Studies in Sports Science and Physical Education
ISSN 2959-5274
www.paradigmpress.org/SSSPE
Volume 4 Number 1 2026

A Review of Foot Strike Patterns and Injury Considerations in Recreational Endurance Runners

Mingyang Wei[1]

[1] AnnpoBio Pharmaceuticals (Guangdong) Co., Ltd., Guangzhou 510515, China
Correspondence: Mingyang Wei, AnnpoBio Pharmaceuticals (Guangdong) Co., Ltd., Guangzhou 510515, China.

doi:10.63593/SSSPE.2026.04.02

Abstract

Background: Running is one of the most widely practiced forms of exercise, but injury rates remain high. Recreational runners report 6.9 to 8.7 running-related injuries per 1000 hours of running (Videbæk S et al., 2015). Foot strike pattern is one biomechanical factor that has been linked to injury risk. ***Objective:*** To review current evidence on the effects of foot strike techniques on running biomechanics and injury risk in recreational runners. ***Methods:*** A targeted literature search of PubMed (2021–2026) was conducted as part of this narrative review, using keywords “foot strike,” “run,” “jog” combined with “injury,” “kinematics,” “kinetics,” “biomechanics,” “muscle,” and “energy.” Eligible studies included clinical trials, systematic reviews, observational studies, and biomechanical studies in English. After deduplication and screening, 29 studies were included. ***Results:*** Rearfoot strike (RFS) was generally associated with higher impact peaks, vertical loading rates, and knee joint loading. Forefoot strike (FFS) reduced impact forces but increased loading on the Achilles tendon and metatarsals. Evidence indicates no universally superior strike pattern; outcomes depend on individual anatomy, injury history, and training characteristics. ***Conclusion:*** Changing foot strike pattern shifts how load is distributed across the lower limb rather than reducing load overall. Any transition should be individualized, gradual, and paired with targeted strength work.

Keywords: foot strike, running injury, biomechanics, rearfoot strike

---

1. Introduction

From an evolutionary perspective, endurance running (ER) may have played a critical role in hominins by promoting fatigue resistance, which could have facilitated prolonged hunting and scavenging activities and contributed to the evolution of human physiological adaptations (Marino FE et al., 2022). As a consequence, the human musculoskeletal system is equipped with optimal features to perform ER, which remains a popular form of exercise today. While living in modern society, embraced by profuse commercial advertising on running shoes, humans are raised to take it for granted that high-quality running is necessarily based on superb shoes with cushioning and supportive properties. However, cushioned running shoes are a recent innovation, representing a brief period relative to the millions of years during which humans engaged in barefoot or minimally shod endurance running (Marino FE et al., 2022;

Lieberman DE et al., 2010).

The existing literature has gaps. Many studies target specific shoe models or small runner cohorts, and relatively few compare forefoot, midfoot, and rearfoot patterns head-to-head in larger samples. Finite element and biomechanical investigations have looked at running loads and injury risk, but findings are scattered and rarely synthesized. Reviews that integrate kinetics, kinematics, and muscle activation into practical guidance for recreational runners are still uncommon. This review draws together evidence on foot strike mechanics, neuromuscular responses, and injury patterns to offer practical guidance for recreational runners and clinicians.

2. Methods

2.1 Literature Selection Strategy

This narrative review employed a targeted literature search of the PubMed database to identify relevant studies on foot strike patterns and running, covering the period from 2021 to 2026. This targeted search approach was used to enhance comprehensiveness while maintaining the flexibility appropriate to a narrative synthesis. The primary search keywords included “foot strike,” “run,” and “jog,” as well as “injury,” “kinematics,” “kinetics,” “biomechanics,” “muscle,” and “energy.” The search strategy first filtered for running-related studies, followed by those addressing kinematics, kinetics, neuromuscular activity, injury, or energy efficiency. The search was limited to studies published in English. Eligible article types included Clinical Trials, Controlled Clinical Trials, Randomized Controlled Trials, Pragmatic Clinical Trials, Systematic Reviews, and Meta-Analyses; observational studies, cross-sectional biomechanical studies, and methodological validation studies were also included where directly relevant to foot strike pattern mechanics or injury outcomes. An initial search yielded 219 records.

2.2 Study Selection

One reviewer independently screened all records. Titles and abstracts were first evaluated to determine eligibility; if insufficient information was available, full texts were reviewed. Inclusion criteria were: healthy adults aged 18–50 years; studies reporting running biomechanics or injury-related outcomes such as kinematics, kinetics, muscle activity, injury incidence, or energy efficiency; and peer-reviewed English publications. Exclusion criteria were: participants with neurological or musculoskeletal disorders, case reports, non-English publications, or studies without specific data analysis. After deduplication and screening of titles, abstracts, and full texts, 29 studies were finally included. Most studies focused on running biomechanics, including kinematic and kinetic analyses, while some addressed injury-related outcomes, and several examined modeling, clinical applications, or epidemiological perspectives. This selection process ensures coverage of the latest evidence on how foot strike patterns influence mechanical loading, neuromuscular responses, and injury risk. Additional foundational references were included beyond the primary search to provide relevant epidemiological and methodological context.

