Journal of Molecular Science

Journal of Molecular Science
Volume 36 Issue 2, Year of Publication 2026, Page 595-605
DoI-10.004687/1000-9035.2026.069

Journal of Molecular Science

www.jmolecularsci.com ISSN:1000-9035

Does Barefoot Running Reduce Injury Risk? A Comparative Study of Injury Patterns and Lower Limb Biomechanics in Recreational Runners

Kakdiya Krishna Ben[1], Dr. Suhani Bhatnagar[2], Dr. Farukh Mohammad Pinjara[3], Dr. K. M. Annamali[4], Dr Sujay Gupta[5], Dr. Hirendra Kataria[6], Dr. Shubham Menariya[7], Dr. Sourabh Soni[8], Dr. Prashant Kumar Ramawat[9], Dr. Renuka Pal[10], Dr. Jafar Khan[11], Dr. Abhishek Arora[12]

[*1]M.P.Th. scholar, Pacific college of Physiotherapy, Pacific medical university, Udaipur, Rajasthan
[2]Assistant Professor, Pacific college of Physiotherapy, Pacific medical university, Udaipur, Rajasthan
[3]Professor, Pacific college of Physiotherapy, Pacific medical university, Udaipur, Rajasthan
[4]Consultant Senior Physiotherapist & Director Physio Alliance Apollo Hospital, Ahmedabad, Gujarat, India
[5]Assistant Professor, Department of orthopedics, Pacific Medical College and Hospital, Pacific medical university, Udaipur, Rajasthan
[6]Assistant Professor, Pacific college of Physiotherapy, Pacific medical university, Udaipur, Rajasthan
[7]Assistant Professor, Pacific college of Physiotherapy, Pacific medical university, Udaipur, Rajasthan
[8]Assistant Professor, Pacific college of Physiotherapy, Pacific medical university, Udaipur, Rajasthan
[9]Assistant Professor, Pacific college of Physiotherapy, Pacific medical university, Udaipur, Rajasthan
[10]Professor, Pacific college of Physiotherapy, Pacific medical university, Udaipur, Rajasthan
[11]Dean & HOD, Pacific college of Physiotherapy, Pacific medical university, Udaipur, Rajasthan
[12]Assistant Professor, Pacific college of Physiotherapy, Pacific medical university, Udaipur, Rajasthan

Article Information
Received: 18-02-2026
Revised: 04-03-2026
Accepted: 21-03-2026
Published: 18-04-2026

Keywords
barefoot running, injury risk, biomechanics, foot strike pattern, recreational runners, lower limb injuries

ABSTRACT
Running is one of the most widely practiced forms of physical activity; however, it is associated with a high incidence of musculoskeletal injuries, particularly among recreational runners. Despite advancements in footwear technology, injury rates have remained relatively consistent, prompting interest in alternative approaches such as barefoot running. The purpose of this study is to examine whether barefoot running reduces injury risk by comparing injury patterns and lower limb biomechanics between barefoot and shod runners. A comparative, literature-based methodology was adopted, synthesizing findings from peer-reviewed studies focusing on foot strike patterns, joint loading, muscle activation, and injury incidence. The analysis indicates that barefoot running promotes a forefoot or midfoot strike pattern, leading to reduced impact forces at the knee but increased loading on the ankle, Achilles tendon, and foot structures. While certain injuries, particularly knee-related conditions, may be less prevalent in barefoot runners, there is a higher risk of metatarsal stress fractures and Achilles tendinopathy, especially during the transition phase. These findings suggest that barefoot running does not eliminate injury risk but rather redistributes mechanical stress across different regions of the lower limb. It is concluded that barefoot running cannot be universally recommended as a safer alternative; however, it may serve as a beneficial supplementary training method when introduced gradually and with proper adaptation strategies.

