, before running inferiorly to insert on the tibial tuberosity. The apparatus is considered a chain, where separate pathologies can occur at any level due to the forces experienced in movement and modified by the varying geometries at each level of the chain.

Four major ligaments of the knee add to the stability of the joint. The MCL, LCL, ACL and PCL all serve separate functions in resisting the effects of anterior/posterior shear, varus/valgus stress and medial or lateral rotation of the knee joint. Ligament injuries account for up to 40 percent of all knee injuries, with the MCL appearing to be the most commonly injured among them.

2.1.1.1 Ligament sprains

As pictured in Figure 1; Isolated grade-I tears may have some local tenderness and swelling but no ligament laxity. Isolated grade-II tears also present with local tenderness, and while fibres are now partially torn, there may or may not be pathological laxity. Isolated grade-III tears present with severe oedema of the joint, tenderness and acute signs of laxity. This laxity may not be immediately present due to the high degree of oedema and inflammation within the region, providing support to the surrounding tissue and masking signs of laxity.
2.1.2 Elements of the leg

In common parlance “leg” is erroneously used in reference to the entire lower limb. In anatomical terminology, the leg is the region that strictly extends between the knee and ankle joints, an area known as the crus or shank.

The main support bones are the medially located tibia and laterally located fibula. Weight bearing is predominantly through the tibia. The two bones are joined at the superior and inferior tibiofibular joints and are further strengthened by the interosseous membrane between them. The membrane helps stabilise the tibia and fibula as well as serving as separation for the leg’s compartments and as an attachment for muscles within the leg.

2.1.2.1 Achilles tendon

The main function of the Achilles tendon (ATn) is the transmission of power from the calf muscles to the heel, allowing plantarflexion of the foot, and the power to toe off during walking, running and jumping. The anatomy of the ATn also provides for both recoil and shock absorbance in the foot. The ATn is thought to be composed predominantly (90%) of type I collagen, creating a structure of fibrils, fibres, and fascicles, although formal compositional data is currently lacking. Considered a viscoelastic material with elastic dominance, its spring-like properties allow the tendon to bear up to 3500N before rupture, enabling it to deliver exceptional propulsion during movement. As illustrated in Figure 2, it is a conjoint tendon shared between the gastrocnemius and soleus muscles and may also include the plantaris longus muscle. It begins approximately mid-calf, at the distal confluence of the

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Figure 1 - Anteromedial view of the left knee showing the injury grade scale for ligament injuries, est. by the American Medical Association Standard Nomenclature of Athletic Injuries.
soleus and gastrocnemius muscles, and gradually thins as it progresses inferiorly to attach to the calcaneal tuberosity of the calcaneus.

Figure 2 - Anatomy of the Achilles tendon

There are three vascular regions of the ATn, with the distal and proximal regions supplied by the posterior tibial artery and the belly of the tendon supplied but the peroneal artery. It is this regional vascularisation that creates a hypovascularized area at the thinner midsection of the tendon, leaving it more at risk for injury.

While the ATn is the thickest, longest and strongest tendon in the human body, it must deal with stress loads that have been reported as high as 9 kN or 12.5 times an individual’s body weight during running. By spiralizing its fibres up to 90°, rather than strict vertical alignment, the ATn produces an area of concentrated stress resulting in better grouping of individual strands when under tension. In doing so, the tendons fibres experience less distortion and interfibre friction, increasing the conjoined tendons strength.

The ATn insertion at the calcaneus is a wide deltoid shaped attachment, becoming briefly broader than its narrowed width at the ankle. The shape creates a fulcrum that increases the ATn lever arm. It is also considered the quintessential enthesis organ, that comprises of not only the enthesis itself but also fibrocartilages in the walls of the neighbouring retrocalcaneal bursa, together with the bursal cavity and its related synovium-covered fat-pad. This highly specialised combination of enthesis structures help in the dissipation of stress away from the osteotendinous attachment site.
Unlike other tendons in the ankle complex that are surrounded by synovial sheaths, the ATn is enveloped within a paratenon originating from the deep fascia of the leg. The paratenon is a two layered membrane consisting of a deeper layer surrounding the epitenon and a superficial layer, the peritenon.\(^{34}\)

Inflammation of the ATn is one of the most common overuse problems for runners and involves several aetiologies. The mesotenon may become chronically inflamed hampering movement of the tendon with its sheath, while the involvement of the tendon itself can be secondary to areas of fibrotic or mucinoid degeneration.\(^ {35}\) In a review of 698 patients with ATn injuries, 89% were male.\(^ {36}\) Other reviews have reported ratios of male to female predominance in ATn injuries between 4:1 and 7:1.\(^ {37}\) Higher male incidence rates of injuries to the ATn are in conflict with the generally held established view that women are more likely to sustain tendon injuries than men due to a lower rate of new connective tissue formation, lower response to mechanical loading and lower mechanical strength of the tendon.\(^ {38}\) The same anatomical and physiological factors should be applicable to the ATn but the incidence rates indicate otherwise. The reason for this difference in male/female ratios of the ATn is unclear and does not seem to have been explored in the literature. Tears or strains to the ATn are grouped into four categories as shown in Table 1.

### Table 1 - Classification of Achilles tendon tears\(^ {39}\)

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Partial ruptures &lt;50%</td>
</tr>
<tr>
<td>II</td>
<td>Complete ruptures with tendinous gap &lt;3cm</td>
</tr>
<tr>
<td>III</td>
<td>Complete ruptures with tendinous gap 3cm to 6cm</td>
</tr>
<tr>
<td>IV</td>
<td>Complete ruptures with a defect of &gt;6cm</td>
</tr>
</tbody>
</table>

#### 2.1.3 Elements of the ankle

Referred to as the talocrural articulation, the ankle joint is the link between the proximal end of the talus and the distal ends of the tibia and fibula.\(^ {40}\) The shape of the talus creates congruence between the trochlea of the talus and the malleolar mortis formed by the tibia and fibula. However, during increased plantar flexion, this congruence decreases and leaves the ligaments of the ankle more prone to sprains.\(^ {41}\)

Consisting of the Anterior talofibular ligament (ATFL); Posterior talofibular ligament (PTFL); Calcaneal fibular ligament (CFL), the lateral ligaments of the ankle are designed to resist inversion and rotational stress during plantarflexion as well as posterior displacement of the talus and talofibular stability during dorsiflexion.\(^ {41}\) The medial ligaments of the ankle, collectively referred to as the deltoid ligament, include the AT, PT, TN & TC ligaments whose role it is to provide stabilisation during eversion of the foot and reinforce the ankle joint as a unit to prevent subluxation.\(^ {41}\)
Lateral ankle sprains are one of the most commonly occurring injuries with estimates of approximately two million acute sprains annually in the USA\textsuperscript{42}. This figure is considered much lower than the actual numbers due to an estimated 55\% of individuals that sprain their ankles and don’t seek treatment\textsuperscript{43}. Several factors likely contribute to this high occurrence rate; Inversion injuries are more common than eversion injuries due to the relative instability of the lateral ankle joint and weaker lateral ligaments, in particular, the ATFL is considered the weakest of the lateral ligament complex and is the most frequently injured\textsuperscript{44}. Seventy percent of those that encounter a lateral ankle sprain will go on to develop ongoing symptoms, termed chronic ankle instability, resulting in articular degeneration of the talus\textsuperscript{43}. Studies investigating runners with chronic ankle instability have found changes in both gait and loading rates while running, such as decreased pronation and higher impact peak forces\textsuperscript{45,46}. Such changes may increase the likelihood of further inversion injuries to the ankle, compounding the problem and leading to surgical intervention\textsuperscript{43}.

2.1.4 Elements of the foot

Consisting of 26 bones, 33 joints, 112 ligaments and controlled by 21 intrinsic and 13 extrinsic muscles, the human foot is both a fixed and flexible structure\textsuperscript{40}. Made up of three distinct sections; forefoot, midfoot and hind foot, it provides an anatomical structure that allows for the complex kinematics required for both weight bearing support, flexibility over uneven surfaces, and as a rigid lever for propulsion\textsuperscript{47}. The metatarsals of the foot are also referred to as the “rays” of the foot, beginning at the hallux, or first digit, as the 1\textsuperscript{st} ray and ending at the 5\textsuperscript{th} digit as the 5\textsuperscript{th} ray\textsuperscript{2}.

2.1.4.1 The plantar fascia

Also known as the plantar aponeurosis, the plantar fascia is a thickened layer of white longitudinal fibrous connective tissue originating from an insertion point at the medial calcaneal tubercle\textsuperscript{48}. The central bundle of the tissue thickens as it extends distally and is bounded by a thinner lateral and medial portion of tissue. As the central bundle progresses, it divides into 5 separate bands surrounding the deep fascia and transverse ligaments. These radiate towards and attach to all five metatarsal heads\textsuperscript{49}. The plantar fascia also blends with the paratenon of the ATn and intrinsic foot muscles. Originally described by Hicks\textsuperscript{50}, the plantar fascia provides the hypotenuse in a triangle truss that is formed by the metatarsals, midtarsal joint and calcaneus (Figure 3). Vertical forces traveling down the tibia flatten the medial longitudinal arch of the foot while GRF travel up from the calcaneus and metatarsal heads\textsuperscript{51}. The presence of the plantar fascia provides an anatomical tie-rod that prevents the collapse of the arch from these forces and, due to its tensile strength, simulates a flexible cable enabling activation of the “windlass mechanism” during a person’s gait cycle\textsuperscript{51,52}.
The windlass mechanism occurs when the first ray moves into extension, pulling the plantar aponeurosis forward around the heads of the metatarsals. This action causes the medial arch of the foot to rise without direct muscle action\textsuperscript{50}.

2.2 Bipedal gait cycle

The gait cycle can be explained as a sequence of movements of the lower extremities between initial contact of the foot with a surface until it reconnects with that surface at the end of a cycle. Both internal and external forces are introduced to the musculoskeletal system during a cycle. Internally, muscles and tendons acting upon bones and joints create various stress loading. Externally, GRF, air resistance and gravity all create additional stressors\textsuperscript{54}. It is a highly repetitive motion, causing frequent GRF to be generated through the lower limbs approximately 90 times per minute\textsuperscript{55}.

The walking gait cycle consists of two central phases: the stance phase, where some part of the foot is in contact with the ground, and the swing phase, where the same foot is no longer in contact with the ground. During a walking gait, the stance phase is responsible for approximately 60\% of the gait cycle and swing phase for the remaining 40\%.

The stance phase is divided into three stages as described in Table 2.

\textit{Table 2 - Stages of stance phase}\textsuperscript{56,57}. *Average degrees of motion

<table>
<thead>
<tr>
<th>Stages</th>
<th>Activity</th>
<th>Joint Motion*</th>
</tr>
</thead>
</table>
| Initial Contact | Initial contact of the foot striking the ground commonly beginning with a lateral heel strike. Lower limb muscles contract eccentrically to absorb ground reaction forces | Hip flexion at 40°  
Knee flexion at 20-25°  
Ankle dorsiflexion at 10°  
Ankle inversion at 6-8° |
Midstance | Muscles change to concentric contraction and force generation. The foot and leg in contact with the ground provide a stable platform for the body weight to pass over and foot pronation occurs. Due to the elastic nature of tendons, the lower limb muscles will return up to 95% of the energy stored during the initial contact phase, primarily provided by the quadriceps.

| Propulsion | As the heel lifts from the ground, foot supination occurs, the windlass mechanism activates, tightening the plantar fascia and aiding in propulsion. Further forward propulsion is provided by the gluteal muscles, hamstrings and plantar flexors.

| Hip moves through flexion as the body passes over midstance
Knee flexion at 45°
Ankle dorsiflexion at 20°
Ankle eversion at 8°

| Hip reaches 10° of extension
Knee flexion 25°
Ankle plantarflexion reaching 20°

The swing phase of the gait cycle begins when the toe leaves the ground and consists of an initial swing, mid swing and terminal swing phase before entering the stance phase once more. If an individual’s pace increases to a run shorter periods are spent in the stance & swing phase and a third “float” phase occurs. This represents the brief period of time that neither foot is in contact with the ground, occurring at the end of both the stance and swing phase, as demonstrated in Figure 4.

![Figure 4 - Running cycle gait phases](image)

It is muscle activity and movement of the joints, both before and after ground contact, that are major factors in how the body absorbs GRF generated by heel strike and muscle propulsion. The angle of impact force and peak brake force, the effectiveness of limb stabilisation, and the efficiency with which the body stores and applies energy in order to maintain forward momentum, are all decided by
joint motion and levels of neuromuscular activity\textsuperscript{55}. Most of the joint motion throughout a runners gait cycle occurs in the sagittal plane, but it is abnormal biomechanical movements in the frontal plane that is more often associated with overuse injury development\textsuperscript{56}. For example, overpronation of the foot is considered a factor in the development of a range of overuse injuries including sesamoiditis, Achilles tendinopathy, patellofemoral pain and stress fractures of the metatarsals, navicular and fibular\textsuperscript{59}. In an overpronator, the triceps surae muscles must contract for longer than normal in order to reduce the excessive internal rotation of the tibia occurring during a gait cycle. This overcompensation leads to greater forces placed on the tibia and the triceps surae, potentially leading to Achilles tendinopathy and stress fractures\textsuperscript{59}. In addition, the increased internal rotation of the leg from overpronation can mean a shift in muscle balance of the quadriceps as they compensate, which can also lead to patella maltracking and eventually patellofemoral pain syndrome\textsuperscript{59}.

2.3 Categories of runner

Runners can be placed into one of three broad categories, based primarily on distances the individual regularly trains for; sprinters, middle distance or long-distance runners\textsuperscript{60}. These three subsets are based on the separate physical requirements of the running styles. They are important to clarify due to the different intrinsic and extrinsic forces involved in a runners injuries based on these running styles.

2.3.1 Sprinters and middle-distance runners

Sprinters require a powerful take-off and fast acceleration over short distances of up to 400 meters, making it a highly anaerobic activity (Table 3). This maximum distance is based on human physiology being unable to provide a top speed for more than 30-35 seconds due to depletion of phosphocreatine stores within the muscles. A large percentage of a sprinters leg musculature will develop into fast-twitch, type II muscle fibre; a muscle fibre providing high anaerobic capacity and contraction speed\textsuperscript{61}.

\textit{Table 3 - Aerobic vs anaerobic energy requirements}\textsuperscript{60}

<table>
<thead>
<tr>
<th>Distance</th>
<th>Time</th>
<th>Aerobic energy (%)</th>
<th>Anaerobic energy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 m</td>
<td>0:09.79</td>
<td>10</td>
<td>90</td>
</tr>
<tr>
<td>400 m</td>
<td>0:43.29</td>
<td>30</td>
<td>70</td>
</tr>
<tr>
<td>800 m</td>
<td>1:41.11</td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td>1500 m</td>
<td>3:26.00</td>
<td>80</td>
<td>20</td>
</tr>
<tr>
<td>5000 m</td>
<td>12:39.36</td>
<td>95</td>
<td>5</td>
</tr>
<tr>
<td>10 000 m</td>
<td>26:22.75</td>
<td>97</td>
<td>3</td>
</tr>
<tr>
<td>42.2 km</td>
<td>2:05.42</td>
<td>&gt; 99</td>
<td>&lt; 1</td>
</tr>
</tbody>
</table>
Middle distance running includes distances involving 800m to 5000m\(^6\). This running style is considered a tactical style of running, requiring the athlete to extend their anaerobic capacity for final sprints to the finish while ensuring a high enough aerobic capacity for the distances involved\(^6\).

### 2.3.1.1 Exclusion of sprinters

Due to the difference in running style, sprinters were excluded from the review process. Many injuries experience by sprinters are of a traumatic nature and tend to favour hamstring damage\(^62-64\). This review seeks to consider overuse injuries in runners. Such injuries are of a broader scope and have a higher potential for intervention and prevention-based approaches to treatment.