2.3 Data Extraction

One reviewer independently extracted key information and outcomes from each included study, including first author, publication year, study design, sample size, participant characteristics, natural foot strike pattern, foot strike comparisons, and other variables. Primary outcome measures included impact magnitude and loading rate, lower limb joint angles, joint range of motion, joint moments, negative work, and joint contact forces.

2.4 Assessment of Risk of Bias

Because this is a narrative review rather than a systematic review, no formal risk-of-bias assessment was performed. Readers should interpret the findings as a qualitative synthesis, and methodological quality likely varied across the included studies.

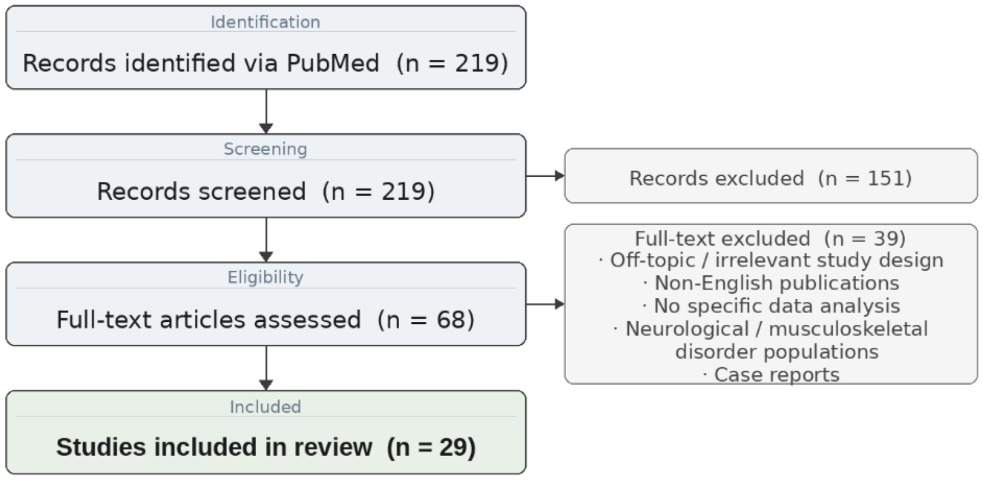
2.5 Data Analysis

Foot strike patterns were typically classified into three categories: forefoot, rearfoot, and midfoot. In some studies, natural midfoot and natural forefoot strike patterns were combined into the forefoot group. Data were synthesized according to forefoot (forefoot or forefoot/midfoot) and rearfoot categories. For studies reporting multiple running speeds or step lengths, results at medium speed and typical step length were prioritized. When data were provided before and after long-distance running, pre-run data were used to avoid the influence of fatigue.

2.6 Statistical Analysis

This review is narrative and uses a targeted search to ensure reasonable breadth of coverage.

No meta-analysis was attempted because differences in study design, populations, and outcome measures across the included literature made statistical pooling inappropriate. Results are presented qualitatively, synthesizing evidence on the effects of different foot strike patterns on biomechanical parameters and injury risk.



* Intermediate screening numbers are estimated. Search: PubMed, 2021–2026.

Figure 1. Flowchart of the study screening process

3. Results

3.1 Spatial-Temporal Variables

In shod conditions, non-rearfoot patterns show shorter ground contact time (Kovács B et al., 2023; Kubo S et al., 2024). Footwear midsole structure significantly influences lower limb biomechanics, including stride length and step rate (Fu F et al., 2022). Individual variability influences cumulative loading more than foot strike type (Ridge ST et al., 2025).

3.2 Kinetic Variables

Under shod running conditions, the comparative literature reports larger impact peaks, higher vertical loading rates, and greater knee joint moments in RFS than in non-rearfoot patterns (Lescure Y et al., 2025). FFS, however, produces higher peak vertical ground reaction forces and ankle plantarflexion moments (Lescure Y et al., 2025; Li Y et al., 2025). Decreasing foot strike angle toward a more forefoot-oriented pattern alters shock attenuation characteristics and both vertical and mediolateral force profiles (Lescure Y et al., 2025; Sarantos L et al., 2025). Cumulative loads on Achilles tendon, plantar fascia, and patellofemoral joint vary with foot strike pattern and footwear (Li Y et al., 2025; Nishiguchi H et al., 2025).

3.3 Kinematic Variables

Compared with RFS, FFS is associated with greater ankle dorsiflexion, wider ankle range of motion, and distinct hip and knee joint angles through stance (Lescure Y et al., 2025; Sarantos L et al., 2025). Peak impact accelerations and acoustic impact profiles differ across foot strike patterns (Hung Au IP et al., 2021; Napier C et al., 2022).