INTRODUCTION:

Background

Running has evolved into one of the most accessible and widely adopted forms of physical activity across diverse populations, owing to its minimal equipment requirements and well-established benefits for cardiovascular health, weight management, and psychological well-being. Its global popularity has been further reinforced by the rise of recreational running communities, marathon events, and fitnessoriented lifestyles, leading to a substantial increase in participation among non-professional athletes. However, alongside this growing engagement, a persistent concern has emerged regarding the high prevalence of running-related injuries, particularly among recreational runners who often lack formal training guidance or biomechanical awareness. Epidemiological evidence indicates that injury rates in this population remain consistently high, with a significant proportion of runners experiencing at least one injury annually, most commonly affecting the knee, ankle, and foot regions. Research suggests that these injuries are multifactorial in nature, involving a complex interaction between training errors, anatomical variations, and biomechanical loading patterns (Goss & Gross, 2012; Ryan et al., 2014). Notably, even with advancements in running shoe technology designed to enhance cushioning and support, injury incidence has not demonstrated a corresponding decline, raising critical questions about the effectiveness of conventional footwear in mitigating biomechanical stress (Kerrigan et al., 2009).

Further biomechanical investigations have highlighted that traditional shod running is often associated with a rearfoot strike pattern, which generates higher impact transient forces that may contribute to repetitive stress injuries over time (Lieberman et al., 2010). In contrast, variations in running mechanics observed across different populations suggest that foot strike patterns and load distribution play a significant role in injury development (Hatala et al., 2013). Despite these insights, the relationship between running mechanics and injury risk remains complex and not fully understood, particularly in recreational settings where variability in technique and training intensity is high. Moreover, studies examining injury patterns have indicated that runners frequently experience a redistribution rather than a reduction of mechanical stress, depending on their running style and footwear condition (Shih et al., 2013; Fuller et al., 2016). This ongoing inconsistency in injury outcomes underscores the need for a more comprehensive evaluation of how different running modalities influence biomechanical loading and injury susceptibility. Consequently, understanding the underlying factors contributing to injury prevalence in recreational runners is essential for developing more effective prevention strategies and informing evidence-based recommendations for safer running practices.

Problem Statement:
Despite continuous advancements in footwear technology aimed at enhancing comfort, cushioning, and biomechanical support, the incidence of running related injuries has not shown a meaningful decline over time, particularly among recreational runners. Modern running shoes have been engineered to reduce impact forces and provide structural stability, yet empirical evidence suggests that these modifications have not translated into a proportional reduction in injury rates. Instead, injury prevalence has remained relatively stable, raising concerns about whether conventional footwear effectively addresses the underlying biomechanical factors associated with running injuries. Research examining joint kinetics has indicated that certain types of running shoes may alter natural movement patterns, potentially increasing loading at specific joints such as the knee, which may contribute to the persistence of overuse injuries (Kerrigan et al., 2009). Similarly, observational studies have demonstrated that injury incidence is not solely dependent on footwear type but is influenced by a combination of gait mechanics, training habits, and individual adaptation (Goss & Gross, 2012). These findings challenge the long standing assumption that cushioned footwear inherently reduces injury risk and instead suggest that it may redistribute mechanical stress without eliminating it.

In this context, barefoot running has emerged as an alternative approach, generating significant debate within the field of sports science. Proponents argue that running without shoes promotes a more natural gait pattern characterized by forefoot or midfoot striking, which has been associated with reduced impact transients and altered loading dynamics (Lieberman et al., 2010). This shift in biomechanics is often presented as a potential mechanism for lowering the risk of impact related injuries, particularly those affecting the knee. However, the growing body of research also indicates that barefoot running introduces its own set of challenges, including increased stress on the foot and ankle structures, especially during the initial transition period (Ridge et al., 2013). Systematic evaluations have further highlighted that while barefoot or minimalist running may modify biomechanical variables, there is insufficient conclusive evidence to support a universal reduction in overall injury risk (Perkins et al., 2014; Warne & Gruber, 2017). Moreover, comparative studies have shown that minimalist footwear does not replicate the exact biomechanical conditions of true barefoot running, complicating the interpretation of existing findings (Bonacci et al., 2013).