### 2.3.2 Long distance running

Physiologically, long distance running is aerobic in nature (Table 3). A human’s aerobic capacity is dependent on the efficiency by which the body transports blood to or from the heart and lungs to reach muscle tissue which is further dependant on high cardiac output, high levels of haemoglobin and an efficient vascular system\(^65\). To this end, a regular long distance runner will develop slow-twitch, type I muscle fibres that are resistant to fatigue and aerobically efficient\(^61\).

Long distance runners can be divided into two subsets based on distances covered. A runner that trains for distances of 5-21km can be classified as an endurance runner. Those that train for distances greater than 21km fall into the marathon runner classification\(^60\). This distinction is due to distinct differences in physiological and psychological demands between a half and full marathon distance.

The accessibility and range of distances of the endurance runner have made this category of running the most popular in recent times. A 2017 United States national runners survey identified the most favoured event distance for regular runners to train for was the half marathon, followed by the 10km and 5km events\(^66\).

### 2.4 The natural running movement

While the earliest footwear from archaeological records dates back some 8300 years, in terms of the length of human history, the use of specialist running shoes is a recent development\(^67\). Prior to the 1970s running shoes were primarily flats that had little or no cushioning or support to them and were more closely related to a sandal or moccasin than what we recognise as a traditional sports shoe\(^68\). For thousands of years prior to this, barefoot or “natural” running has been the normal form of running for humans and is still common today in certain modern populations in parts of Africa and Latin America\(^69\).

In 2007 a study compared the health of the modern humans metatarsal bones with those of pre-pastoral human skeletons dated between 9720 - 2000 years B.P and concluded that pathological lesions in the modern human feet were more severe in nature than the pre-pastoral ancestors\(^70\). This study generated a hypothesis that habitual footwear and exposure to modern substrates may be linked
to common pathological changes, such as hallux valgus, in the modern foot\textsuperscript{70}. Similar to the interest in diets that seek to emulate post Neolithic revolution living\textsuperscript{71}, this evolutionary link to barefoot running, publications and lay media information have prompted a subset of runners to emulate barefoot running. The purported benefits of which include a decrease in injury risk and increases in running performance from factors such as changing to a midfoot or forefoot running style. This change in style helps dissipate GRF to a greater extent than the heel strike style favoured by shod runners\textsuperscript{72,73}.

### 2.4.1 Running footwear

The running shoe itself has been the subject of many studies as to the possible cause of injury associated with running\textsuperscript{74–79}. While there have been many developments in footwear over the last forty years, there appears to be no related correlating reduction in the relative risk increase and runners continue to experience high rates of injury, despite footwear advances\textsuperscript{80,81}.

The traditional running shoe created a large, flared and cushioned heel designed to distribute impact forces over a large region of the rearfoot (Figure 5). Research by the American Academy of Physical Medicine and Rehabilitation observed “disproportionally large increases in joint torque forces” while running wearing traditional running shoes vs barefoot. An average increase of 54% for hip internal rotation, a 36% increase in knee flexion and a 38% increase in knee varus torque were measured in the medial and patellofemoral compartments\textsuperscript{82}. The findings concluded that the increases seen were predominantly due to the elevated heel of the shoes. Approximately 90% of habitually shod runners adopt a rearfoot strike (RFS)\textsuperscript{83} and it is theorized that the elevated and cushioned heel of a traditional running shoe has facilitated this pattern of heel strike-dominate running\textsuperscript{84}.

![Figure 5 - Traditional running shoe](image)

### 2.4.2 Barefoot

Research on barefoot running has found that forefoot strike patterns (FFS) and midfoot strike patterns (MFS) are dominant in barefoot running cultures and in those that become experienced in barefoot running styles\textsuperscript{69}. One study did find opposing results in the women and children of Hadza hunter-gatherers living in Northern Tanzania, who preferentially employed RFS, although the men of the tribe primarily used MFS running styles\textsuperscript{85}. It was theorised that this was reflective of running experience, with the males learning to prefer MFS running styles as they accumulated running experience with the older hunters\textsuperscript{85}.  

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Biomechanically, the use of FFS & MFS patterns creates a more plantar-flexed foot on landing and allows the posterior ankle muscles to more efficiently lower the body over the ankle-foot complex, decreasing the amount of force that collides with the ground. A direct RFS removes this mechanism, exposing the hindfoot to greater collision forces. As shown in Figure 6 below, an FFS or MFS strike pattern creates a more even GRF curve than RFS patterns.

**Figure 6 - Foot strike ground reaction forces**

Due to these changes in strike patterns a range of studies have concluded that a barefoot MFS/FFS style is associated with lower vertical loading rates, reduced knee contact forces and a lower demand of the overall knee mechanics, compared with RFS. These findings would suggest that a runner should experience fewer running injuries if barefoot, however, studies investigating the risks of barefoot running and minimalist running shoes found over 50% of those training for a ten-week period had signs of bone marrow edema in at least one or more bones of the foot compared to those in the control group (P = 0.009) and novice barefoot runners had such variability in strike patterns that they were at a heightened risk of lower extremity injuries. It is theorised that the shift to a barefoot running style too quickly can place too high a demand on previously supported anatomical structures. While an MFS/FFS running gait does allow for better GRF absorption and attenuation, it appears the loss of shoe cushioning is far greater than the gains of the running style, in the short term.

This is an area of study still in its infancy and will continue to be the subject of a range of research for some time to come. Certainly, the scope of such investigations falls outside the scope of this review, but the presence of this division within the running world makes its acknowledgement within this review appropriate.
2.5 Conclusion and statement of research aim

Due to the complex nature of running injuries, the existing literature covers diverse methodologies, definitions, epidemiology’s, anatomical, biomechanical and training RF. It is a broad and extensive field of information crossing multiple modalities providing little amalgamation of its knowledge for clinical practitioners. Petraglia et al.’s systematic review of plantar fasciitis diagnostic and treatment strategies among athletes is a valuable example of an amalgamation and categorisation of RF, albeit for a broad group and not specific to runners91. Understanding the aetiology of injuries is a key step in the rehabilitation and future prevention of them, from both the clinician and patient’s standpoint. This can be assisted through thematic categorisation of such injuries, as shown in Petraglia et al.’s research91, which allows consideration of wider ramifications of the injury’s onset and potential interventions that may be considered in treatment or rehabilitation.

It is the consolidation and categorisation of information regarding foot, ankle, leg and knee overuse injuries in runners which is lacking in the literature and is the aim of this scoping review to provide. It is the identification of characteristics or models within the literature, and the mapping and thematic categorisation of these concepts that is necessary, due to the existing literatures heterogenous nature. Its results seek to deliver a union of information on overuse injuries and a broader picture of the multifaceted RF contributing to those injuries.

3 Methodology

3.1 Methodological approach

The methodological approach for this study was a scoping review. The review protocol was developed based on the framework outlined by Arksey & O’Malley1 and registered with the Open Science Framework in February 2019 (https://osf.io/6yeus/). It was updated during the later stages of the review in January 2020 to include the variations that had occurred during the process.

While there is no formal universal methodology, there is consensus regarding common elements utilising the framework outlined by Arksey & O’Malley (2005). This is underpinned by the methodology used in systematic reviews, in that each stage of the framework is conducted in a rigorous and transparent way1. This framework methodology has been reviewed and appraised in 2014 by Pham et al.93. While it was found to be an excellent tool for determining the extent and scale of a body of literature, there was no universally recognised definition, raising concerns about the validity and transparency of the process. This was rectified in 2015 by Peters et al.’s4 methodological working group, whose research provided formal direction for conducting scoping reviews, to ensure such reviews were rigorous and transparent. Most recently in 2018 Munn et al.5 provided further guidance on when an author should consider a systematic review versus a scoping review, clarifying specific purposes for when each style of review was appropriate. The research conducted by these
groups has ensured that scoping reviews that follow their recommendations contribute valid, robust and replicable information from their research.

Scoping reviews are useful for synthesizing and collating the literature on a broad topic. They examine the range and nature of research in a wide area of study. Unlike a systematic review, where articles chosen are used to summarise the highest quality of evidence around a single question, a scoping review seeks to present an overview of the research material and collate that material in order to summarise and disseminate its findings. A scoping review was particularly relevant in this study, due to the need to answer a broad question beyond those related to the effectiveness of a specific treatment or intervention.

The information available within each of the studies included in the review was assessed using a blend of inductive content analysis; a method involving the establishment of patterns within the data, through examination of that data, without any priori framework, and thematic analysis; emphasizing the identification, organization, and recording of themes within the data. These methods were utilized due to the heterogenous nature of the information that needed to be collated and categorised.

3.2 Methods

Based on Arksey & O’Malley’s 2005 framework, a scoping review consists of specifically delineated stages outlined in Table 5;

<table>
<thead>
<tr>
<th>Stage One</th>
<th>Identification of the research question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage Two</td>
<td>Identification of relevant studies</td>
</tr>
<tr>
<td>Stage Three</td>
<td>Study selection</td>
</tr>
<tr>
<td>Stage Four</td>
<td>Charting the data</td>
</tr>
<tr>
<td>Stage Five</td>
<td>Collating, summarizing and reporting the results</td>
</tr>
</tbody>
</table>

3.2.1 Identification of the research question

Stage one allowed for the development of the initial research question and directs search parameters for stage two. A scoping review, by its design, allows this question to remain broad. The preliminary research question was “What are the types and causes, both intrinsic and extrinsic, of overuse injuries of the foot and lower leg in long distance runners?”. This was a purposefully open question, even with the limitations of the anatomical lower leg and specificity to a subset of runners. The open nature allowed search parameters to generate a wide coverage of results; thus, appropriate decisions were then made on study selection, once a sense of the volume of the literature in the field had been gained.
3.2.2 Identification of an overuse injury definition

The definition of a running injury varies between many studies. Due to these variations a more concise definition was required for clarification within this scoping review. A 2015 consensus paper that expressly sought to address this dilemma among research provided the following classification of a running injury;

“Running-related (training or competition) musculoskeletal pain in the lower limbs that causes a restriction on or stoppage of running (distance, speed, duration or training) for at least seven days or three consecutive scheduled training sessions, or that requires the runner to consult a physician or other health professional”

A separate systematic review that sought to define overuse running injuries classified such injuries as those that progressively develop due to accumulating microtrauma, which is caused by repetitive submaximal strain. Furthermore, an overuse injury can be characterized by four stages of severity:

Table 6 - Stages of the severity of an overuse injury

| Stage 1 | Pain, present only after activity |
| Stage 2 | Pain, present during activity, not impairing performance |
| Stage 3 | Pain, present during activity, impairing performance |
| Stage 4 | Ceaseless pain, not receding even with rest |

3.2.3 Identification of relevant studies

Stage two allowed for a comprehensive search identifying key studies and reviews that were suitable to begin to address the main research question and provide direction for further searches. These searches targeted scholarly literature found in electronic databases accessed through the UNITEC library system. ScienceDirect (Elsevier), Ebsco health databases (Academic Search Complete, AMED, CINAHL, MEDLINE, SPORTDiscus), PubMed and Scopus were searched using a systematic search strategy during March/April 2019 (Table 6). The search was conducted in order to assemble satisfactory information to ensure an extensive investigation of existing sources of research around running injuries.

Searches included a timeframe from 1980 through to the 25th April 2019. This was due to many older papers providing a broader discussion on running injuries. More modern work now favours details on individual RF that lead to specific injury type. Although accessibility to some of the older pre-1985 papers was a frequent issue, both older and modern papers were relevant in the identification of the broadest range of injuries possible. Table 7 provides a list of key terms used and the Boolean search expressions.
Table 7 - Search terms used

<table>
<thead>
<tr>
<th>Search Term 1</th>
<th>Search Term 2</th>
<th>Search Term 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Medical subject heading search terms</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foot Injuries/etiology[Mesh]</td>
<td>“Running”[Mesh]</td>
<td></td>
</tr>
<tr>
<td>Knee Injuries/etiology[Mesh]</td>
<td>“Running”[Mesh]</td>
<td></td>
</tr>
<tr>
<td>Leg Injuries/etiology[Mesh]</td>
<td>“Running”[Mesh]</td>
<td></td>
</tr>
</tbody>
</table>

| **Wildcard Search terms**      |                               |               |
| Lower extremity injur*         | Run*                          |               |
| Lower extremity injur*         | Long-distance run*            |               |
| Lower extremity injur*         | Cross-country                 |               |
| Overuse injur*                | Run*                          |               |
| Overuse injur*                | Long-distance run*            |               |
| Risk factor*                  | Run*                          | Biomechanic*  |

**Search with “OR”**

| risk factors contributing factors predisposing factors | Running injuries |

Where possible medical subject heading terms were employed although certain databases did not support their use. In these instances, formal terms such as “ankle injuries” were used alongside variations of run, running and long distance run*, where appropriate.

3.2.3.1 Inclusion and Exclusion criteria

Due to the differences previously highlighted between sprinters and distance runners, the search excluded studies specific to sprinters. In addition, this review sought to examine overuse injuries; thus, studies that focused exclusively on traumatic injuries were also excluded.

3.2.4 Study selection

Stage three was based on the selection of content appropriate. A scoping study provides for some development of the search parameters post hoc, based on increasing familiarity of the literature
throughout the search process. This process also provides for the identification of further relevant articles through manual searches of reference lists.

The title/abstract search terms were developed based on the search terms from Table 6 and further appraised by the thesis supervisors. The online application abstrackr (http://abstrackr.cebm.brown.edu, Tufts Medical Centre, USA) was used to import the citations of all records for the initial title and abstract screen\textsuperscript{99}. This system shows the reviewer a random citation, one at a time, allowing the selection of positive, negative or unsure options, for the reviewer to decide on the suitability of the paper for inclusion. These results are collated into a master file once each reviewer has completed their review. This is then assessed by the investigator, allowing a comparison to be drawn.

3.2.5 Reproducibility and reliability

To ensure inter-rater reliability and consistency of the review process the first 30 articles were reviewed by both the investigator and the primary supervisor\textsuperscript{100}. These results were then compared and any papers that were in contention were provided to the secondary supervisor for a final decision\textsuperscript{100}. Once the baseline requirements had been agreed on the author proceeded to review the remaining papers.

3.2.6 Data charting and summary

Inductive content analysis begins with organisation of raw data, in this case the array of journal articles that had been selected in earlier phases. Individual papers were initially numbered and categorised based on broad anatomical regions investigated. Open coding was used with physical copies of the articles and specific subject matter extracted as shown in Appendix D. As themes within the articles included in the review were established, similar headings were combined into broader categories based on reoccurring topics, which was converted to a flowchart format. The addition of further articles from references sourced within the material selected earlier provided further insights and additional detail to the final data resulting in the flowcharts provided in Appendix C.

4 Results

Journal articles ranged in publication from 1978 to 2019 and described various overuse injuries and RF that distance runners experience. Noticeably, the older literature was still frequently referenced in modern papers. This suggested that much of the modern research still relies on the initial foundations provided by original studies. A total of 2808 potential articles were reviewed for title and abstract relevance, of which 172 were further reviewed based on content. Sixty six of those met the inclusion
criteria with an additional 84 articles later included from references within the included papers. This is outlined below in Figure 7.

Figure 7 - Research selection flowchart

Papers were initially categorised by anatomical region where possible or were placed in a multiregional category; a category mainly used for systematic reviews or research that investigated epidemiological factors of injuries. These multiregional papers were used to generate the initial thematic categories for overuse injuries which were further refined during review of the specific anatomical regional papers.

4.1 Overuse injuries

4.1.1 Injury proportions

Several systematic reviews on anatomical regional injury proportions across populations have been conducted\(^9,10,101,102\) with the most recent systematic review published in February 2019 by Francis et al.\(^11\). Their findings reported the knee as the most commonly injured site (28%), followed by ankle-foot (26%) and crus (16%). The hip and thigh accounted for 14% with the remaining 15% being
unclear, upper extremity or illness. The only gender specific finding was that women had a larger proportion of knee injuries relative to men (40% vs 31%)\textsuperscript{11}.