3.4 Muscle-Related Variables

FFS alters activation of tibialis anterior, gastrocnemius medialis and lateralis, and flexor digitorum brevis (Kovács B et al., 2023; Sarantos L et al., 2025; Shi S et al., 2025). Acute transitions from RFS to FFS do not induce major changes in plantarflexor activation (Kovács B et al., 2023).

4. Discussion

Drawing on 29 primary studies, supplemented by selected foundational references on injury epidemiology and gait retraining, the following sections summarize the biomechanical profiles of each strike pattern, their neuromuscular demands, injury-related evidence, clinical implications, and the limitations of the current evidence base.

4.1 Biomechanical Profiles of Different Foot Strike Patterns

4.1.1 Rearfoot Strike (RFS)

When runners use a rearfoot strike (RFS), the heel contacts the ground first, followed by rapid forward progression of the foot. This pattern is commonly associated with a visible impact transient at initial contact, a feature that is less prominent in habitual forefoot striking during barefoot running (Lieberman DE et al., 2010). Han et al. (2025) reported that even small changes in foot strike angle can alter tibial loading, while Lescure et al. (2025) found that, under shod running conditions, RFS was generally associated with higher loading rates and greater knee-related loading than non-rearfoot patterns.

These loading characteristics help explain why RFS is often linked to tibial stress injury and patellofemoral symptoms. Higher impact transients and loading rates likely increase cumulative tibial loading, and greater knee extensor demand raises patellofemoral joint stress (Sarantos L et al., 2025; Milner CE et al., 2006). Footwear can attenuate part of this load profile, with technologically advanced shoes reducing some biomechanical risk factors (Kim H & Ahn J., 2025); the underlying differences between strike patterns, though, do not disappear with better shoes.

4.1.2 Forefoot Strike (FFS)

In forefoot strike (FFS), the ball of the foot contacts the ground before the heel, and the heel may remain elevated briefly before lowering. Compared with RFS, this pattern typically reduces the magnitude of the initial impact transient and shifts mechanical demand distally. Under both shod and minimally shod conditions, FFS is often associated with lower vertical loading rates than RFS, although the exact response depends on speed, footwear, and runner-specific characteristics (Lescure Y et al., 2025; Sarantos L et al., 2025).

The reduction in impact loading does not mean that overall demand disappears; rather, load is redistributed. FFS generally increases the demand placed on the ankle plantarflexors and Achilles tendon, which must control ankle dorsiflexion and contribute to elastic energy storage and return. Yawar and Lieberman (2024) also showed that shoe heel height can alter ankle mechanics, which may in turn influence preferred landing strategy. These factors provide a plausible mechanism linking habitual FFS to Achilles tendon symptoms in some runners.

Forefoot strike may also increase pressure under the metatarsal region, which could elevate risk in runners who are vulnerable to forefoot overuse injuries. Lescure et al. (2025) showed that cadence, footwear, and orthotic conditions interact with strike pattern, while Nishiguchi et al. (2025) quantified differences in cumulative loading across the Achilles tendon, plantar fascia, and patellofemoral joint. What emerges is that FFS redistributes running load rather than universally reducing it.

Each pattern has its own loading trade-offs. Pattern selection is therefore better guided by a runner’s history, symptom location, footwear context, and training goals than by any universal recommendation.

4.1.3 Midfoot Strike (MFS)

Midfoot strike (MFS) is often described as an intermediate pattern in which the heel and forefoot contact the ground at nearly the same time. Biomechanically, it may produce impact characteristics that are lower than those of RFS but less distal-loading than those of FFS, although the evidence base remains limited. At present, relatively few studies have examined MFS as an independent category with sufficient depth to support strong conclusions about injury risk. Hata et al. (2025) proposed a Loadsol-based insole method capable of identifying rearfoot, midfoot, and forefoot strike patterns in real running, which may improve future field-based research. Napier et al. (2022) and Hung et al. (2021) also provided indirect evidence that impact-related characteristics differ across strike patterns, but MFS-specific conclusions remain tentative.

4.1.4 Comparative Summary of Biomechanical Characteristics

No single landing pattern appears superior across all biomechanical indicators. RFS may reduce distal calf-Achilles demand but is more often associated with higher impact transients and knee loading. FFS can reduce impact loading but increases demand on the Achilles tendon and forefoot. MFS may represent a compromise pattern, but direct evidence remains sparse. Li et al. (2025) further showed that the interaction between footwear, strike pattern, and runner experience influences patellofemoral and Achilles loading. Ridge et al. (2025) emphasized that between-runner variability may affect cumulative loading more than strike type alone, underscoring the importance of individualized interpretation.