The ongoing debate between barefoot and shod running is therefore characterized by conflicting evidence and a lack of consensus regarding which approach is more effective for injury prevention. While some studies emphasize the potential benefits of altered foot strike patterns and improved proprioception, others point to the increased likelihood of stress related injuries in the lower extremities (Ryan et al., 2014; Hall et al., 2013). This inconsistency underscores a critical gap in understanding how different running modalities influence injury mechanisms in practical settings. Consequently, there is a need for a comprehensive and balanced examination that considers both biomechanical adaptations and injury outcomes, rather than focusing on isolated variables. Addressing this gap is essential for developing evidence-based recommendations and guiding recreational runners in making informed decisions about their running practices.

Rationale of the Study:

The growing interest in barefoot running as an alternative to conventional shod running has generated a substantial body of research; however, much of the existing literature has tended to examine biomechanical variables and injury outcomes in isolation rather than in an integrated manner. This separation has limited the ability to draw meaningful conclusions about the true implications of barefoot running on injury risk, as changes in lower limb biomechanics are directly linked to the distribution of mechanical stress across musculoskeletal structures. For instance, alterations in foot strike patterns and joint loading have been shown to influence how forces are transmitted through the kinetic chain, thereby affecting the likelihood and location of injuries (Lieberman et al., 2010; Fuller et al., 2016). Similarly, variations in muscle activation and movement mechanics between barefoot and shod conditions suggest that the body adapts dynamically to different running environments, which may either mitigate or exacerbate injury risk depending on the context (Yong et al., 2014; Hall et al., 2013). Despite these insights, many studies have focused exclusively on either biomechanical efficiency or injury incidence, resulting in a fragmented understanding of the relationship between running technique and injury development.

Furthermore, the current body of literature presents conflicting evidence regarding the effectiveness of barefoot running in reducing injury risk, thereby highlighting a significant research gap. While some investigations report that barefoot running encourages more natural movement patterns and reduces impact forces associated with heel striking, others emphasize the increased stress placed on the foot and ankle structures, particularly during the transition period (Ridge et al., 2013; Warne & Gruber, 2017). In addition, comparative studies have demonstrated that factors such as running economy and physiological demand may differ between barefoot and shod conditions, further complicating the evaluation of their overall benefits (Hanson et al., 2011; Tam et al., 2014). The diversity of findings is also influenced by methodological variations, including differences in study design, participant characteristics, and definitions of injury, which contribute to inconsistencies in reported outcomes (Perkins et al., 2014). Moreover, evidence suggests that foot strike patterns and surface conditions can vary widely even among habitually barefoot populations, indicating that there is no single biomechanical model that applies universally (Hatala et al., 2013; Gruber et al., 2013).

Given these inconsistencies, there is a clear need for a comprehensive approach that simultaneously examines both biomechanical adaptations and injury patterns to provide a more balanced and evidence based understanding of barefoot running. Integrating these dimensions allows for a more accurate assessment of whether observed biomechanical changes translate into meaningful reductions in injury risk or merely result in a redistribution of stress across different anatomical regions (Shih et al., 2013; Bonacci et al., 2013). Additionally, emerging evidence from longitudinal and controlled studies suggests that adaptation plays a critical role in determining outcomes, as runners who transition gradually may experience different injury patterns compared to those who adopt barefoot running abruptly (Hollander et al., 2019; Altman & Davis, 2016). This further reinforces the importance of considering both short term and long-term effects within a unified analytical framework. Therefore, the present study is grounded in the necessity to bridge the gap between biomechanics and injury research, offering a more holistic perspective that can inform practical recommendations for recreational runners and contribute to the ongoing scientific discourse in this field.

Objectives of the Study:

The present study is designed to systematically examine the relationship between barefoot running and injury risk by integrating biomechanical analysis with observed injury patterns among recreational runners. The primary objective is to compare the overall injury risk associated with barefoot and shod running conditions, with particular attention to the distribution and frequency of injuries across different regions of the lower limb. In addition to injury outcomes, the study seeks to analyze the biomechanical differences between these two running modalities, focusing on variables such as foot strike patterns, joint loading, muscle activation, and force distribution, which have been identified as critical determinants of running efficiency and injury susceptibility (Lieberman et al., 2010; Fuller et al., 2016). A further objective is to evaluate the practical applicability of barefoot running within recreational contexts by considering factors such as adaptability, transition challenges, and long term sustainability. This includes assessing whether the theoretical biomechanical advantages of barefoot running translate into meaningful and realistic benefits for individuals who do not possess professional training or supervision (Warne & Gruber, 2017; Perkins et al., 2014). Through this multi dimensional approach, the study aims to provide a comprehensive understanding that extends beyond isolated findings and contributes to more informed decision making in running practices.