### 4.1.2 Common overuse injuries

In the literature, there appears to be discrepant uses of the word “common” as it relates to running injuries. Older research uses the term “common running injuries” but provides no specific metadata to explain why the authors were considering the injuries common\textsuperscript{103}. More detailed systematic reviews or retrospective analysis provide detailed metadata to support their selection of those injuries they are deeming “common” for analysis\textsuperscript{11,104,105}. A working definition of a “common running injury” may benefit future study designs but does not seem to currently exist in the literature.

Of the common injuries identified within the literature assessed, those that were classified as traumatic were excluded from the review, as well as those that occurred above the knee. The remaining injuries shown in Table 8 are a combination of overuse running injuries identified from the information that were considered clinically significant within their papers or seem to be recognised within older running literature as “common injuries”.

<table>
<thead>
<tr>
<th>Anatomical region</th>
<th>Overuse injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knee</td>
<td>Patellofemoral pain syndrome\textsuperscript{10,11,103,104,106}</td>
</tr>
<tr>
<td></td>
<td>Iliotibial band friction syndrome\textsuperscript{11,103,104,106}</td>
</tr>
<tr>
<td></td>
<td>Patellar tendinopathy\textsuperscript{11,104,106}</td>
</tr>
<tr>
<td>Leg</td>
<td>Stress fracture of the tibia\textsuperscript{11,104,106}</td>
</tr>
<tr>
<td></td>
<td>Chronic compartment syndrome\textsuperscript{18,104}</td>
</tr>
<tr>
<td></td>
<td>Medial tibial stress syndrome\textsuperscript{10,11,103,104,106}</td>
</tr>
<tr>
<td>Ankle</td>
<td>Achilles tendinopathy/paratenonitis\textsuperscript{10,103,104,106}</td>
</tr>
<tr>
<td>Foot</td>
<td>Metatarsalgia / Mortons Neuroma\textsuperscript{18,104}</td>
</tr>
<tr>
<td></td>
<td>Plantar Fasciosis\textsuperscript{10,11,103,104,106}</td>
</tr>
<tr>
<td></td>
<td>Stress fractures of the metatarsal or navicular\textsuperscript{17,18,106}</td>
</tr>
</tbody>
</table>

It may be reasoned that iliotibial friction syndrome is actually an overuse injury of the thigh, however, due to the iliotibial bands distal insertion at the lateral condyle of the tibia, the syndrome being a result of friction around that insertion and its commonly cited status as a “common running injury” within key papers, it has been included within this review.
4.2 Multiregional injuries

Multiregional injuries are not limited to a single anatomical region and refer to injuries that can occur in two or more anatomical regions. Bone stress fractures fall within this category due to their presence within the literature in both the leg and foot.

4.2.1 Bone stress injuries / Stress fractures (BSI)

The term stress “bone stress injuries” covers an array of defects that occur due to bone failing to adapt to repetitive submaximal stress being placed upon it. These defects cover a continuum from radiographic findings of periosteal or bone marrow oedema, through to fracture lines within the bone\textsuperscript{107}. The overall health of the human bone depends on nutritional, genetic, mechanical and hormonal factors which all contribute to the risk of stress fractures in runners.

Wolff’s law states that bone has the capability to remodel its cellular and molecular structure to adapt to functional mechanical stress\textsuperscript{108}. This adaption occurs based on a range of factors including; amount of stress, strain rate, frequency of loading, quantity of loading cycles and the overall stress applied during a cycle\textsuperscript{108}. Runners are particularly prone to BSI, with such injuries accounting for 15-20% of all musculoskeletal-related running injuries\textsuperscript{109} and ground reaction forces generated during running are three to eight times higher than those generated by walking\textsuperscript{110}. The most common location for BSI is the tibia, although pain in this region can be confused with medial tibial stress syndrome (MTSS), which is inflammation of the connective tissue that attaches to the tibia rather than damage to the tibia itself\textsuperscript{111}. Bones of the foot are also a common site for runners with BSI, frequently found in the mid or distal portions of the second or third metatarsal bones, or the tarsal navicular\textsuperscript{112}. Known colloquially as a “Jones fracture”, BSI’s that progress to frank fractures of the metaphyseal-diaphyseal junction of the fifth metatarsal frequently require specialist intervention due to the high rate of malunion during healing\textsuperscript{112}.

BSI are the result of microtrauma progressively accumulated due to fluctuating stressors placed on the bones matrix. A high degree of fatigue loading with inappropriate remodelling culminates in crack propagation within the bones structure\textsuperscript{113}. Such stress induced injuries can occur due to excessive loading beyond the body’s ability to keep up with normal skeletal repair. It may also occur due to depressed osteoblast activity or heightened osteoclast activity in response to normal bone stress\textsuperscript{110}. In addition, a function of muscle tissue is to protect cortical bone by acting as the shock absorber during movement. Muscle contraction reduces the bending stress placed on cortical bone surfaces. It is thought that as muscles fatigue, the effect of this force dampening is reduced, leading to greater force transmitted directly to the bone and a higher rate of microtrauma accretion\textsuperscript{110}. Conversely, the repetitive contraction of a strong muscle at its insertion may also generate enough force to apply its own degree of microtrauma to the bone\textsuperscript{110}.
4.3 Overuse injuries of the knee

4.3.1 Patellofemoral pain syndrome (PFPS)

One of the most common overuse injuries amongst runners, identified in the literature, is patellofemoral pain syndrome\textsuperscript{104,106}. This may be due to the variety of pathologies that lead to anterior knee pain and the amalgam of diagnoses that fall under the PFPS diagnosis\textsuperscript{110}. While PFPS produces anterior knee pain in the patella and retinaculum it is mainly a diagnosis of exclusion and is the result of overuse, malalignment and trauma\textsuperscript{114}. While not all anterior knee pain is the result of PFPS, it is a commonly used diagnosis for ill-defined knee pain that is a sum of complex symptoms\textsuperscript{110}. PFPS generally worsens with activities that demand high degrees of flexion of the knee such as steep gradient running, squatting or stair climbing\textsuperscript{106}.

Patellar instability and PFPS both with and without malalignment all fall under the single PFPS heading and describe a current theory of injury being caused to the subchondral bone due to patellar maltracking\textsuperscript{110}. The pain generator of PFPS is also undetermined, with theories including plica, irritated bursa, inflamed synovial lining, retinaculum neuromas, inflamed infrapatellar fat pad or apophyses\textsuperscript{110}.

4.3.2 Iliotibial band friction syndrome (ITBS)

Iliotibial band friction syndrome results from recurring “snapping” movements of the iliotibial band (ITB) back and forth across the lateral femoral epicondyle of the knee, during repetitive flexion and extension movements\textsuperscript{106}. The greatest amount of friction to the ITB occurs when its posterior fibres pass over the lateral epicondyle of the femur during 20-30° of knee flexion, known as the impingement zone, creating symptomatic lateral knee pain\textsuperscript{110}. Runners frequently experience greater pain during downhill running, due to the longer periods of time that the ITB spends in the impingement zone, while paradoxically, faster running rates allows a runner to spend more time with their knees at angles greater than 30°, and thus experience less pain\textsuperscript{110}.

4.3.3 Patellar tendinopathy (PT)

Colloquially known as “jumpers knee”, patellar tendinopathy is a chronic degenerative change to the patellar tendon similar to other tendinosis pathologies\textsuperscript{115}. A conclusive pathophysiology behind tendinopathies is still unclear, and such discussions are beyond the scope of this review, but the current mechanical theory is one of tendon damage via excessive loading or injury, leading to cell changes and matrix degradation of the tendon involved\textsuperscript{116}. Due to the patellar tendons link to the patellar in the extensor apparatus, patellar tendinopathy is closely related to PFPS\textsuperscript{102}. 

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4.4 Overuse injuries of the leg

4.4.1 Chronic compartment syndrome (CCS)

During exercise, muscular expansion and swelling naturally occurs\(^{117}\). In the case of CCS, this expansion represents abnormal increases in pressure within the osseofascial compartments, resulting in pain that subsides with rest\(^{118}\). During strenuous exercise, muscle mass can increase by as much as 20% due to interstitial fluid accumulating within the muscle\(^{57}\). In addition, the natural hypertrophy of the leg muscles resulting from regular exercise further reduces the reserve volume available within the osseofascial compartments\(^{117}\). This increase in muscle volume and mass, combined with a noncompliant or unresponsive osseofascial compartment, increases the overall pressure within the leg\(^{118,119}\). While it is clear an increase in intracompartmental pressure is the cause of symptoms linked to CCS, the reason behind its pain is still being questioned\(^{117}\). Initial research on the possible cause of pain generation from CCS suggested that abnormal increases in intramuscular pressure during exercise led to an impairment of muscle tissue perfusion, resulting in transient ischemia and pain in the involved extremity\(^{117}\). This theory is no longer universally accepted due to a range of studies failing to show causal relationships between intercompartmental pressure and ischemia, or demonstrating no difference in perfusion rates of the leg muscles between CSS and control patients\(^{57,120-122}\). Current theories attribute the pain to overstimulation of sensory nerves or intramuscular pressure fibres due to excessive stretching, the local release of kinins that can occur during muscle contractions suffering from reduced blood flow or from an imbalance in oxygen supply versus demand\(^{120,122-124}\).

4.4.2 Medial tibial stress syndrome (MTSS)

The term “shin splints” is a colloquial term frequently used by the running community to describe pain along the anteromedial surface of the tibia. The term is broad and has caused considerable confusion, referring to a wide variety of leg disorders such as stress fractures, compartment syndromes, fasciitis and myositis\(^{125}\). MTSS is a formal medical diagnostic term for anterior tibial pain commonly described as “shin splints”\(^{126}\). The pathophysiology of MTSS has been controversial. MTSS was originally thought to be inflammation of the periosteum that occurred along the border of the tibia as a result of muscular fibres separating from the muscle-bone interface\(^{127}\). It was hypothesized that the periosteum was traumatically detached from the bone by ballistic avulsion or local inflammation actively lifting the periosteum from the bone\(^{127}\). Later studies hypothesized that MTSS was a bone stress reaction that became painful after biopsies in one study found osseous metabolic changes in 37 limbs with MTSS\(^ {128}\). Moen et al.’s 2009 study suggests a variant aetiology of a mismatch between bony re-absorption outpacing bone formation at the tibia, resulting in an overload of the tibial cortex\(^ {129}\). This variation is based on a lack of histological evidence to prove the presence of periostitis and bone scan findings from MRI and CT imaging studies that support the presence of the overload of the tibial cortex\(^ {129,130}\).
MTSS is characterized by exercise induced shin pain along the medial surface and distal two thirds of the crus, exacerbated with repetitive weight-bearing activities and excessive use of the foot flexor muscles\textsuperscript{131}. Historically the tibialis posterior muscle was thought to be the main contributing factor, but other studies now identify the soleus, flexor digitorum longus or the deep crural fascia as potential contributors to MTSS due to their muscular attachments matching the common site of pain being generated from the injury\textsuperscript{132–134}.

4.5 Overuse injuries of the ankle

4.5.1 Achilles tendinopathy (AT)

The aetiology of a tendinopathy remains unclear, but the development of AT is considered to be a multifactorial issue with impact from anatomical, biomechanical and training specific RF\textsuperscript{135}. It is perhaps one of the more severe overuse injuries in regard to its impact on training time lost and rehabilitation required\textsuperscript{55}.

Excessive loading of the ATn during running is considered the main pathological impetus in the development of AT\textsuperscript{136}. During the running gait cycle, as the foot contacts the ground, GRFs are transferred up through the joints and soft tissue structures in order to allow progressive dissipation of the forces being experienced by the body\textsuperscript{55}. GRFs from the foot are transferred via the ankle to the leg, meaning the ATn and calf muscles experience higher amounts of force due to their proximity in the kinetic chain of dissipation. This proximity results in loads reported between 6-12.5X the runners body weight being placed upon the ATn during every initial contact phase of the gait cycle\textsuperscript{55,57}. The blending of the gastrocnemius-soleus muscles, and the 90° spiral direction of their fibres, allow the combination to absorb tremendous amounts of force\textsuperscript{57}, and loading that causes less than 4% stretch of the collagen fibres allows the tendon to recover normally post load, assuming that sufficient recovery time is provided to repair any microtrauma caused\textsuperscript{34}.

Loads above 4% stretch cause elevated amounts of microtrauma to the ATn, but loads greater than 8% can lead to macroscopic rupture of the ATn, leading to more acute injuries\textsuperscript{34}. The ATn may react to excessive loading placed upon it with either degeneration of the tendon fibres, inflammation of the paratenon sheath, which is known as Achilles paratenonitis, or a combination of both\textsuperscript{136}. AT can occur in two locations of the ATn; the mid portion of the tendon where its cross-sectional area is smallest, classified as non-insertional and is subject to higher stress ex vivo, or where the tendon inserts into the calcaneus, classified as insertional and is the site of the greater internal strain\textsuperscript{55}.
4.6 Overuse injuries of the foot

4.6.1 Metatarsalgia

Metatarsalgia is a term characterized as pain under the forefoot beneath one of more of the metatarsal heads, regardless of cause\textsuperscript{137}. The structures involved can include metatarsal bones, metatarsophalangeal joints, plantar plates, digital nerves, and soft tissues in the immediate area of the first to fifth rays\textsuperscript{137}. It is classified as either primary, secondary or iatrogenic; post-surgery\textsuperscript{138}. Its primary classification is based on anatomical differences in the metatarsal heads themselves, such as hallux valgus, or variances in associated structures, such as a pes cavus arch or excessive plantar flexion of the hindfoot, that predispose the forefoot to increased pressure\textsuperscript{138}. Secondary metatarsalgia is due to any indirect mechanisms that increase loading of the metatarsals. This includes such physiological issues as chronic synovitis and Morton’s neuroma\textsuperscript{138}.

Irrespective of classification, the underlying cause of metatarsalgia is one of repetitive transfer of GRF and plantar pressures to the forefoot during a gait cycle\textsuperscript{138}. Metatarsalgia is also categorised as either static or propulsive\textsuperscript{138}. During the midstance phase of a gait cycle, as the heel begins to lift from the ground, if one or more of the metatarsal heads are closer to the ground than others then pressure on the metatarsophalangeal joints is increased. This is referred to as static metatarsalgia. Propulsive metatarsalgia is a subtle variation similar to static in that the alignment of the metatarsal heads and their proximity to the ground are still the main factor at play. However, it is during the end of stance phase from heel lift to toe off by the hallux that additional pressure is being applied to the metatarsal bones\textsuperscript{138}.

4.6.1.1 Morton’s Neuroma

Morton’s neuroma is one of the most common causes of metatarsalgia\textsuperscript{139}. It is an interdigital nerve disease of the foot commonly located at the third intermetatarsal space\textsuperscript{140}. The neuroma consists of a benign fusiform bulge caused by a thickening of the tissue around the medial digital plantar nerve, distal to the metatarsal transverse ligament but prior to the bifurcation of the digital nerve\textsuperscript{139} as illustrated in Figure 8. The presence of a neuroma results in pain and sensory loss on the ball of the foot at the approximate location of the bifurcation of the digital nerves involved, but similar pain and sensation loss may also include the third and fourth digits themselves\textsuperscript{140}. In rare cases, the neuroma can develop between the second and third digits and even more rarely occurs bilaterally\textsuperscript{139}.
4.6.2 Plantar fasciitis (PF)

PF is one of the most common foot pain conditions treated, accounting for approximately 11% to 15% of all foot problems\(^1\). With a prevalence rate as high as 17.5% among runners, it is also one of the most common running-related musculoskeletal injuries\(^2\). A study by Taunton et al. found that 60% of runners with lower extremity injuries also had PF\(^3\). In spite of its high incidence, understanding about its pathogenesis is still limited\(^4\).