Table 1. Comparative Biomechanical Summary of Foot Strike Patterns

Foot Strike	Impact	Joint Load	Muscle Activity	Injury Risk	Evidence
RFS	High impact peak, distal load low	Knee load higher	Tibialis anterior ↑	Knee loading ↑	(Farina KA et al., 2021; Han S et al., 2025; Kim H & Ahn J., 2025; Li Y et al., 2025); 4 studies (biomechanical/sensor); impact peak ↑, VLR ↑, knee moment ↑
MFS	Moderate impact	Moderate joint load	Limited data	Evidence limited	(Hata K et al., 2025); 1 sensor validation study; MFS classification tool; injury biomechanics not directly assessed
FFS	Low impact peak	Achilles & forefoot load ↑	Gastrocnemius ↑	Achilles/forefoot loading ↑	(Farina KA et al., 2021; Kovács B et al., 2023; Li Y et al., 2025; Sarantos L et al., 2025); 4 studies (biomechanical/sensor); impact peak ↓, Achilles load ↑, plantarflexion moment ↑

4.2 Muscle Activation and Coordination

Foot strike choice also changes what the muscles have to do, not only how force passes through the joints. FFS places greater demand on the plantarflexor muscle-tendon unit, particularly the gastrocnemius-soleus complex, which has to pre-activate and then tolerate eccentric loading immediately after contact. Kovács et al. (2023) reported that an acute transition from RFS to FFS did not immediately produce major changes in plantarflexor activation, suggesting that neuromuscular adaptation to a new strike pattern may require repeated practice rather than a single-session change.

By contrast, RFS generally places greater demand on the tibialis anterior during initial contact as the foot is lowered toward the ground after heel strike. FFS may place greater demand on the intrinsic foot muscles and plantar structures that help support the longitudinal arch, particularly when forefoot loading is increased (Sarantos L et al., 2025). Shi et al. (2025) compared lower-limb EMG characteristics across strike patterns and showed that muscle activation profiles differ in both timing and frequency content, further supporting the idea that strike pattern modification is not merely a kinematic change but also a neuromuscular one.

Gunaratne and Tamura (2025) developed an EMG-based model to estimate plantar pressure distribution during walking for active ankle orthosis development. Although that study was not conducted in running, it illustrates a potentially useful methodological direction: combining surface EMG and plantar loading data to monitor how strike-related neuromuscular demand changes over time. Kubo et al. (2024) further showed that different strike patterns influence ankle co-contraction and oxygen uptake during high-speed running, suggesting that strike pattern may alter both coordination strategy and metabolic cost.

Adaptation to a new strike pattern is therefore not purely mechanical. Repeated exposure is likely needed for the nervous system and musculoskeletal tissues to reorganize. Although direct evidence on neuromuscular adaptation to foot strike pattern change is sparse, a related line of work is informative. Khassetarash et al. (2021) showed that neuromuscular, biomechanical, and energetic responses progressively adjust across repeated bouts of downhill running, an analogous training paradigm that involves novel eccentric loading. By analogy, adopting a new foot strike pattern likely requires repeated exposure for the nervous system and tissues to adapt, rather than a single acute technique change.

4.3 Injury Patterns and Epidemiological Evidence

4.3.1 RFS-Associated Injuries

RFS loading places elevated mechanical demand on several injury-prone structures. Tibial stress fractures are one concern: greater bending moments and higher loading rates can drive cumulative microdamage. Patellofemoral pain is another, reflecting the increased knee flexion moments and quadriceps loading that accompany RFS mechanics. Plantar fasciitis may also be relevant, since the impact transient can raise tensile strain on the plantar fascia. Finally, hip and lower-back pain may develop as shock transmitted up the kinetic chain reaches more proximal structures. It should be noted that most included studies are biomechanical in design; direct prospective epidemiological evidence linking RFS to higher injury incidence rates is limited and should be interpreted cautiously. One retrospective study found that habitual RFS runners had approximately twice the rate of repetitive stress injuries compared with forefoot strikers (Daoud AI et al., 2012), though causal inference remains limited.

Chabot et al. (2024) reported that sudden changes in foot strike pattern increased loading-rate variability, suggesting that abrupt transitions may temporarily increase mechanical inconsistency during adaptation. Farina et al. (2021) also showed that foot strike pattern can change within a maximal 800-m run, indicating that fatigue may influence strike behavior during running. MFS may offer a more evenly distributed loading profile in some runners, but direct epidemiological comparisons among MFS, RFS, and FFS remain limited. Hata et al. (2025) described a Loadsol-based detection approach that may facilitate larger real-world studies in the future.

4.3.2 FFS-Associated Injuries

FFS shifts the loading profile toward structures at the distal end of the leg. Achilles tendinopathy is the most commonly cited concern, given that tendon demand tends to rise during stance and push-off. Calf muscle strain or overload is a related issue, because the plantarflexors perform more eccentric and concentric work. Metatarsal stress injury is also plausible, as forefoot pressure generally runs higher. These links make biomechanical sense, but direct prospective injury data are still limited.