Research Questions:
The study is guided by a set of focused research questions that address both theoretical and practical dimensions of barefoot running. The central question examines whether barefoot running leads to a significant reduction in injury risk when compared to traditional shod running, taking into account the complexity of injury mechanisms and individual variability among recreational runners. In parallel, the study investigates how barefoot running alters lower limb biomechanics, particularly in relation to foot strike patterns, impact forces, and joint kinetics, which are known to influence injury development (Yong et al., 2014; Hall et al., 2013). Another key question explores the types of injuries commonly associated with each running style, recognizing that biomechanical changes may not eliminate injuries but instead shift their occurrence to different anatomical structures (Ridge et al., 2013; Ryan et al., 2014). Collectively, these questions aim to clarify the extent to which barefoot running can be considered a viable alternative to conventional footwear and to identify the conditions under which it may be beneficial or potentially harmful.

Hypothesis:
H0 There is no significant difference in injury risk between barefoot and shod running among recreational runners.

H1 Barefoot running significantly influences injury risk and lower limb biomechanics compared to shod running, leading to differences in injury patterns and mechanical load distribution.

Literature Review:
Foot Strike Patterns and Running Mechanics:
Foot strike patterns represent a fundamental component of running mechanics and play a critical role in determining how forces are generated, absorbed, and transmitted through the lower extremities during locomotion. In the context of running styles, the distinction between forefoot and rearfoot strike patterns has received considerable attention, particularly in relation to barefoot and shod conditions. Rearfoot striking, which is commonly observed in runners wearing cushioned footwear, involves initial ground contact with the heel and is typically associated with a distinct impact transient in the vertical ground reaction force profile. This abrupt loading pattern has been linked to higher rates of repetitive stress on the skeletal system, particularly affecting the knee joint and contributing to the development of overuse injuries (Lieberman et al., 2010). In contrast, forefoot striking, more frequently adopted during barefoot running, involves initial contact with the front portion of the foot, allowing for a more gradual loading response and a reduction in the magnitude of impact transients. This modification in strike pattern facilitates greater energy absorption through the ankle and foot structures, thereby altering the distribution of mechanical stress across the lower limb.

The relationship between foot strike patterns and ground reaction forces is complex and influenced by multiple biomechanical factors, including running speed, surface characteristics, and individual neuromuscular control. Studies have demonstrated that barefoot runners tend to exhibit lower vertical loading rates due to the absence of heel cushioning, which encourages adaptations in landing mechanics and promotes a softer, more controlled foot placement (Divert et al., 2005). However, this reduction in impact forces at initial contact does not necessarily imply a decrease in overall mechanical load, as the redistribution of forces toward the plantar flexor muscles and foot structures may increase localized stress in these regions (Shih et al., 2013). Furthermore, variations in foot strike patterns are not uniform across all individuals, even within habitually barefoot populations, indicating that running mechanics are highly adaptable and subject to individual differences in anatomy and motor control (Hatala et al., 2013). This variability suggests that the relationship between strike pattern and injury risk cannot be generalized without considering contextual and individual factors.

In addition to altering force distribution, changes in foot strike patterns influence muscle activation and joint kinematics throughout the gait cycle. Forefoot striking has been associated with increased activation of the calf muscles and greater reliance on elastic energy storage within the Achilles tendon, which may enhance shock absorption but also elevate the risk of strain related injuries if adequate adaptation is not achieved (Yong et al., 2014). Conversely, rearfoot striking places greater emphasis on passive shock absorption through skeletal structures and footwear cushioning, potentially increasing joint loading at the knee (Fuller et al., 2016). The interplay between these mechanical adjustments highlights that neither foot strike pattern can be considered inherently superior, as each presents distinct biomechanical advantages and limitations. Consequently, understanding how foot strike patterns interact with ground reaction forces is essential for evaluating their role in injury development and for informing evidence-based recommendations in both barefoot and shod running contexts.