Historically, the term fasciitis indicated a chronic inflammatory process. While the acute stages of PF are characterized by an acute inflammatory response with fibroblast proliferation\(^5\), histopathologic research has meant that the condition has been reclassified as a fasciosis or fasciopathy; a chronic dysfunction or disease of the foot similar to a tendinopathy\(^6\)–\(^8\). This is to reflect that the condition can include both acute inflammation and chronic degenerative changes in the fascia characterized by micro tears, collagen degeneration, vascular hyperplasia and plantar fascia fibrosis\(^9\). In its acute phase, a runner may experience localised pain on the medial insertion of the plantar fascia at the rear of the calcaneus during running or upon initial weight bearing in the morning\(^10\). As with other tendinopathies, it is the increased loading of the tendon, or in this case, the fascia, that leads to chronic degeneration. Studies on the loading rate of the foot in runners with acute PF have shown a shift to a midfoot, forefoot or toe loading pattern\(^11\)–\(^12\). This weight shift, theorised as a protective mechanism to avoid the painful heel region, creates greater loading of the planter fascia by increasing the tensile stress at its insertion point of the calcaneus, pushing the acute PF through to a chronic continuum\(^10\).
4.7 Risk factors (RF)

While certain papers provided tables categorising RF, they were often specific to a single overuse injury, and the thematic categorisation used was not applicable across different overuse injury types. Many papers referred to two primary categories of extrinsic or intrinsic RF but quickly developed into specialist subcategories from this point. These themes and subcategories are illustrated in detail in the master flowchart shown in Appendix C and represent the major findings of this review. A concise version is provided in Figure 9;

![Risk Factors for Overuse Running Injuries](image)

**Figure 9-Risk Factors for overuse running injuries**

Subsequent RF identified among overuse injuries were categorised using the master flowchart template. This generated a subset of flow charts for each anatomical location identifying individual overuse injuries and providing elements of specific RF for that injury (Appendix C).

The following sections provide a detailed evaluation of the various RF that were identified during the literature search. Many of these RF occur across a range of overuse injuries, but the mechanism by which they influence the occurrence of an injury can vary and these are analysed within each specific injury type below.
The number of variables that must be taken into account for research of an overuse running injury is especially complex due to variances in each individual subject's gait, training, anatomical structures, activities outside of running and footwear used, to name a few. This makes individual findings difficult to conclusively prove and replicate in future studies, leaving some papers able to only provide theories on the potential mechanisms of how a specific RF is involved in the development of an overuse injury. These theories are still included as they represent potential risk factors that can be taken into consideration for the treatment and prevention of future injuries.

4.7.1 Common risk factors

Many of the identified overuse injuries share common RF, with training errors, gait, and structural variations being some of the more frequently identified issues. These more commonly occurring RF are analysed below.

4.7.1.1 Training errors

Hreljac (2005) theorised that the root cause of all overuse running injuries is the result of training errors. He posits that in order to initially sustain an overuse injury, a runner must have subjected a musculoskeletal structure in their body to repeated microtrauma that exceeded the body’s ability to compensate, remodel or repair the accumulating damage. Rapid increases in factors such as pace and volume (distance, duration, or frequency) have a range of impacts, as demonstrated in Table 10.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faster pace</td>
<td>Higher ground reaction forces being generated due to greater stride length or lift off/landing at each gait cycle.</td>
</tr>
<tr>
<td>Greater distance* or duration</td>
<td>Increases in the number of repetitions structures undergo due to increase in steps taken.</td>
</tr>
<tr>
<td>Higher frequency</td>
<td>Creating periods of inadequate recovery needed for the body to remodel or adapt to the microtrauma caused by each run.</td>
</tr>
</tbody>
</table>

Based on Hreljac’s hypothesis, if a runner could identify their threshold of microtrauma and had adequate recovery time during training, building suitable levels of resilience, an overuse injury would be unlikely to ever occur. Consequently, the decision of a runner to modify their training variables is conceivably the RF most likely to have the greatest impact on injury risk and should be considered the first point of intervention during any type of rehabilitation or treatment. Unfortunately, an individual’s threshold to microtrauma will vary greatly and be further influenced by various RF, making predictions on the necessary modifications to a runners training variables difficult.
4.7.1.2 *Training surfaces & gradients*

The solidity or softness of training surfaces and the gradients of the surfaces are all factors that impact many of the RF of the injuries identified\(^{149}\). Firmer surfaces such as concrete or asphalt can triple or quadruple the frequency of injuries due to the mechanical shock introduced and greater GRF, overloading tendons and joints\(^{149}\). Conversely, softer surfaces, such as sand, allow for hypermobility of the joints, causing faster muscle fatigue and similar problems with overuse of the tendons and joints\(^{149}\). Uneven surfaces introduce abnormal tension to sides of the body, sometimes creating a functional leg length discrepancy during a run. This creates disproportionate unilateral pronation, muscle imbalances and pelvic torsions\(^{149}\). Steeper uphill gradients cause the weight of the runner's body to fall in a more vertical axis on the knee joint making quadriceps muscles fatigue faster, while higher downhill gradients introduce excessive forces to the patellofemoral joint and the knee's extensor apparatus\(^{149}\). Moreover, given the high muscle activation and higher anaerobic energy production required, there is greater physiological stress placed on a runner during uphill running\(^{150}\). Conversely, downhill running results in greater mechanical stress, due to impact shock attenuation demands as the runner is forced to reduce downhill acceleration\(^{150}\). A clinician must understand and appreciate how these changes in gradients & surface tensions impact a runner's physiology and biomechanics, if sound running or rehabilitation advice is to be provided.

4.7.1.3 *Running experience*

Various studies have indicated that a lack of running experience is a factor in overuse injuries\(^{9,151,152}\). In Kluitenbergen et al.’s 2015 NLstart2run study, it was found that of the 1696 participants in the study 185 of these experienced injuries\(^{9}\). Of those injured, 132 were runners with no previous experience, representing 71% of all injuries occurring in the study. Those with some prior experience but that had not engaged in running for over a year were the next highest injured group, representing 21% of the injuries. The lowest injuries were from those that had engaged in regular running for at least one year prior (7%).

A lack of experience may be linked to the training load that a runner chooses to place upon themselves, which results in training errors as previously discussed (6.2.1.1). When this is coupled with a mentality of “no pain, no gain” which is considered a central feature in running by both runners and coaches\(^{153}\), minor overuse injuries can evolve to become chronic injuries\(^{154}\). Lopes et al.’s findings on the prevalence of musculoskeletal pain among recreational runners about to compete stated that:

> "the consequences for amateur athletes of participating in training sessions and races despite their pain is unknown as this research question remains poorly investigated\(^{155}\)."

Lopes et al. further commented that prospective cohort studies were urgently needed\(^{155}\). Their findings are further reiterated here; this potential combination of a lack of experience and “no pain, no gain”
mentality can lead to a cyclic progression of injury and poor recovery. Such a cycle may prevent a novice runner from gaining the experience needed to help avoid running injuries and cause a departure from the sport. Recent research in this field has demonstrated that protocols aimed at improving the running techniques of novice runners can reduce injury rates\textsuperscript{156}.

### 4.7.2 Bone stress injuries / Stress fractures

#### 4.7.2.1 Demographic

Some studies have found that women have higher rates of BSI\textsuperscript{110}. The reasons for these higher rates are multifactorial and likely secondary to associated RF specific to females, such as bone demineralization, narrower bone widths, dietary deficiencies and hormonal irregularities leading to menstrual irregularities. However, a previous history of BSI is a significant factor in determining the risk of future BSI in both sexes. Wright et al.’s systematic review reported that runners with a previous history of BSI had a 5x greater risk of future BSI\textsuperscript{109}, while Tenforde et al.’s study of adolescent runners concluded that a prior fracture was the most robust predictor of BSI among the other identified RF\textsuperscript{157}. This may indicate that secondary RF relating to a runners reduced bone mineral density (BMD) are the underlying problem for those experiencing more than a single incidence of BSI. It could be conjectured that a second BSI occurring in the same bone indicates poor healing at the original injury site or an underlying pathophysiological issue of that specific bone. However, a BSI in another bone, unrelated to the first injury site, would then suggest a more systemic physiological issue underlying a runners BMD. Further research in this area should consider an assessment of the locations of secondary or historical BSI sites to help provide more complete epidemiological data.

#### 4.7.2.2 Anatomical

One of the functions of the foot is to provide shock absorption during gait cycles and distribute that shock through various regions of the lower limbs\textsuperscript{47}. This distribution can vary depending on the arch of the foot. A firmer pes cavus arch will transmit more of the force through to the tibia, fibula and femur while a pes planus foot absorbs more force into the foot directly and transmits less up to the rest of the lower limb\textsuperscript{110}. While there is some disagreement among study findings, it is possible that pes planus arches are more likely to sustain metatarsal BSI, while pes cavus arches are more at risk for tibial and femoral BSI\textsuperscript{158,159}.

Studies involving RF and BSI found links with leg length difference, particularly in female athletes; however the studies provided no hypothesis as to how this leg length inequality attributed to the increased risk\textsuperscript{157,158}. The presence of valgus knee alignment and a quadriceps angle greater than 15\textdegree{} is also considered a RF for tibial BSI\textsuperscript{110}. It may be this combination of valgus knee and q-angle places excessive force through the tibia during a gait cycle, however, the studies that reported these findings were specific to infantry recruits and may not be applicable to the general public\textsuperscript{160,161}. A further study
also found that female runners with a history of previous tibial BSI exhibited greater peak hip adduction and rearfoot eversion angles during the stance phase of running. The effect of such a gait may be an escalation in axial and torsion loading of the tibia, increasing the risk of a BSI.

4.7.2.3 Physiological

BMD seems interrelated to several of the principal RF identified in BSI and is prominent among female athletes. This is due to its association with low energy availability, poor nutrient uptake, and hormonal disturbances leading to amenorrhea and osteoporosis. Distance running emphasizes leanness and runners that feel pressure to excel in their field are likely to gravitate to training and eating patterns designed to reach the preferred lean body morphology, which for some are detrimental. While these RF can occur in isolation, they are more likely to be interconnected, as illustrated in Figure 10, culminating in multi-level bone mineral density issues and potentially osteopenia or early osteoporosis.

![Figure 10 Multifactorial impact to BMD, *amenorrhea, oligomenorrhea.](image)

4.7.2.3.1 Menstrual disturbances & reduced BMD

Studies on athletes and BSI have indicated that female athletes may reach menarche at a later age than non-athletes and that this occurs more frequently in certain sports, including running. These studies suggested that there may be links between delayed menarche and lower peak bone mass levels, although how this occurs has not been explored beyond links with low body weight, nutrient deficiency, low body fat and excessive training.
Additional studies over the last two decades found links between runners with menstrual disturbances (amenorrhea or oligomenorrhea) and an increase in the risk of BSI\textsuperscript{158,166,167}. Female runners with menstrual disturbances have been found to have lower basal oestrogen concentrations, and it is theorized that the oestrogen limitations make it more difficult for the bodies metabolic systems to activate its cellular response to induce bone remodelling and adaption to stress forces placed upon it, thus increasing the risk of BSI\textsuperscript{110}. Kelsey et al.’s stress fracture study did suggest an association between irregular menstrual cycles and BSI, but they were not considered statistically significant (Rate ratio=3.41 [0.69-16.91]) in its female cross country study group of 127 runners\textsuperscript{168}. Conversely, Tenforde et al.’s 2013 study of 428 female athletes found those with late menarche or amenorrhoea were 3-5X more at risk for BSI\textsuperscript{157}. Both studies covered a similar two-year time period but Kelsey et al.’s study was, to some extent, underpowered in comparison to Tenforde et al.’s work. Kelsey et al. utilised a more detailed prospective study design over Tenforde et al.’s questionnaire, allowing for baseline data from physical examinations to be collected prior to the runners training. However, Kelsey et al.’s conclusion still suggested menstrual irregularity was a risk factor even though they reported its findings as being statistically insignificant within their own study. This is likely due to the weight of evidence of other research supporting menstrual irregularity as a risk factor for BSI\textsuperscript{158,163,166,167}.

4.7.2.4 Training & footwear

As previously discussed, rapid changes in training volume is a commonly occurring RF in many overuse injuries. In BSI it is considered a particularly major risk factor for both sexes\textsuperscript{110}. In Tenforde et al.’s study of sex-specific RF for stress fractures male runners training more than 32km/week had up to twice the risk of a BSI-related injury, with females increasing this to three times, compared to those running shorter distances\textsuperscript{157}. This would indicate that there is an upper limit to what a runners physiology can tolerate and while Tenforde et al.’s study was limited to adolescents, separate studies have similar findings with training volume and increased BSI risk\textsuperscript{169}.

There is a great deal of debate on running shoes with evidence to support both sides of the argument\textsuperscript{112}. Regarding BSI, shoes older than six months were an identified risk factor by Hoch et al., due to loss of support or cushioning from the shoe\textsuperscript{110}. Similar recommendations by Butts et al. suggest that shoes be replaced every twelve months, or 300-500 miles, whichever comes first\textsuperscript{112}. It would seem that monitoring of the cushioning provided by running shoes is the key factor in either timeframe and theoretically, the distance a running shoe has covered would be a more accurate measure for replacement cycles, assuming exclusive use of the shoes for running.
4.8 Risk factors of the knee

4.8.1 Patellofemoral pain syndrome

4.8.1.1 Demographics

According to Nielsen et al., 62% of PFPS cases occur in women\textsuperscript{102} with a slightly higher incident rate specifically among adolescents or young active adults\textsuperscript{170}. This higher prevalence among women is considered to be due to females typically having less muscle mass than males, creating more lateral pressure on the patella during running\textsuperscript{102}.

4.8.1.2 Inflexibility

Increases in knee flexion during the gait cycle creates higher patellofemoral joint reaction forces\textsuperscript{110}. Such an increase in flexion can be created by tight gastrocnemius and hamstring musculature. The corresponding joint reaction forces have been identified as contributing to the development of PFPS\textsuperscript{110}.

4.8.1.3 Muscle dysfunction

As PFPS is an issue with patellar maltracking, biomechanical imbalances that contribute to such problems, including weakness or strength in opposing muscle groups located around the knee, may exacerbate its onset\textsuperscript{10}. Weak quadricep muscles, in particular the portion of the vastus medialis located just superior to the patella, referred to as vastus medialis oblique (VMO), has been linked in the development of PFPS. Weakness in the VMO results in lateral distraction of the patella, due to the lateral forces being applied by the vastus lateralis, lateral retinaculum and the iliotibial band (ITB)\textsuperscript{110}. Furthermore, tight lateral structures (ITB) with a combination of weak gluteus medius muscles can cause internal rotation of the femur. This internal rotation also creates a lateral pelvic tilt and results in additional lateral displacement to the patella.

4.8.1.4 Gait & Pes Cavus arch

Thijs et al. investigated gait related RF in the development of PFPS and measured vertical peak forces via footscan pressure plates during a 10 week prospective cohort study\textsuperscript{171}. The findings showed that those that developed PFPS had significantly more laterally directed pressure distribution during initial heel strike, with greater roll-over on the lateral side of the foot, producing higher vertical peak loading forces\textsuperscript{171}. They concluded that those with a less pronated step and a roll over to the lateral side of the foot during gait were at higher risk of developing PFPS. Unfortunately, the arch heights among the participants were not identified in Thijs et al.’s study\textsuperscript{171}. This information would have been useful in detecting if the presence of a pes cavus foot contributed to the lateral foot roll identified among the participants who developed PFPS during the study. A pes cavus arch lends a runner to lateral foot displacement during a gait cycle, particularly on the heel and forefoot\textsuperscript{172}. This natural proclivity to lateral displacement with a pes cavus arch would suggest such a runner would also be at risk of developing PFPS based on Thijs et al.’s findings\textsuperscript{171}. Previous texts have suggested this link\textsuperscript{173} but
current research in this field is both limited and unable to provide a link between pes cavus arch and PFPS\textsuperscript{174,175}. High quality prospective studies specific to arch height and PFPS would be of benefit in this field in order to provide more comprehensive evidence on the effect or lack thereof, of pes planus/cavus arches and PFPS.

4.8.2 Iliotibial friction syndrome

4.8.2.1 Muscle dysfunction
Poor neuromuscular control of popliteus, semimembranosus and semitendinosus, after heel strike, results in an abrupt tension increase at the ITB’s distal insertion site from sudden internal rotation vectors being applied to the knee joint\textsuperscript{110}. As the gluteus medius and tensor fascia lata are decelerators of internal rotation of the knee, weakness in these muscles is also likely to create similar stress at the ITB’s insertion due to biomechanical imbalances between the internal and external rotators\textsuperscript{110}.