MFS may represent a middle ground, potentially distributing loads more evenly. However, the epidemiological evidence specifically comparing MFS to RFS and FFS remains limited. Hata et al. (2025) developed foot strike pattern detection using a Loadsol sensor insole, providing a method for real-world foot strike monitoring that could enable larger epidemiological studies in the future.

4.3.3 Individual Variability as a Key Modulator

Ridge et al. (2025) argued that cumulative loading may be influenced more by variability among individual runners than by strike pattern alone. This complicates any attempt to recommend a single ‘best’ landing strategy. Running experience, muscle strength, flexibility, body mass, injury history, and anatomical differences may all modify the relationship between strike pattern and injury risk.

External conditions also matter. Song et al. (2025) reviewed finite-element approaches in running-footwear biomechanics and showed that shoe characteristics can alter stress distribution across the foot-lower-limb system. Although such modeling studies do not directly measure injury incidence, they support the broader point that strike pattern interacts with footwear rather than acting in isolation.

Runner-specific structure may further shape how strike pattern is expressed mechanically. Tovaruela-Carrión et al. (2025) reported spatiotemporal and foot-kinematic differences in people with cavus feet, while Shen et al. (2026) showed that foot progression angle can modulate lower-limb biomechanics in flexible flatfoot. Liu et al. (2026) further reported that orthotic insoles changed gait biomechanics in runners with flatfoot. Studies like these suggest foot structure and strike pattern should be considered together, not as separate layers of the problem.

Strike-pattern selection is not really a search for a universally best option. Muscle capacity, foot morphology, flexibility, footwear, training history, and current symptoms all shape how load is distributed, so an individualized assessment is usually more useful than a standard recommendation.

4.3.4 Mechanism of Biomechanical Damage

A substantial body of biomechanical research supports the broader principle that changes in loading distribution may alter exposure of specific tissues to stress. Yanguma-Muñoz et al.

(2024) developed a computational model of the three foot-rocker mechanisms during gait, which helps illustrate how different loading pathways may emerge across the stance phase. Although that model was not designed to prove running injury causation, it provides useful mechanistic context for why reduced knee loading may coexist with increased forefoot or Achilles demand.

Siegel et al. (2025) examined 90-degree change-of-direction tasks and showed that acute footwear changes can influence both performance and foot strike behavior. While this is not the same as steady-state endurance running, it reinforces the point that foot strike is task-sensitive rather than fixed.

The injury relevance of strike pattern is best interpreted alongside task demands, footwear, adaptation history, and individual structure, not as a single causal factor.

4.4 Clinical Implications and Transition Recommendations

4.4.1 When to Consider Changing Foot Strike Patterns

Runners with recurrent tibial stress symptoms or stubborn patellofemoral complaints may be reasonable candidates for considering a move away from a heavily rearfoot-dominant pattern, especially when impact-related loading seems clinically relevant. Any benefit has to be weighed against the distal demand FFS adds. Runners currently dealing with Achilles tendon pain, calf overload, or forefoot stress symptoms are generally poor candidates for a forefoot-oriented transition. What ties all of this together is that the decision should follow the symptom source, not a blanket preference for one pattern.

Rodríguez et al. (2023) developed KeepRunning, a motion-capture-based clinical toolkit for rapid assessment of running-related injury and gait biomechanics. Although it was not designed specifically to test strike-pattern conversion, it illustrates how objective gait analysis may help clinicians determine whether a runner is likely to tolerate a technique change and which mechanical targets are most relevant.

In practice, the decision to change strike pattern belongs inside a broader biomechanical assessment, not on top of a single clinical trend or preference. Clinicians who consider symptom location, overall gait, tissue capacity, and training context before recommending change are less likely to send runners into poorly matched or unsupervised retraining.

4.4.2 Safe Transition Strategy

In practice, many runners attempt to change strike pattern abruptly and without supervision, only to abandon the change because of discomfort or new symptoms. Chabot et al. (2024) showed that sudden changes in strike pattern increase loading-rate variability, which supports the idea that the adaptation period should be managed carefully. Based on motor-learning and tissue-adaptation principles, a gradual transition over several weeks is more appropriate than an immediate change, although the optimal timeline likely differs across runners.

A reasonable set of transition principles looks as follows. First, introduce the new pattern gradually so that musculoskeletal tissues have time to adapt. Second, consider raising step rate; a 10% increase reduces hip and knee energy absorption (Heiderscheit BC et al., 2011). Third, build in structured feedback and adherence monitoring across the retraining period. Crowell et al. (2023) described a telehealth gait-retraining protocol in soldiers with overuse knee injuries; although it was a protocol paper rather than an outcome trial, it highlights the practical importance of feedback and compliance tracking during retraining.