Biomechanical Differences:
The comparison between barefoot and shod running reveals significant biomechanical differences that extend beyond surface level gait alterations and directly influence joint loading patterns, muscle activation, and neuromuscular control. One of the most critical distinctions lies in how mechanical loads are distributed across the knee and ankle joints during the stance phase of running. In conventional shod running, particularly with cushioned footwear, runners tend to adopt a rearfoot strike pattern that increases the magnitude of loading at the knee joint, as the impact forces are transmitted more directly through the skeletal system with limited engagement of the ankle's elastic structures (Kerrigan et al., 2009). This pattern has been associated with higher knee joint torques and is often implicated in common overuse injuries such as patellofemoral pain syndrome. In contrast, barefoot running typically encourages a forefoot or midfoot strike pattern, which shifts the mechanical demand away from the knee and toward the ankle joint and surrounding musculature. This redistribution of load results in greater ankle plantarflexion and increased reliance on the calf muscle complex to absorb and dissipate forces (Fuller et al., 2016). While this may reduce stress on the knee, it simultaneously increases the mechanical burden on the Achilles tendon and foot structures, highlighting a trade off rather than a clear reduction in overall loading.

In addition to joint loading differences, muscle activation patterns vary substantially between barefoot and shod running conditions. Barefoot running has been shown to require greater activation of intrinsic foot muscles and the triceps surae group, as the absence of external cushioning necessitates active stabilization and shock absorption by the musculoskeletal system (Yong et al., 2014). This increased muscular engagement may contribute to improved strength and functional capacity over time, particularly in the foot and ankle complex. However, it also places greater immediate demand on these structures, especially in individuals who are not adequately conditioned or who transition too rapidly. On the other hand, shod running tends to reduce the need for intrinsic muscle activation due to the supportive features of modern footwear, which can lead to a more passive form of shock attenuation but may also limit the development of natural stabilizing mechanisms (Hall et al., 2013). These contrasting activation patterns underscore the importance of considering neuromuscular adaptation when evaluating the long-term implications of different running styles.

Furthermore, proprioception and dynamic stability are notably influenced by footwear conditions, with barefoot running often associated with enhanced sensory feedback due to direct contact between the foot and the ground. This increased sensory input allows for more precise adjustments in foot placement and movement coordination, potentially improving balance and reducing the likelihood of certain types of injuries related to instability (Hollander et al., 2019). However, the extent to which improved proprioception translates into reduced injury risk remains uncertain, as enhanced sensory awareness does not necessarily prevent overload injuries resulting from excessive or improperly distributed forces. In contrast, cushioned footwear may dampen sensory feedback, which can reduce immediate discomfort but may also impair the runner's ability to detect subtle changes in terrain or loading patterns. Overall, the biomechanical differences between barefoot and shod running illustrate a complex interplay between joint loading, muscular activity, and neuromuscular control, emphasizing that the choice of running style involves a balance of benefits and limitations rather than a universally optimal solution.

Injury Patterns in Shod Running:
Injury patterns observed in shod running have been widely documented in the literature, with a substantial proportion of these injuries affecting the knee joint and arising from repetitive impact related stress. Recreational runners who predominantly use cushioned footwear often exhibit a rearfoot strike pattern, which is associated with a pronounced impact transient at initial ground contact. This abrupt loading response generates high vertical loading rates that are transmitted through the lower limb, placing considerable stress on the knee joint and surrounding structures. Biomechanical analyses have demonstrated that such loading conditions contribute to elevated joint torques at the knee, which are frequently implicated in the development of conditions such as patellofemoral pain syndrome and iliotibial band syndrome (Kerrigan et al., 2009). The repetitive nature of running amplifies these effects over time, leading to cumulative microtrauma that may exceed the body's capacity for recovery, particularly in individuals with suboptimal running mechanics or inadequate training progression.