4.8.2.2 Downhill gradients
As previously discussed, the greatest amount of friction to the ITB occurs when its posterior fibres pass over the lateral epicondyle of the tibia during 20-30° of knee flexion, known as the impingement zone\textsuperscript{110}. Runners frequently experience greater ITB pain during downhill running\textsuperscript{110}. During a decent the body’s running biomechanics substantially change to enable a different landing pattern, acting to reduce downhill acceleration\textsuperscript{150}. Downhill running is associated with substantially more knee extension and reduced knee flexion\textsuperscript{150}; consequently the ITB is more frequently exposed to its impingement zone.

4.8.3 Patellar tendinopathy
Many of the various RF identified relating to PT implicate the loading of the patellar tendon in some form and are based upon the mechanical pathophysiological theory of tendon overloading\textsuperscript{116,147}. The evidence around these RF are considered of poor to medium quality due to limiting or conflicting evidence across proposed RF\textsuperscript{115,176}. In addition, a lack of prospective studies mean limited support for findings and many of the studies found for review were only specific to elite athletes\textsuperscript{176}. Elite athletes do not represent a broadly applicable base by which to apply study findings. Their training regimes and physical conditioning are far above those of recreational runners and amateur athletes\textsuperscript{177,178}. Future research in this area requires larger prospective study designs, specific to recreational runners, in order to better formalise the current theories.

4.8.3.1 Structural variations
Williams et al.’s study on arch structure and injury patterns found that runners with pes planus arches had greater peak knee flexion angles and postulated that such a runner required greater quadriceps muscle force to attempt to reduce further knee flexion\textsuperscript{179}. Greater quadriceps force could create greater tendon loading; if the tendon itself is stiff or has not had time to develop resilience in pace with the quadriceps muscle, an imbalance can be created and higher loads transferred to the tendon\textsuperscript{115}.
4.8.3.2 **Inflexibility**

Decreased flexibility of the hamstrings and quadriceps may also be associated with PT\textsuperscript{115}. It is hypothesized that restrictions in hamstring flexibility contribute to PT by decreasing the effectiveness of the extensor mechanism and thus increase the demands on the quadriceps during knee extension\textsuperscript{176}. Similarly, decreased quadriceps flexibility would increase passive tension on the tendon before any loading was placed on it and this would become further exacerbated during joint flexion\textsuperscript{176}.

4.8.3.3 **Muscle dysfunction & downhill gradients**

During the early stance phase of gait, the quadriceps muscle group has been found to be the largest contributor to braking and support during running\textsuperscript{180}. Due to the demands of downhill deceleration, loading of the quadriceps muscle group during downhill gradients can cause eccentric overloading, which is considered a major etiological factor in the development of PT\textsuperscript{102}. Conversely, weakness of the quadriceps may result in higher degrees of knee flexion and a slower return to extension during the swing phase of a gait cycle, causing longer periods of knee flexion and greater loading of the patella tendon\textsuperscript{181}.

4.9 **Risk factors of the leg**

4.9.1 **Chronic compartment syndrome**

4.9.1.1 **Demographics**

Young adult males with a mean age of 20 are at higher risk of CCS\textsuperscript{121}. Links between hypertrophy of the leg muscles and CCS may indicate that this age risk is due to the hormonal increase in muscle mass experienced by young males between the ages of 17 and 25\textsuperscript{182}.

4.9.1.2 **Muscle dysfunction**

While the pathophysiology behind the pain generation of CCS is still being studied, the underlying causation of increased compartmental pressure is linked to factors such as muscle composition and capillary density within skeletal muscle leading to abnormal increases in muscle mass during exercise\textsuperscript{57}. As muscle volume can increase by as much as 20% during activity, additional pressure placed on specific compartments within the leg make those compartments more susceptible to CCS\textsuperscript{118}.

4.9.1.3 **Gait**

Overpronation is a common physical finding in cases of CCS\textsuperscript{183}. Overpronation can increase the risk of CCS secondary to weight loading variations caused by the pressure on individual muscle groups within the leg\textsuperscript{118}. Ninety five percent of presented CCS cases occur within the anterior and lateral compartments of the leg, suggesting that greater pronation during a gait cycle places higher demands on the tibialis anterior muscle, long toe extensors, and the peroneus longus and brevis muscles\textsuperscript{118}. Runners with pes planus arch may also be at risk of CCS due to the nature of a pes planus arch contributing to greater pronation during gait\textsuperscript{184}.
4.9.1.4 Pharmacological

Creatine supplementation is promoted as a natural aid to help increase muscle mass and athletic performance\textsuperscript{185}. A study in the use of creatine supplementation showed a link between its use and increases in anterior compartmental pressures of the leg, both at rest and after exercise. The hypothesis behind the pressure increase is that the rise in blood creatine levels contributes to increased water uptake in the muscle fibres of the leg, resulting in swelling of the muscle fibre to higher than normal levels\textsuperscript{185}.

A second pharmacological factor in the development of CCS is the use of steroids. Steroids are chemically related to testosterone in that steroidal androgens include natural androgens as well as synthetic androgens that are structurally related to natural testosterone. Androgens are one of three types of sex hormone agonists which include oestrogens and progestogens. Testosterone is a male hormone that promotes muscle growth, with over 100 synthetic varieties having been developed since the original 1935 experiments in synthesizing it\textsuperscript{186}. Steroids affect a person’s body in two key forms. Androgenic effects include the masculinization of the individual such as a deepening of the voice and an increase in facial hair\textsuperscript{187}. Anabolic effects are primarily increases in muscle mass by increasing the amount of protein within cells, but can also cause enlargement of internal organs and increase bone calcium\textsuperscript{187}. It is this increase in muscle mass, creating hypertrophy of the leg muscles, that can lead to CCS\textsuperscript{117}.

4.9.2 Medial tibial stress syndrome

4.9.2.1 Demographics

Females are at greater risk from MTSS according to a range of studies\textsuperscript{126,188,189} with incidence ratios as high as 6:1 female to males\textsuperscript{126}. This substantial sex difference in incidence rates does not appear to have been studied, potentially due to the many variabilities that such a study may face, including tracking of biomechanical variables, musculature variations, bone geometry, gait differences and training regimes\textsuperscript{126,127,189}. Several possible reasons for this difference in ratios are discussed below but have not been studied in any depth. The studies that provoke the theories are of a broad nature, examining overall RF associated with MTSS but not specific to females\textsuperscript{127,129,188–190}. Therefore, the explanation as to why females are at greater risk is uncertain. To understand this more, similar prospective cohort studies would need to be carried out comparing male and female control groups, specifically investigating the theories described below.

4.9.2.2 Structural variation

A small study by Burne et al. found the presence of increased internal and external hip ROM was one of two factors that may be associated with MTSS\textsuperscript{188}. An increased hip ROM may be responsible for the presence of an abductory twist during the gait cycle, a contributing factor to MTSS\textsuperscript{127}. It was speculated within Burne et al.’s study that the presence of the increased hip ROM may be associated
with different running styles that place a higher degree of loading on the medial portion of the tibia on impact\textsuperscript{188}. Further research across this finding would be required to understand how the factor is truly related to MTSS and in particular, the potential link between MTSS in females secondary to a greater hip ROM than males\textsuperscript{191}.

The second risk factor identified by Burne et al. was leaner calf girth\textsuperscript{188}. While not directly linked to calf muscle strength, there was a 10-15mm difference in calf girth, corrected for skin thickness, between male symptomatic and asymptomatic subjects\textsuperscript{188}. The presence of a leaner calf girth may be related to MTSS due to the decrease in the shock absorbing capacity of the leg, which may be a potential factor in the higher rate of MTSS in women due to the generally lower muscle mass of females compared to males\textsuperscript{129,192}.

4.9.2.3 Bone geometry & gait

Overpronation has been identified across many studies as one of the common factors leading to MTSS\textsuperscript{127,129,134,189}. During pronation of the foot, medial structures of the leg are placed under stress and are exposed to injury\textsuperscript{127}. The tibialis posterior muscle is the most efficient at decreasing pronation of the leg, followed by flexor digitorum longus. During running the tibia undergoes rapid internal rotation as the calcaneus shifts between inversion and eversion at heel strike\textsuperscript{127}. Excessive pronation during this cycle applies an increased load on the posterior tibialis muscles tendons as they attempt to decrease the internal rotation of the tibia while simultaneously controlling the lowering of the medial arch\textsuperscript{127}. Subtalar joint pronation plays an important factor in absorbing ground reaction forces during gait but excessive pronation of the joint has been recognised as a contributing factor to MTSS, although what constitutes “excessive” has not been defined\textsuperscript{189}.

Navicular drop testing, the difference in distance between the lower border of the navicular and the ground, is used as a gauge of midfoot pronation at the subtalar joint\textsuperscript{129}. The presence of a drop greater than 10mm was considered to create abnormal pronation\textsuperscript{193}. Bennett et al.’s study of 125 cross country runners reported the mean drop distance in runners with MTSS as 6.8 mm compared to 3.7 mm in asymptomatic runners (p=0.003) and its findings indicated the positive relationship between increased navicular drop, higher pronation and the presence of MTSS\textsuperscript{126}. A prospective study by Plisky et al. in 2007 failed to find a significant relationship between MTSS and navicular drop\textsuperscript{184}. Initially, differences in measuring technique were discussed as a potential factor in this differing finding. The thickness of a marker used and the use of an index card vs ruler, in making the mark on a participant’s foot, was thought to create a potential underestimation of the actual navicular drop distance\textsuperscript{194}. However, Plisky conducted a reliability study and found both techniques reliable (index card, 0.84-0.88; ruler 0.88-0.91). Another discrepancy was differences in the two studies design, with Plisky et al.’s prospective design taking navicular drop measurements of all runners pre-season in order to minimise research bias, while Bennett et al. only took navicular drop measurements once
injured runners had reported their MTSS symptoms and then compared those to randomly selected injury-free runners post season\textsuperscript{126,194}. A small 2008 study by Bandholm et al. researching medial longitudinal arch deformation during standing and gait in subjects with MTSS had similar findings to Bennett\textsuperscript{195}. The MTSS group demonstrated a significantly larger navicular drop (7.7 ± 3.1mm) compared to the control (5.0 ± 2.2mm)\textsuperscript{195}.

Restrictions in ankle dorsiflexion create an abnormal gait pattern referred to as apropulsive gait\textsuperscript{127}. Dorsiflexion of the talocrural joint is required at the midstance phase of gait as the leg shifts across the planted foot prior to heel lift\textsuperscript{196}. During apropulsive gait, the ankle locks out early and an individual cannot move forward sufficiently across it to achieve normal propulsion\textsuperscript{127}. This lack of propulsion creates early heel lift and forward momentum must then be artificially created by the introduction of biomechanical deviations such as excessive forward arm swinging, forward head thrusting, forward leaning of the torso and excessive knee lift-hip flexion\textsuperscript{197}. This series of deviations are all in an effort to pull the individual’s body mass past the planted foot and then lift the planted foot off the ground to continue the cycle. Tweed et al. found that the presence of an apropulsive gait was a very strong predictor of MTSS, estimating an increase of over 800 times the risk of developing MTSS, over a person with similar physical characteristics but a normal propulsive gait\textsuperscript{127}.

4.9.2.4 Inflexibility

Newman et al.’s 2013 systematic review and meta-analysis on MTSS initially listed shortened hamstring length, gastrocnemius length and soleus length as RF in the development of MTSS\textsuperscript{190}. However, the references provided for this finding instead discussed such RF as navicular drop rates, external hip rotation and previous running injuries. Biomechanically, the presence of tight calves and their attachments to the tibia does seem to indicate that a runner could indeed be at risk of MTSS if the muscles were chronically shortened, but there does not appear to be any research justifying this supposition. Eventually, the conclusions reported by Newman et al.’s meta-analysis did not list muscle length shortness as a potential risk factor, although it is not discussed as to why this disappears from the review\textsuperscript{190}.

4.10 Risk factors of the ankle

4.10.1 Achilles tendinopathy

4.10.1.1 Demographics

Adults over the age of 30 are more at risk of developing AT due to a decrease in the average maximum diameter and density of muscle and tendon collagen fibrils\textsuperscript{198}. As fibrils diminish, the tendons lose their wavy appearance and begin to straighten out, leading to a loss of the AT’s tensile strength and a reduction in its elasticity\textsuperscript{198}.
4.10.1.2 Structural variations & gait (REF)

Overpronation and prolonged pronation during the midstance of a gait cycle with a more lateral heel strike creates a “whipping” or “bowstring” action, placing the ATn under higher strain135,199, as shown in Figure 11.

Figure 11 - Whipping action of the Achilles tendon 199

Forefoot varus and a pes planus arch are two structural variations that can contribute to overpronation. Forefoot varus is angling or inversion of the bones of the foot, relative to the heel, at the level of the midtarsal joint200,201 (Figure 12).

Figure 12 - Uncompensated vs Compensated FF Varus202

Two variations of this varus are uncompensated and compensated203. Uncompensated refers to no change in the posterior portion of the foot or ankle to deal with the inversion. The rigidity of the subtalar joint means that any compensation takes place from the midtarsal joint forward203. When compensated, the subtalar joint will become supinated with an inverted calcaneus in order to bring the medial forefoot into contact with the ground. During a normal gait cycle at the beginning of midstance and into terminal stance, the subtalar joint re-supinates to provide a firm lever for toe-off203. Forefoot varus creates prolonged pronation into the midstance forcing a much faster re-supination of
the subtalar joint, creating a whipping motion that creates a greater eccentric load on the medial side of the tendon, predisposing it to injury. In a similar vein, pes planus arches also tend towards overpronation during gait, exposing the medial portion of the ATn to abnormal loads, leading to the same cycle of eccentric strain and eventual injury.\textsuperscript{204}

Peak braking forces (PBF) are defined as the amount of force a runners front foot pushes backwards horizontally during the initial contact and loading phase of the gait cycle.\textsuperscript{205} High braking forces are a contributing factor to AT.\textsuperscript{55} This may be due to a higher posteriorly directed centre of force, causing greater eccentric loading, which swiftly leads to overloading of the lower limb muscles and tendons during repeated initial contact gait cycles.\textsuperscript{55} Napier et al.’s 2018 study found that runners in the higher tertiles PBF group had an eight-fold increase in general overuse injury rates vs the lowest tertile PBF group.\textsuperscript{205} While not specific to AT it does suggest the impact that PBF may have on the risk of overuse injuries.

4.10.1.3 Muscle dysfunction & inflexibility

Delayed activation of the tibialis anterior, decreased activity of the gluteus medius and rectus femoris muscles, decreased strength of the knee flexors and increased activity of the gastrocnemius and soleus complex (GSc) have all been identified as potential factors leading to AT.\textsuperscript{135,206,207} The interactive nature of the various muscle groups and joint kinetic variables makes defining each individual issue as a primary cause very difficult. For example, decreased knee flexor strength may be the cause or result of altered lower limb biomechanics which leads to increased tension of the ATn.\textsuperscript{135} In the former, it is theorised that the muscle weakness itself results in alterations to lower leg gait patterns. Stabilization of the knee joint, especially during the weight bearing stage of gait, is usually handled by the knee flexors. Weakness in this area is compensated by increased extension of the knee, which induces more tension on the GSc, ultimately creating greater tension at the ATn.\textsuperscript{135} Additionally, with the soleus’s insertion point along the medial tibial border, a more extended soleus could result in greater torsional force to the ATn.\textsuperscript{135} In the latter, whereby knee flexor strength is decreased as a result of altered biomechanics, higher pronation during gait creates greater internal tibial rotation, causing tension in the GSc.\textsuperscript{208} This tension results in greater knee extension due to the insertion points at the femoral condyles of the gastrocnemius and soleus. The lower limbs compensate for this increased extension by reducing dorsiflexion at the upper ankle, already limited due to tension in the GSc, resulting in reduced activation of the knee flexors and their eventual deconditioning.\textsuperscript{135} It has also been reported that poor flexibility of the GSc is a leading factor in AT.\textsuperscript{199} Tension of the GSc causing reductions in dorsiflexion of the upper ankle, knee flexor deconditioning and higher tibial rotational moments, likely culminate in greater pronation during gait cycles.
4.10.1.4 Training surfaces & Shoe fit

Training programs that incorporate many uphill gradients place the ATn under greater strain due to the elongation of the GSc. This may not only push the GSc fibres past their 4% approximate stretch threshold, but the extended elongation of the soleus will also cause greater torsional force due to its insertion along the medial tibial border.