Fourth, shorten stride length where appropriate, because overstriding may increase impact-related loading.

Fifth, consider gradual footwear transitions as a separate adaptation process rather than changing both strike pattern and shoe condition too aggressively at the same time.

Rivadulla et al. (2021) developed and validated FootNet, a kinematics-based algorithm for detecting foot-strike and toe-off events during treadmill running. Tools of this kind may be useful during transition because they provide more objective monitoring of technique change than visual observation alone, although their clinical value in routine field settings still requires further study.

4.4.3 When Not to Change

Most recreational runners do not need to change their foot strike pattern. Asymptomatic runners with efficient RFS mechanics and adequate shock attenuation have little reason to transition. Runners dealing with current Achilles, calf, or forefoot overload symptoms should also be cautious about shifting toward a more forefoot-dominant pattern. Individual anatomy (e.g., cavus foot (Tovaruela-Carrión N et al., 2025) or flatfoot (Liu H et al., 2026; Shen L et al., 2026)) may also influence what pattern is most tolerable.

Clinically, the goal is not to pursue a theoretically perfect landing pattern, but to find the pattern and training context that are safest and most sustainable for a given runner. Anatomy, injury history, goals, and adaptation capacity all feed into that decision. Ridge et al. (2025) made a similar point: individual differences may matter more than strike type alone.

4.5 Limitations of the Current Evidence Base

A few limitations are worth keeping in mind when interpreting this review. First, the included studies were too heterogeneous in speed, footwear, running surface, measurement methods, and outcome variables to support a meaningful meta-analysis. Second, because no formal risk-of-bias assessment was performed, the methodological quality of the included evidence cannot be graded precisely within this review.

Third, many studies classify foot strike visually, which can introduce measurement error and between-rater variability. Emerging sensor-based approaches, such as the method described by Hata et al. (2025), may improve classification accuracy in future research. Fourth, cross-sectional biomechanical designs predominate, which limits causal inference: it remains difficult to determine whether strike pattern contributes to injury development or whether runners adopt a different pattern after symptoms emerge.

Fifth, laboratory findings may not fully generalize to real-world running, as treadmill and overground conditions can produce different mechanics. Sixth, most studies focus on acute biomechanical outcomes rather than long-term injury endpoints, leaving an important evidence gap.

Seventh, participants are often healthy, young, male, and relatively experienced runners, which limits generalizability to recreational novices, female runners, older athletes, and clinical populations. Eighth, relatively little evidence addresses how strike pattern interacts with training volume, running surface, and specific shoe characteristics over time. Ninth, definitions and classification thresholds for foot strike pattern remain inconsistent across the literature, making cross-study comparison difficult.

The recurring biomechanical contrast between RFS and FFS remains clinically useful as a framework for thinking about how load gets redistributed. Better strike-pattern detection tools (Hata K et al., 2025; Rivadulla A et al., 2021) and improved biomechanical modeling (Yanguma-Muñoz N et al., 2024) should make future research more ecologically valid. Moving from mechanistic plausibility to stronger injury-prevention guidance, though, will require prospective longitudinal studies in more diverse runner populations.

5. Conclusion

The clearest message from this body of literature is that changing foot strike pattern does not reduce overall running load; it redistributes load across lower-limb structures, so the site of injury risk shifts but total demand does not disappear. Several main points follow from the literature reviewed here.

RFS consistently shows higher impact peaks, vertical loading rates, and knee joint loads. These features raise the biomechanical demand on structures that figure in tibial stress fractures, patellofemoral pain, plantar fasciitis, and hip injuries.

FFS lowers impact forces and loading rates, but it raises Achilles tendon loading, calf muscle activation, and metatarsal pressure. That redistribution adds demand to structures implicated in Achilles tendinopathy, calf injuries, and metatarsal stress fractures.

MFS may offer a biomechanical compromise between the two, although the supporting evidence is still thin.

Injury risk is shaped by individual variability in anatomy, running experience, injury history, and biomechanics; this variability may matter more than strike pattern alone (Ridge ST et al., 2025).

No single foot strike pattern is universally optimal. The evolutionary record points to a long history of minimally shod running, but modern runners have grown into their musculoskeletal systems under shod, rearfoot-dominant conditions. Pattern selection is therefore a function of individual adaptation history, structural characteristics, and injury background rather than a universal prescription.