The role of impact related stress in injury development is further reinforced by studies examining the relationship between foot strike patterns and injury incidence. Runners who

Journal of Molecular Science
Volume 36 Issue 2, Year of Publication 2026, Page 595-605
DoI-10.004687/1000-9035.2026.069

consistently adopt a rearfoot strike pattern tend to experience higher rates of impact loading, which has been associated with an increased likelihood of repetitive stress injuries (Daoud et al., 2012). While modern running shoes are designed to attenuate these forces through cushioning technologies, evidence suggests that such features may alter natural gait mechanics without effectively reducing overall mechanical load. Instead, cushioning can create a false sense of protection, potentially encouraging runners to adopt movement patterns that increase joint stress, particularly at the knee (Bonacci et al., 2013). This phenomenon highlights a critical limitation of footwear-based interventions, as the reduction of perceived discomfort does not necessarily correspond to a reduction in underlying biomechanical strain.

In addition to knee related injuries, impact forces in shod running have been linked to broader patterns of musculoskeletal stress affecting the lower extremities. High loading rates and repetitive ground contact forces contribute to the development of stress related conditions such as tibial stress syndrome and joint degeneration over prolonged periods of activity. Research indicates that these injuries are often multifactorial, influenced by a combination of biomechanical, physiological, and training related variables (Ryan et al., 2014). Moreover, variations in individual gait patterns and footwear design further complicate the relationship between impact forces and injury outcomes, suggesting that the effectiveness of cushioned shoes in preventing injuries may be limited and highly context dependent. Comparative analyses have also shown that while shod running may reduce localized stress on certain structures such as the foot, it often results in a redistribution of forces toward proximal joints, particularly the knee, thereby altering rather than eliminating injury risk (Squadrone & Gallozzi, 2009).

Overall, the injury patterns associated with shod running underscore the complex interaction between impact mechanics and joint loading, emphasizing that cushioning alone is insufficient as a protective mechanism. The persistence of knee dominant injuries and impact related stress highlights the need for a more comprehensive understanding of how footwear influences running biomechanics and injury development. These findings provide a critical foundation for evaluating alternative approaches such as barefoot running, which seek to modify loading patterns and potentially address some of the limitations observed in traditional shod running practices.

Research Gap:
Despite the expanding body of literature examining barefoot and shod running, a clear and unified consensus regarding their relative effectiveness in reducing injury risk remains absent. Existing studies present divergent findings, with some emphasizing biomechanical advantages associated with barefoot running while others highlight an increased susceptibility to specific injury types, particularly during the transition phase. Systematic evaluations of the literature indicate that variations in study design, participant characteristics, and definitions of injury contribute significantly to these inconsistencies, making it difficult to establish definitive conclusions (Perkins et al., 2014; Warne & Gruber, 2017). Additionally, prospective and observational studies have reported conflicting outcomes in relation to injury incidence, with some suggesting reduced rates of certain injuries in barefoot or minimalist runners, while others demonstrate no significant difference when compared to traditional shod running (Altman & Davis, 2016; Ryan et al., 2014). This lack of agreement underscores a fundamental limitation in current research, where isolated findings are often generalized without sufficient consideration of contextual and individual factors.

A critical gap within the literature lies in the tendency to interpret biomechanical changes as direct indicators of injury prevention without adequately examining how these changes translate into real world injury patterns. While barefoot running has been associated with reduced impact transients and altered loading mechanics, these adaptations do not necessarily eliminate mechanical stress but instead redistribute it across different anatomical regions. Evidence suggests that runners who adopt a forefoot strike pattern may experience decreased loading at the knee but increased stress on the foot and ankle complex, particularly affecting structures such as the metatarsals and Achilles tendon (Ridge et al., 2013; Fuller et al., 2016). Similarly, variations in foot strike patterns and running surfaces indicate that biomechanical responses are highly individualized and cannot be universally applied across populations (Hatala et al., 2013). This phenomenon highlights that injury risk is not removed but rather shifted, with different running styles predisposing individuals to distinct categories of injuries.