Excessively soft or slippery training surfaces appear to have a clear association in the development of AT. Highly compliant surfaces, such as sand, are linked to AT development, while semi compliant surfaces similar to grass or athletic tracks are not recommended for those recovering from AT. The more compliant a surface is, the more activity will be required by the foot, ankle and leg muscles to compensate for the shifting surfaces underfoot. Sand is a particularly unpredictable surface requiring high amounts of tendon and muscle activity to compensate for the constant rebalancing and weight transference during running. In addition, Knobloch et al.’s 2008 review found that stiffer asphalt surfaces provided a small protective effect. This is likely due to the reduced levels of activity required by tendons and muscles to rebalance during gait cycles due to the firmer surface.

Running shoes that are too tight may cause pressure in the insertional region of the ATn. During running, external friction from the shoe on the heel can lead to paratenonitis of the ATn sheath. If this becomes chronic, scar tissue that builds up between the skin, paratenon and tendon can lead to ongoing pain and disability, that has to be surgically resolved.

4.10.1.5 Pharmacological

Fluoroquinolones are a class of antibacterial agents which originally functioned by inhibiting essential bacterial enzyme catalyse processes, known as DNA gyrase. The newer classes of the drug have been expanded to respiratory agents as a first line therapy for community acquired pneumonia and chronic obstructive pulmonary disease issues. They are commonly prescribed to treat infections by medical specialists and surgeons and were first available in the mid-1980s. The ir use has been linked to AT and tendon rupture, with incidence rates estimated around 0.14-0.04%. A retrospective cohort study completed by Linden et al. collected data for a two-year period and concluded that the adjusted relative risk of AT to the use of fluoroquinolones was 3.7 (95% CI: 0.9-15.1), while the highest risk was associated with a specific subtype of fluoroquinolones called ofloxacin (relative risk 10.1, 95% CI:2.2-46.0). While more recent observational studies and systematic reviews have had similar findings, the pathophysiological mechanism behind this link remains unknown. The risk of tendon rupture due to the use of fluoroquinolones was also found to be higher in people over the age of 60 years although the reason for this increase is also undetermined. Runners that are prescribed specific fluoroquinolones may be at increased risk of tendon rupture.
4.11 Risk Factors of the foot

4.11.1 Metatarsalgia / Morton’s Neuroma

4.11.1.1 Demographics

This condition is more common for those older than 60 years of age due to two main factors. The first factor is that in some individuals, the plantar fat pad atrophies with age and fails to provide the necessary cushioning during push-off in the gait cycle\textsuperscript{216}. Without the cushioning of the fat pad, the interdigital nerves are more exposed to GRF and become demyelinated and scarred\textsuperscript{140}. Secondary to the loss of fat pad cushioning, or to the natural morphology of the individual, hyperplasia can occur.

At the sites of the metatarsal heads, where subcutaneous tissue has become thin from excessive pressure, calluses evolve, leading to compression of the interdigital nerves (IdN). Females over 60 years are at higher risk than males\textsuperscript{217}. It is unclear why metatarsalgia is more common for older females than males but is theorised that it may be secondary to wearing tight fitting shoes and high heeled dress shoes, both of which create compression or excessive pressure on the metatarsal heads, as will be further discussed in 4.11.1.3\textsuperscript{140}.

4.11.1.2 Structural variations and gait

Hallux valgus, a hypermobile first ray, overpronation, and hypertrophy of the adductor hallucis muscle are all factors that can place increased pressure on the IdN\textsuperscript{140}. Hallux valgus is a progressive foot deformity in which a bony mass forms on the first MTP joint, causing gradual subluxation and lateral deviation to the joint\textsuperscript{218}. The presence of a hallux valgus may lead to callus formation on the plantar aspects of the MTP heads, which leads to increased compression of the IdN\textsuperscript{140}. With a significant hallux valgus, the GRF absorption from the first metatarsal diminishes and can lead to the formation of a “transfer lesion” under the second metatarsal, creating similar compression to the IdN\textsuperscript{216}.

A hypermobile first ray can also result in a plantar callus formation\textsuperscript{140}. The first ray of the foot is considered an unstable axial array that relies on a delicate balance between dynamic support from the small muscles of the foot and static stabilises such as the plantar fascia and ligaments\textsuperscript{218}. During the stance phase of gait, the presence of a hypermobile first ray causes increased pressure to transfer to the lesser metatarsal heads. These lesser heads have tighter articulation at the tarsometatarsal joint and thus pass the pressure onto the second and third metatarsal heads\textsuperscript{219}. The repetitive nature of this action can create a callus and subsequent compression of the interdigital nerves\textsuperscript{140}.

Overpronation causes biomechanical changes to a runners gait which can dorsiflex the third metatarsal relative to the fourth during push-off in the gait cycle\textsuperscript{140}. This motion compresses and stretches the interdigital nerves resulting in scarring and injury\textsuperscript{140}. The adductor hallucis muscle is formed by an oblique and transverse head. The transverse head originates from the second to fifth metatarsophalangeal joints while the oblique head originates from the cuboid bone, lateral cuneiform...
bone and the base of the second and third metatarsal bones. Its insertion is at the base of the proximal phalanx of the hallux. It is the origin points, located close to the interdigital nerves, that can cause compression to those nerves should the muscle become hypertrophic.

4.11.1.3 Footwear

As previously mentioned, the use of high heels is a RF in the development of metatarsalgia owing to the pressure placed on the metatarsal heads due to the angle of the foot (Figure 13). While the use of high heels themselves is not specific to runners, the use of such footwear during day to day activities may facilitate the development of metatarsalgia that could then be further exacerbated during running. Soft soled running shoes can create similar pressure at the metatarsal heads due to increased toe dorsiflexion during the push-off phase of gait. As weight is loaded to the forefoot, the softer material within the shoe compresses to a greater degree than a firmer support shoe exposing the IdN to greater compression.

Figure 13 - Angles of the foot in a high heel

4.11.2 Plantar fasciitis

The RF discussed below all share a common theme, in that the plantar fascia is placed under high loads, resulting in microtrauma to the fascia. The cause of this stress varies in its mechanism, but all result in similar histological changes to the plantar fascia as discussed previously in 4.6.2.

4.11.2.1 Structural variation

A pes cavus arch is associated with an elevated medial longitudinal arch (MLA). Di Caprio et al. proposed that an elevated MLA could result in a tighter plantar fascia and thus reduced flexibility within the connective tissue. This reduction in flexibility reduces the efficiency of the MLA to dissipate GRF and could result in higher loads placed on the plantar fascia to compensate. This was also shown to be the case in Ribeiro et al.’s 2016 study investigating plantar pressure patterns in runners, which found that an elevated MLA was a predictor for higher plantar loads over the forefoot.
while running\textsuperscript{142}. This suggested that the combination of an elevated arch and greater loading would result in higher tension to the plantar fascia along the metatarsal heads and contribute to the progression of PF\textsuperscript{142}.

Biomechanically similar in effect to overpronation, a rearfoot valgus is an anatomical irregularity that causes the rear of the foot to curve outwards at the ankle due to the calcaneotalar joint angling laterally away from the midline. When combined with an elevated MLA, the two variations are considered a “primary mechanism”\textsuperscript{142} in the development of the initial acute stages of PF.

4.11.2.2 Gait

Two main gait related factors that may influence the onset of PF are reduced ankle dorsiflexion and excessive rearfoot loading\textsuperscript{143,221}. Restrictions in ankle dorsiflexion were analysed in Riddle et al.’s 2003 matched case-controlled study of plantar fascia RF\textsuperscript{221}. Fifty patients presenting with unilateral PF were examined and compared to a matched control with no PF. The study found that those patients with PF had significant reductions in ankle dorsiflexion on the symptomatic side, suggesting that such restrictions in ankle dorsiflexion indicated an increased risk of PF. Those that were limited to 6° to 10° of dorsiflexion had an odds ratio (OR) of 2.9 (95% CI, 1.6 to 5.0)\textsuperscript{221} of an increased risk of PF relative to an individual who had more than 10° of dorsiflexion. Those that were limited to 1° to 5° of dorsiflexion increased that OR to 8.2 (95% CI, 2.7 to 24.9) and those that were severely limited to 0° moved to an OR of 23.3 (95% CI, 4.3 to 124.4)\textsuperscript{221}. Riddle et al.’s study indicated that there was an exponential relationship in the increase of risk of developing PF as ankle dorsiflexion reduced\textsuperscript{221}. Biomechanically, the reduction in ankle dorsiflexion could result in greater loading to the plantar fascia as approximately 10° of dorsiflexion is required during normal gait\textsuperscript{221}. If this dorsiflexion is limited or absent, then greater pronation of the foot may occur, flattening the medial arch and causing more loading of the plantar fascia\textsuperscript{221}.

The second gait related factor to influence the onset of PF is excessive rearfoot loading. Excessive rearfoot loading over the calcaneal area increases the stretch placed on the plantar fascia, leading to damage to the connective tissue\textsuperscript{143}. The repetitive nature of running can produce an acute inflammatory response as the connective tissue continues to experience microtrauma, resulting in fibroblast proliferation\textsuperscript{143}. Continuation of training without adequate recovery time pushes the inflammatory stage into a chronic process resulting in degeneration of the plantar fascia and fibrosis formation along the medial calcaneal insertion, without inflammation\textsuperscript{143}. Similar tension can distribute to the plantar fascia through stress and strain on the ATn. A 500% increase in ATn force will increase the strain on the plantar fascia by 120%\textsuperscript{102}. 

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5 Discussion

5.1 Risk factors vs protective factors

There was an expectation during data gathering that each injury would have clearly defined RF that could be attributed to that injury’s onset for a runner and thus allow for changes to modifiable RF to avoid future injury and help in recovery. What was not anticipated was a crossover effect where certain RF for one injury were a protective factor for another injury. Such findings create a situation whereby advice provided by professionals regarding rehabilitation strategies from one injury may require a substantially more detailed background of the runners previous injury history than would normally be observed. While a patient’s case history is considered a normal part of a clinician’s diagnostic procedure, time constraints or poor patient recall of previous injuries may hamper this process. Couple these issues with a clinician’s lack of knowledge around the interactive nature of overuse running injuries and issues may arise; e.g. a runner diagnosed with a stress fracture could be advised that running on softer surfaces will help them prevent future fractures. This advice would be detrimental to a runner that had a previous history of ATn injuries, due to the RF for AT including softer running surfaces. Such dichotomies represent an additional external RF not formally identified within the literature of this review that could be classified as “Inappropriate professional advice”. Advice of this nature could lead to a reoccurrence of previous injuries and as such could result in the development of more chronic issues at the injury site.

5.2 Q-angle as a risk factor

Noticeable in its absence amongst the many identified RF is that of Q-angle variations being significantly associated with any of the identified injuries. There seem to be two likely elements for this. The first; that differences in Q-angle may be more closely related to hip or thigh injuries, which fell outside the purview of this review. Secondly, while several of the papers discussing knee running injuries cited the presence of Q-angle findings in several papers, they dismissed those findings based on studies such as Duffey et al., Caylor et al. and Messier et al., which had been unable to find any associations with the Q-angle and any force or moment potential RF. In fact, Messier et al.’s 2008 paper went so far as to refute his own earlier 1991 paper that had linked a Q-angle over 16° with anterior knee pain. The consensus view coming from the research in this area seems to be that the role of a Q-angle variance as a risk factor in a runners knee pain is extremely questionable. While a scoping review allows for the inclusion of evidence that is not yet conclusive or is still in question, in order to best observe themes, Q-angles seem to be on the verge of being refuted entirely in their association with knee pain and runners. Furthermore, they do not seem to have any identifiable links with injuries below the knee. Clinicians should seriously consider the worth of engaging in any treatments or rehab specific to dealing with a patients q-angle variation, when dealing with running injuries of the lower limb.
5.3 Application of findings in practice

Francis et al.’s 2019 systematic review of the proportions of lower limb running injuries by gender, anatomical location and specific pathology highlighted the problems that were faced in the data extraction required for accurate information gathering\(^1\). They concluded that it may be more informative to have qualitative discussions around the types or rates of injuries reviewed due to such issues as a lack of consistency and clarity among key definitions within the studies and the many variables involved in injury research\(^1\).

This statement resonates strongly throughout the findings of this scoping review and is highlighted on several occasions during the discussion of the identified RF. Quantitative research serves an important role within any field, but the demands of such research can make its findings impractical in a clinical setting. Taking Francis et al.’s suggestion further, there is a question of the importance of statistical significance vs qualitative synthesis, within the field of injury investigation, rehabilitation and prevention. The reticence of many quantitative authors to make definitive statements or recommendations, due to the high demands of quantitative research, leaves a clinical practitioner, who is utilizing evidence-based information in their practice, in a limbo state of “possibly applicable”. Qualitative research can be of more use when attempting to understand underlying reasons behind concepts and it may be that scoping reviews provide a bridge between the meticulousness of evidence-based research and the pragmatism of clinically applicable data.

5.3.1 Recognition of the impact of training errors

As previously discussed, it is the rapid increase of several training variables for a runner that is frequently cited as being commonly responsible for overuse injuries and according to Hreljac could be considered as the root risk factor behind all overuse injuries\(^5\). From a practitioner’s standpoint, this also means that changes to a runners training load may have the greatest impact on their patient’s. The human body is made to adapt to introduced stressors and can, if given appropriate time and training, build resilience to the repetitive and traumatic forces that running introduces\(^1\). Addressing a runners training schedule is likely to have the greatest long-term impact in limiting future overuse injury occurrences. However, it is important to acknowledge that modifications to a single risk factor are unlikely to be adequate to avert injury reoccurrence. It is a combination of factors that lead to injury and a practitioner needs to be aware of the many variables that can contribute to overuse injuries, to provide effective treatment and advice to patients.

5.3.2 Interprofessional collaboration

The potential risks of poor advice from a professional that does not understand the complexities and interconnected nature of RF opens the discussion of whether that professional is the best person to be providing rehabilitation advice or therapy to the patient involved. Recognition of one’s limitations within their field of practice is an important consideration and drives the importance of inter-
professional collaboration and referral that is being highlighted in current research\textsuperscript{227,228}. The anatomical, structural, kinematic, pharmacological, nutritional, and training methods that need to be considered when seeking the best outcome for a patient are a heterogeneous group. Such a diverse range of factors are unlikely to fall within a single professionals purview, and thus reinforce the need for interprofessional collaboration, as highlighted by the World Health Organisations framework for collaborative practice\textsuperscript{229}. This scoping reviews findings on the interactive nature of RF in injuries highlights this need. Clinicians need to be mindful of their own learning within such a specialist field and be open to referral outside their practice if they wish to provide the best results for patients.

5.4 Limitations

A limitation of this review is that RF identified across the papers were not assessed for frequency among the studies. A positively identified risk factor within a single study was given the same consideration as a risk factor that may have occurred among several studies. In the same category, certain studies may have failed to find the presence of a risk factor that had occurred in other studies. The absence of these studies findings did not invalidate previous studies, but often created questions around why findings were not comparable across similar studies. The purpose of this review was to provide an overview of the potential injury types and RF related to overuse injuries in runners, for use in a clinical setting, and not to evaluate the validity of one risk factor over another. Thus, incongruity between study findings or frequency of a RF appearance did not exclude a risk factor from the review.