When changing foot strike patterns, one should consider physical condition, injury history, and personal preference, while undertaking specific training for the calf, gluteus, and foot intrinsic muscles, and adjusting stride length and frequency. Given that the majority of current evidence derives from cross-sectional biomechanical studies with limited longitudinal follow-up, runners modifying their foot strike pattern should adhere to two core principles: remain pain-free throughout the transition, and progress load gradually to allow adequate musculoskeletal adaptation. Real-world foot strike monitoring tools, such as the Loadsol sensor insole (Hata K et al., 2025) for field-based classification and the FootNet kinematic algorithm (Rivadulla A et al., 2021) for event detection, offer a pathway toward individualized, data-driven transition protocols outside the laboratory. Future research should prioritize prospective longitudinal studies in diverse populations, including female runners, older recreational athletes, and clinical groups who remain underrepresented. Establishing causal links between foot strike patterns and injury outcomes will require both standardized classification systems and ecologically valid field-based designs. Without these, translating biomechanical findings into evidence-based guidance for the broader recreational running community will remain a slow process.

References

Chabot M, Thibault-Piedboeuf A, Nault ML, Roy JS, Dixon PC, Simoneau M. (2024 December). Influence of Sudden Changes in Foot Strikes on Loading Rate Variability in Runners. *Sensors (Basel), 24*(24), 8163.

Crowell MS, Brindle RA, Miller EM, Reilly N, Ford KR, Goss DL. (2023 October). The effectiveness of telehealth gait retraining in addition to standard physical therapy treatment for overuse knee injuries in soldiers: a protocol for a randomized clinical trial. *Trials, 24*(1), 672.

Daoud AI, Geissler GJ, Wang F, Saretsky J, Daoud YA, Lieberman DE. (2012 July). Foot strike and injury rates in endurance runners: a retrospective study. *Med Sci Sports Exerc, 44*(7), 1325-1334.

Farina KA, Needle AR, van Werkhoven H. (2021 August). Continuous Tracking of Foot Strike Pattern during a Maximal 800-Meter Run. *Sensors (Basel), 21*(17), 5782.

Fu F, Guo L, Tang X, Wang J, Xie Z, Fekete G, Cai Y, Hu Q, Gu Y. (2022). Effect of the Innovative Running Shoes with the Special Midsole Structure on the Female Runners' Lower Limb Biomechanics. *Front Bioeng Biotechnol, 10*, 866321.

Gunaratne PN, Tamura H. (2025 June). An EMG-Based GRU Model for Estimating Foot Pressure to Support Active Ankle Orthosis Development. *Sensors (Basel), 25*(11), 3558.

Han S, Moon J, Lee J, Han S, Sterzing T, Farris D, Rice H. (2025 May). Influence of Manipulating Running Foot Strike Angle on Internal Loading of the Tibia. *Scand J Med Sci Sports, 35*(5), e70066.

Hata K, Yamazaki Y, Ishikawa M, Yanagiya T. (2025 July). Foot Strike Pattern Detection Using a Loadsol Sensor Insole. *Sensors (Basel), 25*(14), 4417.

Heiderscheit BC, Chumanov ES, Michalski MP, Wille CM, Ryan MB. (2011 February). Effects of step rate manipulation on joint mechanics during running. *Med Sci Sports Exerc, 43*(2), 296-302.

Hung Au IP, Ng L, Davey P, So M, Chan B, Li P, Wong W, Althorpe T, Stearne SM, Cheung R. (2021). Impact Sound Across Rearfoot, Midfoot, and Forefoot Strike During Overground Running. *J Athl Train., 56*(12), 1362-1366.

Khassetarash A, Vernillo G, Krüger RL, Edwards WB, Millet GY. (2021). Neuromuscular, biomechanical, and energetic adjustments following repeated bouts of downhill running. *J Sport Health Sci, 11*(3), 319-329.

Kim H, Ahn J. (2025 May). Technologically advanced running shoes reduce biomechanical factors of running related injury risk. *Sci Rep, 15*(1), 17828.

Kovács B, Petridis L, Négyesi J, Sebestyén Ö, Jingyi Y, Zhang J, Gu Y, Tihanyi J. (2023 September). An Acute Transition from Rearfoot to Forefoot Strike does not Induce Major Changes in Plantarflexor Muscles Activation for Habitual Rearfoot Strike Runners. *J Sports Sci Med, 22*(3), 512-525.

Kubo S, Yaeshima K, Suzuki T, Daigo E, Kitaoka Y, Kinugasa R. (2024 September). Influence of foot strike pattern on co-contraction around the ankle and oxygen uptake during running at 19 km/h. *Physiol Rep, 12*(17), e70023.

Lescure Y, Nicolas MA, Perrin E, Sanchis-Sales E, Lopezosa-Reca E, Travouillon C, Gijon-Nogueron G. (2025 April). Biomechanical

Strategies to Improve Running: Cadence, Footwear, and Orthoses-A Quasi-Experimental Study. *Sensors (Basel), 25*(8), 2414.

Li Y, Nie Y, Zhang X, Gu Y. (2025 June). Effects of footwear and foot strike patterns on patellofemoral joint and Achilles tendon loading in novice runners and experienced runners. *Front Sports Act Living, 7*, 1610514.