Furthermore, many studies fail to account for the dynamic process of adaptation, which plays a crucial role in determining injury outcomes. Runners transitioning from shod to barefoot conditions often undergo significant neuromuscular and structural adjustments, and insufficient adaptation has been linked to increased injury risk during this period (Hollander et al., 2019). The absence of long term longitudinal studies further limits the ability to assess whether observed benefits or risks persist over time or are primarily associated with short term changes in running mechanics. As a result, the current evidence base lacks a comprehensive framework that integrates biomechanical alterations, adaptation processes, and injury outcomes into a cohesive understanding.

This gap highlights the need for a more holistic and comparative approach that simultaneously examines biomechanics and injury patterns rather than treating them as independent variables. Addressing this limitation is essential for developing evidence based recommendations and for clarifying whether barefoot running represents a genuinely safer alternative or simply a different distribution of mechanical stress within the lower limb.

Methodology:

The present study adopts a comparative and descriptive research design grounded in a structured literature-based approach, aimed at synthesizing existing empirical evidence on barefoot and shod running. This design is particularly appropriate given the complexity of the research problem, which requires the integration of biomechanical data with injury related outcomes rather than reliance on a single experimental dataset. A literature-based methodology enables the examination of a wide range of controlled and observational studies, thereby providing a more comprehensive understanding of how different running conditions influence lower limb biomechanics and injury patterns. Previous scholarly work has emphasized the importance of comparative synthesis when addressing multifactorial issues such as running related injuries, where variability in individual biomechanics and training conditions plays a significant role (Perkins et al., 2014; Warne & Gruber, 2017). By adopting this approach, the study is able to critically evaluate and compare findings across multiple research contexts, ensuring a balanced and evidence based analysis.

The data for this study have been collected exclusively from peer reviewed journal articles to ensure the credibility and academic rigor of the analysis. Reputable databases such as PubMed, Google Scholar, and other recognized scientific indexing platforms have been utilized to identify relevant studies within the domain of sports biomechanics and injury prevention. The selection of sources has been guided by their relevance to the research topic, methodological soundness, and contribution to understanding the relationship between running mechanics and injury risk. Prior research has demonstrated that systematic retrieval of peer reviewed literature from established databases enhances the reliability of findings and minimizes the inclusion of non validated or anecdotal evidence (Hryvniak et al., 2014). This methodological rigor is essential for maintaining the integrity of the study and ensuring that conclusions are drawn from scientifically validated sources.

To maintain consistency and relevance, specific inclusion criteria have been established for the selection of studies. Only those studies that focus on recreational runners have been considered, as this population represents the primary focus of the research and exhibits distinct biomechanical and injury characteristics compared to elite athletes. Additionally, selected studies are required to address both biomechanical aspects and injury related outcomes, ensuring that the analysis captures the interaction between movement patterns and injury development. Emphasis has also been placed on recent and relevant research to reflect current advancements in the field and to incorporate contemporary perspectives on barefoot and shod running. This selective approach is supported by existing literature, which highlights the importance of clearly defined inclusion criteria in reducing bias and enhancing the validity of comparative research (Altman & Davis, 2016).

The study examines both independent and dependent variables to facilitate a structured comparative analysis. The independent variable is defined as the type of running condition, categorized into barefoot and shod running. The dependent variables include injury type, injury incidence, and key biomechanical parameters such as foot strike pattern, joint loading, and muscle activation. This classification allows for a systematic evaluation of how changes in running conditions influence biomechanical behavior and subsequent injury outcomes. Previous biomechanical studies have demonstrated that variations in footwear significantly alter load distribution and movement patterns, thereby affecting injury susceptibility (Fuller et al., 2016; Hall et al., 2013). By clearly defining these variables, the study ensures a focused and coherent analytical framework.