Another limitation is the depth of detail that can be provided by a scoping review. Considerable time by groups of researchers is necessary when looking to consolidate information on a single specific overuse injury, as in many systematic reviews. The depth of such research cannot be matched in a scoping review attempting to discuss such a broad spectrum of injuries. Thus, while each injury has been discussed using some of the most recent research that could be sourced, its original search parameters were unable to go beyond broad concepts of “general injuries”. This can be seen in the high number of additional references added from citations post screening. Scoping reviews expect and allow for this as the nature of a scoping review is one of mutability as themes emerge, but it does mean that papers specific to certain injuries may not have been included in the final review.

Many running studies used within this review are retrospective in design, where certain differences identified between injured and uninjured runners may only be present due to compensation patterns developed by the runner, to avoid the pain of the injury. In addition, studies on a single injury type tend to design their investigations based on previously identified RF. This could create a narrow scope of research that leads to findings that may not be significant if evaluated within a larger framework. Conversely, study designs that attempt to encompass too wide array of factors lack strength in their results due to the large number of complex variables that they cannot account for. These variables lead to difficulties in proving conclusive findings. However, study designs that attempt to encompass
a wider array of factors decrease the strength of their results, due to the increasingly complex variables that must be acknowledged. The impact of such variables makes conclusive findings difficult to report.

As previously discussed, this review was limited to overuse running injuries of the knee and below. While etiologically the predominant injury sites for runners are within this anatomical region, based on the volume of information found a similar scoping review for overuse running injuries above the knee may be worth investigating.

5.5 Reflections on the research process

Systematic reviews around running injuries were not particularly helpful in the discovery for a scoping review. The constant demand for high quality research has created a situation whereby many systematic reviews can provide little to no direction other than the phrase “further high-quality studies need to be conducted”. As an example, Hulme et al.’s 2017 paper reviewed 73 articles. While some of the included studies reported findings that were contested among multiple sources, there were many that were classified as not high enough quality for their findings to be included in the review. Such findings may have provided actionable information for a practitioner. While the academic community should ensure high standards in its peer reviewed research, there must be something to be said for more moderate discussion around papers that still achieve clinically significant findings. Not all research manages to reach the levels of high quality RCT trials, but their findings still provide useful information to people involved with runners at multiple levels, and such consideration likely applies across the broader scope of other sports injuries.

6 Conclusion

The results of this scoping review demonstrate how many variables potentially contribute to the development of overuse running injuries, as demonstrated in the appendices diagrams (Appendix C). Among these variables are extrinsic factors such as training load and distance, training surfaces, footwear and intrinsic variables such as anatomical & physiological differences. Interaction between these variables is considerable, and an awareness of how such variables may interact is important for health practitioners providing advice to patients. Prevention of future overuse injuries can be aided by understanding how previous and existing injuries occurred. Appreciation of a single practitioner’s limitations to be able to provide such advice, either due to a lack of knowledge or time constraints with the patient, reinforces the need for greater interprofessional collaboration. Changes to identified modifiable RF, the most significant of which appears to be training errors such as load, distance and pace, need to be tailored to the individual to reduce the risk of specific injuries. Such changes need to be in consultation with the patients running goals but must also help to enable optimum recovery from overuse injuries. In addition, the longevity of an amateur runner’s participation in the sport may be
severely curtailed due to injuries caused by a lack of knowledge about training and recovery. Prospective cohort studies on amateur runners and their participation in training, despite pain from an injury, is still needed. Future research in the field of running injuries may also well consider broader, more clinically applicable studies, that could be more readily utilised in the development of both recovery and prevention treatment.
7 References


68. Modern running shoes & heel striking [Internet]. Available from: http://barefootrunning.fas.harvard.edu/2FootStrikes&RunningShoes.html


123. de Fijter WM, Scheltinga MR, Luiting MG. Minimally invasive fasciotomy in chronic


202. Speck J. Forefoot varus and supinatus [Internet]. Fix Flat Feet. 2013. Available from:
https://www.fixflatfeet.com/forefoot-varus/


8 Appendices

8.1 Appendix A: Terms Searched

<table>
<thead>
<tr>
<th>Search Term 1</th>
<th>Search Term 2</th>
<th>Search Term 3</th>
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<tr>
<td>MESH search terms</td>
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<td>Ankle</td>
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<td>“AND”</td>
</tr>
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<td>“Running”[Mesh]</td>
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<td>Lower extremity injur*</td>
<td>Run*</td>
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<tr>
<td>Lower extremity injur*</td>
<td>Long-distance run*</td>
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<td>Lower extremity injur*</td>
<td>Cross-country</td>
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<td>Overuse injur*</td>
<td>Run*</td>
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<td>Risk factor*</td>
<td>Run*</td>
<td>Biomechanic*</td>
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<td>predisposing factors</td>
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<td>Running injuries</td>
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8.2 Appendix B: Search Results
8.3 Appendix C: Risk Factor Tables
Risk Factors for Overuse Running Injuries

Intrinsic
- Demographic
  - Age
  - Sex
  - History of injury
  - Structural variations
    - Inflexibility
    - Muscle dysfunction
    - Bone geometry
    - BMI
    - Gait

- Anatomical
  - Knee alignment
    - Foot arch morphology
      - Leg length asymmetry
    - Joint or muscle
      - Hyper/hypotrophy
    - Neuromuscular control

- Physiological
  - Bone mineral density
  - Nutrition
  - Pharmacological
  - Hormonal
  - Pace
    - Experience
    - Volume
    - Gradient
    - Firmness
    - Shoe fit/style
    - Shoe mileage/age

Extrinsic
- Training Errors
- Training Surface
  - Gradient
  - Firmness
- Footwear
  - Shoe fit/style
  - Shoe mileage/age

- Eating disorders
  - Dietary restrictions
  - Supplements
  - Medication
    - Delayed menarche
    - Menarche disturbance
  - Duration
  - Frequency
Leg Overuse Running Injuries & Associated Risk Factors

- Chronic compartment syndrome
  - Demographic
  - Anatomical
  - Physiological

- Medial tibia stress syndrome
  - Demographic
  - Anatomical
  - Structural variation
  - Bone geometry
    - BMI > 20.2
    - BMI < 18.5

- Young adult male mean age 20
  - Muscle dysfunction
    - Gait
  - Hypertrophy of leg muscles
    - Rear foot landing
      - Overpronation
    - Creatine use
      - Anabolic steroid use

- Female
  - Previous history of MTSS

- Increased Int. and Ext. hip ROM
  - Lean calf girth
  - Increased navicular drop

- Increased subtalar joint pronation
  - Overpronation
  - Apropulsive gait
  - Early heel lift
Knee Overuse Running Injuries & Associated Risk Factors

Demographics
- Females
- Adolescents
  - Pes cavus feet
  - Hamstrings and calves
  - Iliotibial band
  - Weak vastus medialis
  - Weak glut medius
  - Overstriding by >15%
  - Hyperpronation
  - Higher peak vertical loading

Anatomical
- Patellofemoral pain syndrome
- Patellar tendinopathy
  - Rapid increase in pace
  - Rapid increase in volume

Training Errors

Structural Variations
- Pes planus feet
- Hamstrings
- Quadriceps

Inflexibility
- Hamstrings
- Quadriceps

Higher BMI
- Weak quadriceps

Muscle dysfunction

Training surface
- Downhill gradients
Knee Overuse Running Injuries & Associated Risk Factors

- Knee
- Iliotibial friction syndrome
  - Anatomical
  - Training errors
  - Training Surface
- Muscle dysfunction
- Rapid increase in volume
- Downhill gradients
- Neuromuscular control of internal rotation vectors
Ankle Overuse Running Injuries & Associated Risk Factors

Demographic
- History of injuries
  - Pes planus arch
  - Forefoot varus

Structural Variations
- Triceps surae
- Upper ankle complex
  - Delayed activation of tibialis anterior
  - Decreased activity of gluteus medius and rectus femoris
  - Decreased strength of knee flexors
  - Increased activity of soleus and gastrocnemius

Anatomical
- Muscle dysfunction

Gait
- Higher tibial external rotation moment
  - Increased leg abduction
  - High loading rates
  - High braking force
  - Increased foot pronation with lateral heel strike

Training Errors
- Rapid increase in pace
- Highly compliant

Training Surfaces
- Slippery/Poor traction
- Steeper gradients

Footwear

Shoe fit

Physiological

Pharmacological
- Use of fluoroquinolone antibiotics
### 8.4 Appendix D: Data Collection table