Lieberman DE, Venkadesan M, Werbel WA, Daoud AI, D'Andrea S, Davis IS, Mang'eni RO, Pitsiladis Y. (2010 January). Foot strike patterns and collision forces in habitually barefoot versus shod runners. *Nature, 463*(7280), 531-535.

Liu H, Ye D, Yang Y, Zhang S. (2026 January). Effects of Orthotic Insoles on Gait Biomechanics in Runners with Flatfoot Under Different Gait Loads. *Scand J Med Sci Sports, 36*(1), e70205.

Marino FE, Sibson BE, Lieberman DE. (2022). The evolution of human fatigue resistance. *J Comp Physiol B., 192*(3-4), 411-422.

Milner CE, Ferber R, Pollard CD, Hamill J, Davis IS. (2006 February). Biomechanical factors associated with tibial stress fracture in female runners. *Med Sci Sports Exerc, 38*(2), 323-328.

Napier C, Fridman L, Blazey P, Tran N, Michie TV, Schneeberg A. (2022). Differences in Peak Impact Accelerations Among Foot Strike Patterns in Recreational Runners. *Front Sports Act Living, 4*, 802019.

Nishiguchi H, Takabayashi T, Kikumoto T, Kubo M. (2025 November). Effects of Foot-Strike Patterns During Running on Cumulative Load of Achilles Tendon Force, Plantar Fascia Force, and Patellofemoral Joint Stress. *J Sports Sci Med, 24*(4), 747-754.

Ridge ST, Trotter T, Sponbeck JK, Johnson AW, Hunter I, Bruening DA. (2025 April). Variability Among Individual Male Runners Influences Cumulative Loading More Than Foot Strike Type. *Sports Health, 18*(1), 214-221.

Rivadulla A, Chen X, Weir G, Cazzola D, Trewartha G, Hamill J, Preatoni E. (2021 August). Development and validation of FootNet; a new kinematic algorithm to improve foot-strike and toe-off detection in treadmill running. *PLoS One, 16*(8), e0248608.

Rodríguez J, Marín J, Royo AC, Padrón L, Pérez-Soto M, Marín JJ. (2023). KeepRunning: A MoCap-Based Rapid Test to Prevent Musculoskeletal Running Injuries. *Sensors (Basel), 23*(23), 9336.

Sarantos L, Zeppetelli DJ, Dempsey CA, Nagai T, Johnson CD. (2025 April). The Effects of Decreasing Foot Strike Angle on Lower Extremity Shock Attenuation Measured with Wearable Sensors. *Sensors (Basel), 25*(9), 2656.

Shen L, Sun D, Fang Y, Lu Z, Li X, Xu Y, Song Y, Zhu C, Cen X, Fekete G, Jemni M, Gu Y. (2026 March). Foot Progression Angle Modulates Three-Dimensional Lower-Limb Biomechanics in Flexible Flatfoot: Kinematic-Kinetic Patterns and Clinical Implications. *J Foot Ankle Res, 19*(1), e70126.

Shi S, Ni X, Ieong L, Li L, Liu Y. (2025 September). Comparison of Time-Frequency Characteristics of Lower Limb EMG Signals Among Different Foot Strike Patterns During Running Using the EEMD Algorithm. *Life (Basel), 15*(9), 1386.

Siegel SD, Sproll M, Warneke K, Mason J, Zech A. (2025 December). Acute Change of Footwear Limits Performance and Alters Foot Strike Patterns During Anticipated and Unanticipated 90° Change of Direction. *J Foot Ankle Res, 18*(4), e70103.

Song Y, Cen X, Wang M, Gao Z, Tan Q, Sun D, Gu Y, Wang Y, Zhang M. (2025 June). A Systematic Review of Finite Element Analysis in Running Footwear Biomechanics: Insights for Running-Related Musculoskeletal Injuries. *J Sports Sci Med, 24*(2), 370-387.

Tovaruela-Carrión N, Casado-Hernández I, Becerro-de-Bengoa-Vallejo R, Losa-Iglesias ME, López-López D, Gómez-Salgado J, Bayod-López J. (2025 December). Spatiotemporal and foot kinematic differences during gait in individuals with cavus foot. *Sci Rep, 15*(1), 44896.

Videbæk S, Bueno AM, Nielsen RO, Rasmussen S. (2015). Incidence of running-related injuries per 1000 h of running in different types of runners: a systematic review and meta-analysis. *Sports Med, 45*(7), 1017-1026.

Yanguma-Muñoz N, Bayod J, Cifuentes-De la Portilla C. (2024 November). A single computational model to simulate the three foot-rocker mechanisms of the gait cycle. *Sci*

Rep, 14(1), 29051.

Yawar A, Lieberman DE. (2024 August). Effects of shoe heel height on ankle dynamics in running. *Sci Rep, 14*(1), 17959.