<table>
<thead>
<tr>
<th>PMID</th>
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<th>Main Findings</th>
<th>Knee</th>
<th>Leg</th>
<th>Ankle</th>
<th>Foot</th>
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<tr>
<td>18845979</td>
<td>Risk factors and mechanisms of knee injury in runners.</td>
<td>Body weight, weekly mileage, and concentric knee extension strength were significantly correlated with tibiofemoral compressive force</td>
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<tr>
<td>10994917</td>
<td>Evaluation of lower extremity overuse injury potential in runners.</td>
<td>These results suggest that runners who have developed stride patterns that incorporate relatively low levels of impact forces, and a moderately rapid rate of pronation are at a reduced risk of incurring overuse running injury</td>
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<tr>
<td>16952751</td>
<td>Management of common running injuries</td>
<td>Detailed gait information and a range of common running overuse injuries</td>
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<tr>
<td>27244060</td>
<td>Factors Influencing Running-Related Musculoskeletal Injury Risk Among U.S. Military Recruits</td>
<td>Following an explorative, 1-year prospective cohort study involving 873 healthy novice runners, reported increased risk for certain injuries among runners who increased weekly distance by greater than 30% across 2 weeks versus those who increased distance by less than 10%</td>
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<tr>
<td>21619710</td>
<td>Lower limb biomechanics during running in individuals with achilles tendinopathy: a systematic review.</td>
<td>There are differences in lower limb biomechanics between those with and without Achilles tendinopathy that may have implications for the prevention and management of the condition</td>
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<tr>
<td>24054856</td>
<td>Medial foot pain in a runner: a case presentation</td>
<td>4 months of medial foot pain after an eversion ankle sprain - bone edema adjacent to a navicular synchondrosis, which confirmed a diagnosis of type 2 accessory navicular with synchondrosis injury</td>
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<tr>
<td>24179587</td>
<td>Common leg injuries of long-distance runners: anatomical and biomechanical approach</td>
<td>Leg pain due to bone, musculotendinous, and vascular causes is common among long-distance runners</td>
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<tr>
<td>ID</td>
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<td>Protective Factors</td>
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<td>26736073</td>
<td>Relationships between static foot alignment and dynamic plantar loads in runners with acute and chronic stages of plantar fasciitis: a cross-sectional study</td>
<td>Some specific risk factors around foot alignment and PF - The risk factors for the development of plantar fasciitis (PF) have been associated with the medial longitudinal arch (MLA), rearfoot alignment and calcaneal overload.</td>
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<tr>
<td>2818115</td>
<td>Predicting lower-extremity injuries among habitual runners</td>
<td>Results identified that running 64.0 km (40 miles) or more per week was the most important predictor of injury for men during the follow-up period (odds ratio = 2.9). Risk also was associated with having had a previous injury in the past year (odds ratio = 2.7) and with having been a runner for less than 3 years (odds ratio = 2.2).</td>
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<td>24572303</td>
<td>Evaluation of the injured runner</td>
<td>Emphasizes the identification of intrinsic and extrinsic risk factors in addition to establishing injury specific diagnosis</td>
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<td>15659961</td>
<td>Foot and ankle injuries in the adolescent runner.</td>
<td>Retrocalacaneal bursitis, Osteochondral lesions of the talus (OCD), Calcaneal apophysitis, Jogger nerve</td>
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<td>25786820</td>
<td>Peroneal tendinosis as a predisposing factor for the acute lateral ankle sprain in runners</td>
<td>Reflect the correlation between peroneal tendinosis and ankle sprain trauma</td>
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<tr>
<td>24149785</td>
<td>Foot and lower limb diseases in runners: assessment of risk factors.</td>
<td>Morphological characteristics of the foot, the most prone to injury were the varus hindfoot (87.5% of cases) and the cavus arch (71.4%).</td>
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<td>26667506</td>
<td>Risk Factors and Protective Factors for Lower-Extremity Running Injuries A Systematic Review</td>
<td>Running injuries are, by nature, complex and multifactorial. They have extrinsic and intrinsic causes, the former being distance, ground stiffness, footwear, flexibility, time, intensity, and training frequency and the latter being the alignment of the foot, muscle weakness, previous injuries, biomechanical abnormalities, sex, and body mass index</td>
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<td>16736123</td>
<td>Liposynovitis prepatellaris in athletic runner (Hoffa's syndrome): case report and review of the literature</td>
<td>Hoffa's syndrome</td>
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<td>n/a</td>
<td>Arch structure and injury patterns in runners</td>
<td>High-arched runners reported a greater incidence of ankle injuries, bony injuries and lateral injuries. Low-arched runners exhibited more knee injuries, soft tissue injuries and medial injuries</td>
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<td>n/a</td>
<td>An overview of common lower extremity soft tissue injuries in athletes</td>
<td>The knee is the commonest site involved comprising up to 44% of running injuries.2,3 This article outlines the natural history, pathophysiology, investigation and management of common conditions.</td>
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<tr>
<td>25851584</td>
<td>What are the Differences in Injury Proportions Between Different Populations of Runners? A Systematic Review and Meta-Analysis.</td>
<td>Details of the injury definition, method of injury assessment, number of injuries and injury locations were extracted from the articles.</td>
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<td>20610032</td>
<td>Neuropathies in runners</td>
<td>Neurologic conditions currently account for 10% to 15% of all exercise-induced leg pain among runners. All detail on nerve entrapment conditions and symptoms/risks.</td>
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<td>9462910</td>
<td>What are causes and treatment strategies for patellar-tendinopathy in female runners?</td>
<td>Biomechanical evaluations indicate eccentric overloading of the quadriceps muscle group, increased pronation velocity as well as a lack of joint coordination as major etiological factors in the development of PT.</td>
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<td>26616180</td>
<td>Foot and Ankle Injuries in Runners.</td>
<td>Achilles tendinopathy, Plantar fasciitis, Ankle sprain, Posterior tibial tendinitis, plus categories of joint and nerve disorders in the foot and ankle.</td>
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<td>20463502</td>
<td>Prevention of Running Injuries.</td>
<td>Two anatomical factors - cavus feet and leg length inequality - demonstrate a link to injury.</td>
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<tr>
<td>11570734</td>
<td>Factors contributing to the development of medial tibial stress syndrome in high school runners.</td>
<td>study supported the hypothesis that a pronatory foot type is related to medial tibial stress syndrome.</td>
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<tr>
<td>n/a</td>
<td>Common Running Overuse Injuries and Prevention.</td>
<td>The most common running related injuries include medial tibial stress syndrome, Achilles tendinopathy, plantar fasciitis, patellar tendinopathy, iliotibial band syndrome, tibial stress fractures, and patellofemoral pain syndrome.</td>
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<td>n/a</td>
<td>Take a Mental Break! study: Role of mental aspects in running-related injuries using a randomised controlled trial</td>
<td>Good RRI definition plus unique study on impact of mental role in injury. Not part of the main findings as such but worth its own sub section. Just a protocol at this stage , no findings released that Im aware.</td>
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<tr>
<td>22049346</td>
<td>Getting injured runners back on track.</td>
<td>Diagnostic guide covering a range of common running injuries. A lower level template of what this review is doing.</td>
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<td>n/a</td>
<td>Analysis of gait differences in healthy runners and runners with chronic Achilles tendon complaints.</td>
<td>Compare biomechanical gait characteristics by means of plantar pressure distribution (PPD), EMG and ground reaction forces (GRF) in healthy runners and in runners with chronic Achilles tendon complaints. Healthy runners differ from Achilles tendon complaint patients in terms of movement characteristics especially in running.</td>
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<td>n/a</td>
<td>Association between the Foot Posture Index and running related injuries: A case-control study</td>
<td>Our regression model showed that high supination was associated with 76.8 times higher odds of injury than a neutral Foot Posture Index score (P &lt; 0.001). High pronation was associated with 20-fold higher odds of injury than neutral foot posture (P &lt; 0.001). Other variables such as running surface, number of shoes used, and body mass index were also associated with injury.</td>
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<tr>
<td>7378670</td>
<td>Tendoperiostitis in the lateral femoral condyle in long-distance runners.</td>
<td>Unique condition discussed as well as good information on mechanical stressors applied to the ITB during running.</td>
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<td>19417381</td>
<td>Suspected mechanisms in the cause of overuse running injuries: a clinical review.</td>
<td>A majority of the risk factors that have been researched over the past few years can be generally categorized into 2 groups: atypical foot pronation mechanics and inadequate hip muscle stabilization.</td>
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<td>11858335</td>
<td>Heel pad thickness—a contributing factor associated with plantar heel pain in young adults</td>
<td>A weight-bearing platform measured heel pad thickness by real-time ultrasound scanning. The results demonstrated a significant difference between the Plant Heel pain and both the NPHP and control groups (P &lt;0.05).</td>
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<td>6417562</td>
<td>Overuse injuries of the lower extremities associated with marching, jogging, and running: a review.</td>
<td>Over 50 specific injuries can be tabulated from the available literature. However, five categories of injury account for more than 50 per cent of all injuries in both civilian and military populations.</td>
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<td>23748735</td>
<td>Forefoot strikers exhibit lower running-induced knee loading than rearfoot strikers.</td>
<td>This is the first study that shows differences in patellofemoral loading and knee frontal plane moment between FFS and RFS. FFS exhibit both lower patellofemoral stress and knee frontal plane moment than RFS, which may reduce the risk of running-related knee injuries. On the other hand, parallel increase in ankle plantarflexor and Achilles tendon loading may increase risk for ankle and foot injuries.</td>
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<tr>
<td>18746659</td>
<td>Incidence, risk factors and prevention of running related injuries in long-distance running: a systematic review</td>
<td>Most common injuries sustained by long-distance runners were found to be Achilles tendinopathy, Iliotibial Friction Syndrome (ITBS) and Medical Tibial Stress Syndrome (MTSS). Most common risk factors are age, running history and injury history</td>
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<td>1</td>
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<tr>
<td>3063674</td>
<td>A retrospective case-control analysis of 2002 running injuries</td>
<td>Women with a body mass index less than 21 kg/m² were at a significantly higher risk for tibial stress fractures and spinal injuries. Patellofemoral pain syndrome was the most common injury, followed by iliotibial band friction syndrome, plantar fasciitis, meniscal injuries of the knee, and tibial stress syndrome,</td>
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<td>n/a</td>
<td>Risk and Protective Factors for Middle- and Long-Distance Running-Related Injury</td>
<td>A history of previous injury was associated with an increased risk of both general and specific RRI. The use of oral contraceptives was found to be associated with a decreased risk of skeletal stress fracture. Conversely, irregular and/or absent menstruation was associated with an increased risk</td>
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<td>24898814</td>
<td>Achilles tendon injury risk factors associated with running</td>
<td>Two variables, high vertical forces and high arch, showed strong evidence for reduced injury risk. High propulsive forces and running on stiffer surfaces may also be protective. Only one biomechanical variable, high braking force, showed clear evidence for increasing Achilles injury risk.</td>
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<td>25441558</td>
<td>FACTORS INFLUENCING THE OCCURRENCE OF PAIN AND INJURY IN RUNNERS</td>
<td>The largest percentage of these (36%, n = 26) were related to knee injuries. As factors causing injuries, the interviewees mentioned one-sided training plan (24%, n = 17), overtraining (24%, n = 17), and insufficient warm-up (16%, n = 12). The analysis of the results has shown a statistically relevant positive correlation (r = 0.177, p &lt; 0.05) between weekly frequency of training and the number of injuries sustained in the last year.</td>
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<tr>
<td>11079510</td>
<td>Etiologic factors associated with anterior knee pain in distance runners</td>
<td>Pronation through the first 10% of stance, arch index, shoe mileage, and extension peak torque were the best overall (P &lt; or = 0.05) predictors. The Anterior knee pain group had smaller mean values on all four significant predictors. anterior knee pain group had a significantly lower arch index relative to the control group. a bigger, leaner, and stronger body helps to protect the distance runner from injury by more effectively dissipating the stresses associated with running.</td>
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<tr>
<td>8784929</td>
<td>Walking aches and running pains. Injuries of the foot and ankle</td>
<td>Overall discussion on a wide array of injury types. Older data but good baseline information.</td>
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<tr>
<td>2922489</td>
<td>Lower extremity injuries in runners</td>
<td>Running injuries are primarily musculoskeletal, usually the result of a change in training regimen or technique. A sudden increase in mileage is the most common cause. Athletes who run more than 40 miles a week have an increased risk of injury. Most injuries affect the knee, but the shin, ankle, and foot are also common sites.</td>
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<tr>
<td>28481686</td>
<td>Lower extremity joint loads in habitual rearfoot and mid/forefoot strike runners with normal and shortened stride lengths.</td>
<td>Summarising, a particular foot strike style does not universally decrease joint contact forces. However, shortening one’s SL 10% decreased nearly all lower extremity contact forces, so it may hold potential to decrease overuse injuries associated with excessive joint loads.</td>
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<td>23531971</td>
<td>Foot injuries in runners</td>
<td>Plantar fasciitis and tendinopathies of the midfoot and forefoot have a high incidence in running athletes. Bone injuries caused by overuse also have a high prevalence among runners. The metatarsals, tarsal navicular, and sesamoids are most at risk for stress damage.</td>
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<tr>
<td>9057188</td>
<td>Prospective analysis of intrinsic and extrinsic risk factors on the development of Achilles tendon pain in runners.</td>
<td>In an uninjured state, AT runners already demonstrated decreased knee flexor strength and abnormal lower leg kinematics (sagittal knee and ankle joint) compared with a matched control group.</td>
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<tr>
<td>29263457</td>
<td>Is there a relationship between functional at foot and prevalence of non-insertional achilles tendinopathy in joggers? - a pilot study</td>
<td>All subjects who were diagnosed with overuse injuries in the Achilles tendon area showed a functionally inefficient transverse arch of the foot. This is one of the risk factors for the occurrence of changes due to overuse injuries within the Achilles tendon.</td>
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<tr>
<td>20610025</td>
<td>Evaluation of the Injured Runner</td>
<td>Leadbetter’s principle of transition seeks to identify extrinsic risk factors and states that injury is most likely to occur when the athlete experiences a change in mode or use of the involved part. Macintyre’s principle of “victim and culprits” underscores the importance of the biomechanical and functional examination. The presenting injury represents the “victim,” which has occurred as a result of an inability to compensate for a primary dysfunction at another site, the “culprit.”</td>
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<td>19017851</td>
<td>Biomechanical risk factors in the development of medial tibial stress syndrome in distance runners.</td>
<td>Variables identified as being significant predictors of medial tibial stress syndrome were the difference between the neutral and relaxed calcaneal stance positions, range of motion of the talocrural joint with the knee extended, early heel lift and abductory twist during gait, and apropulsive gait. Runners with suspected symptoms of medial tibial stress syndrome should be assessed dynamically and statically for abnormal or mistimed pronation.</td>
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<td>30787648</td>
<td>The Proportion of Lower Limb Running Injuries by Gender, Anatomical Location and Specific Pathology: A Systematic Review.</td>
<td>The knee (28%), ankle-foot (26%) and shank (16%) accounted for the highest proportion of injury in male and female runners, although the proportion of knee injury was greater in women (40% vs. 31%). Relative to women, men had a greater proportion of ankle-foot (26% vs. 19%) and shank (21% vs. 16%) injuries. Patellofemoral pain syndrome (PFPS; 17%), Achilles tendinopathy (AT; 10%) and medial tibial stress syndrome (MTS; 8%) accounted for the highest proportion of specific pathologies recorded overall.</td>
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<td>26582192</td>
<td>Risk factors associated with lower extremity stress fractures in runners: a systematic review with meta-analysis</td>
<td>Only previous history of stress fracture and female sex are risk factors for lower extremity stress fractures strongly supported by the data.</td>
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<tr>
<td>26616181</td>
<td>Bone Stress Injuries in Runners</td>
<td>Studies suggest the annual incidence of BSI may be greater than 20% in runners. Risk factors for BSI can be divided into biological and biomechanical risk factors (Table 1)</td>
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<td>6869653</td>
<td>Some biomechanical aspects of the foot and ankle in athletes with and without shin splints</td>
<td>The athletes with shin splints had significantly greater (P less than 0.05-0.01) angular displacement values in inversion, eversion, and in their sum than the control group. While running, the Achilles tendon angle of the shin splint group was significantly greater (P less than 0.01) at the heel strike. Further, the shin splints group had a significantly greater (P less than 0.01) angular displacement between the heel strike and the maximal everted position</td>
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<td>6695641</td>
<td>Overuse syndromes in runners</td>
<td>Common running-related problems include iliotibial tract tendinitis, chondromalacia patellae, “shinsplints,” stress fractures and various heel and foot syndromes. Most causes of overuse syndromes can be traced to training errors, anatomic factors, poor shoes and uneven running surface</td>
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<td>ID</td>
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<td>729244</td>
<td>Medial plantar neurapraxia (jogger's foot): report of 3 cases</td>
<td>Unique condition - Entrapment of the medial plantar nerve in the longitudinal arch causes burning heel pain, aching in the arch, and deficient sensation in the sole of the foot behind the great toe. Long distance valgus running may cause such a disorder in a jogger.</td>
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<td>3014057</td>
<td>LEG-LENGTH INEQUALITY AND RUNNING-RELATED INJURY AMONG HIGH SCHOOL RUNNERS</td>
<td>No statistically significant associations were found between leg-length inequality and (RRI) for female or male runners, with the exception that after adjusting for BMI, males with a leg-length inequality &gt; 1.5 cm were over seven times more likely to incur a lower leg RRI than males with a leg-length inequality &lt; 0.5 cm. While leg-length inequality was not associated with RRI, in general, males with a leg-length inequality &gt; 1.5 cm were at greater likelihood of sustaining a lower leg RRI.</td>
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<td>n/a</td>
<td>Determinative Factors in The Injury Incidence on Runners: Synthesis of Evidence “Injuries on Runners”</td>
<td>Many variables can contribute to the injury process, among them extrinsic factors such as training methodology, running shoes and surface. Large information on these factors in this paper.</td>
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<tr>
<td>17883966</td>
<td>Risk factors for overuse injuries in runners</td>
<td>This article reviews and summarizes several relevant studies on this topic, focusing on anatomic (intrinsic) risk factors as well as risk factors related to training (extrinsic).</td>
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<td>19228665</td>
<td>A prospective study on gait-related intrinsic risk factors for lower leg overuse injuries.</td>
<td>Findings suggest that a less pronated heel strike and a more laterally directed roll-off can be considered as risk factors for Lower Limb occurrence injury. Clinically, the results of this study can be considered important in identifying individuals at risk of LLOI.</td>
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<td>29791183</td>
<td>A 2-Year Prospective Cohort Study of Overuse Running Injuries: The Runners and Injury Longitudinal Study (TRAILS)</td>
<td>The results of this study indicate the following: (1) among recreational runners, women sustain injuries at a higher rate than men; (2) greater knee stiffness, more common in runners with higher body weights (≥80 kg), significantly increases the odds of sustaining an overuse running injury; and (3) contrary to several long-held beliefs, flexibility, arch height, quadriceps angle, rearfoot motion, lower extremity strength, weekly mileage, footwear, and previous injury are not significant etiologic factors across all overuse running injuries.</td>
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<tr>
<td>0306-3674</td>
<td>Incidence and determinants of lower extremity running injuries in long distance runners: a systematic review</td>
<td>A bit broad but supports other papers findings of knee being the most common, training distance per week and previous injuries are all risk factors.</td>
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<td>16005402</td>
<td>Stress fractures and knee injuries in runners.</td>
<td>Excellent discussion on what constitutes bone stress fractures and the etiology behind them for runners as well as all risk factors around them</td>
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<td>21592896</td>
<td>CLASSIFYING RUNNING-RELATED INJURIES BASED UPON ETIOLOGY, WITH EMPHASIS ON VOLUME AND PACE.</td>
<td>Evidence from clinical and experimental studies is presented to support the assertion that rapid change in running volume may lead to the development of patellofemoral pain syndrome, iliotibial band syndrome, and patellar tendinopathy, while change in running pace may be associated with the development of achilles tendinopathy, gastrocnemius injuries, and plantar fasciitis.</td>
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<tr>
<td>30895549</td>
<td>Injury incidence and risk factors: a cohort study of 706 8- km or 16-km recreational runners</td>
<td>Background evidence on previous injury being a major factor</td>
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<td>21592896</td>
<td>RUNNING INJURY DEVELOPMENT: THE ATTITUDES OF MIDDLE- AND LONG-DISTANCE RUNNERS AND THEIR COACHES</td>
<td>A total of 68 athletes and 19 coaches were included in the study. A majority of the athletes (76% [95%CI: 66%; 86%]) and coaches (79% [95%CI: 61%; 97%]) reported &quot;Ignoring pain&quot; as a risk factor for running injury. A majority of the coaches reported &quot;Reduced muscle strength&quot; (79% [95%CI: 61%; 97%]) and &quot;high running distance&quot; (74% [95%CI: 54%; 94%]) to be associated with injury, while half of the runners found &quot;insufficient recovery between running sessions&quot; (53% [95%CI: 47%; 71%]) important.</td>
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<td>9057188</td>
<td>The NLstart2run study: Incidence and risk factors of running-related injuries in novice runners</td>
<td>The multivariable Cox regression analysis showed that a higher age, higher BMI, previous musculo-skeletal complaints not attributed to sports and no previous running experience were related to RRI.</td>
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<td>1439399</td>
<td>Running injuries. A review of the epidemiological literature</td>
<td>Aetiological factors associated with running injuries include previous injury, lack of running experience, running to compete and excessive weekly running distance.</td>
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<tr>
<td>12917533</td>
<td>Bone SPECT Findings in Runner’s Knee</td>
<td>Formal explanation of “runners knee” or ITB friction. Results from overuse and is characterized by lateral knee pain typically induced by exertion. The syndrome is caused by friction between the lateral femoral condyle and the iliotibial band.</td>
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8.5 Appendix E: Ethics Exemption

From: Unitec Research Ethics Committee
Sent: Thursday, 18 January 2019 3:22 PM
To: morgan@elitehealth.co.nz
Subject: Ethics exemption request

Kia ora Morgan,
I can confirm that your project does not require approval by the Unitec Research Ethics Committee.

Asher Lewis
Research Administrator
Tūāpapa Rangahau | Partnering Research & Enterprise
Email alewis@unitec.ac.nz

---

From: Morgan Hancock
Sent: Thursday, 8 November 2018 1:32 PM
To: ethics@unitec.ac.nz
Subject: Ethics exemption request

To whom it may concern

RE: Ethics Application - 3.6. Exceptions from Approval Requirements

As per the Unitec Ethics Guidelines document version March 2014, I am seeking confirmation that my intended thesis will not require specific approval from the UREC due to subclauses 3.6 a and 3.6 c stating that; “Research that does not involve humans or animals and is not foreseen to adversely affect humans or animals” and “Research involving existing, publicly available documents or data (e.g. analysis of archival records, which are publicly available)" does not require ethics approval.

The thesis titled “Defining types and causes of injuries of the foot and lower leg in runners: A scoping review” is a 90 credit thesis, for the fulfilment of the requirements of the Master of Osteopathy paper HEAL9312. The thesis is a scoping review involving the author researching the types and causes of non-traumatic injuries that may be sustained to the lower leg and feet, by runners. That research is entirely limited to the collation, review, and appraisal of publicly available peer-reviewed articles. At no time will the research involve human or animal participants, nor will it make use of grey literature sources. The final thesis is designed to provide an overview of the various types and causes of injuries to runners and the content of its results should have no adverse effect on humans or animals. You will find the formal proposal attached to confirm this information.

Can I ask UREC to please consider this information and provide confirmation of the exemption from the formal ethics approval process.

Kind regards

Morgan Hancock