For data analysis, a thematic and comparative synthesis approach has been employed. This involves organizing the selected studies into thematic categories based on key variables such as foot strike patterns, joint loading, injury distribution, and adaptation processes. Within each theme, findings are critically compared to identify patterns, similarities, and discrepancies across studies. This method allows for the integration of diverse research outcomes into a cohesive narrative, providing a deeper understanding of the underlying mechanisms associated with barefoot and shod running. Thematic synthesis has been widely recognized as an effective approach for analyzing complex and heterogeneous data in sports science research, as it enables the identification of broader trends while preserving the contextual nuances of individual studies (Jahn et al., 2020). Through this analytical process, the study aims to generate meaningful insights that bridge the gap between biomechanics and injury research, ultimately contributing to a more comprehensive evaluation of running practices.

Results and Findings:

The analysis of the selected studies reveals consistent yet nuanced patterns in how barefoot and shod running influence foot strike behavior, impact forces, injury distribution, and adaptation processes among recreational runners. A prominent finding relates to the observable shift in foot strike patterns between the two running conditions. Runners who perform in barefoot conditions demonstrate a higher tendency to adopt a forefoot or midfoot strike, whereas those using conventional footwear predominantly exhibit a rearfoot strike pattern. This distinction has been widely documented and is closely associated with differences in how the body manages initial ground contact and subsequent force transmission (Lieberman et al., 2010). However, it is also evident that this transition is not uniform across individuals, as variations in technique, experience, and environmental conditions can influence strike patterns even within similar groups (Hatala et al., 2013). Moreover, research indicates that footwear alone does not entirely dictate strike pattern, as runners may maintain habitual movement strategies despite changes in external conditions (Shih et al., 2013). These findings suggest that while barefoot running encourages a modification in foot strike, the extent of change is influenced by individual adaptation and neuromuscular control.

In relation to impact forces and load distribution, the findings indicate a complex redistribution rather than a simple reduction of mechanical stress. Barefoot running is generally associated with lower impact transient peaks due to the absence of heel cushioning and the adoption of a forefoot strike, which allows for a more gradual application of force during ground contact (Divert et al., 2005). This altered loading pattern reduces the magnitude of forces transmitted to the knee joint, potentially lowering the risk of certain knee related injuries. However, the reduction in proximal loading is accompanied by an increase in demand on the distal structures of the lower limb, particularly the ankle joint and associated musculature. Studies have demonstrated that this shift results in greater reliance on the calf muscles and Achilles tendon for shock absorption and propulsion (Fuller et al., 2016). Additionally, comparative analyses have shown that barefoot running may influence the overall distribution of mechanical work across joints, with increased energy absorption occurring at the ankle and reduced contribution from the knee (Squadrone & Gallozzi, 2009). These findings reinforce the concept that barefoot running modifies the pathway of force transmission rather than eliminating mechanical stress.

The comparison of injury types between barefoot and shod runners further supports the notion of a redistribution of risk. Evidence indicates that shod runners are more likely to experience injuries associated with repetitive impact and joint loading at the knee, including patellofemoral pain and related conditions (Daoud et al., 2012). In contrast, barefoot runners demonstrate a higher prevalence of injuries affecting the foot and ankle, such as metatarsal stress fractures and Achilles tendinopathy, particularly during periods of inadequate adaptation (Ridge et al., 2013). Observational and survey based studies have also reported that injury patterns vary according to running experience and transition practices, with some runners experiencing initial increases in injury incidence before achieving adaptation (Hryvniak et al., 2014). Furthermore, research comparing different footwear conditions suggests that minimalist shoes do not fully replicate barefoot mechanics, leading to variations in injury outcomes that complicate direct comparisons (Bonacci et al., 2013). These findings highlight that injury risk is not inherently reduced in one condition over the other but is instead influenced by the interaction between biomechanics, training behavior, and individual physiology.

Adaptation emerges as a critical factor in determining both biomechanical outcomes and injury risk. The transition from shod to barefoot running requires significant neuromuscular and structural adjustments, including increased strength and endurance of the intrinsic foot muscles and improved coordination of movement patterns. Longitudinal studies have demonstrated that runners who undergo a gradual and structured transition exhibit more favorable biomechanical adaptations and a lower incidence of injury compared to those who adopt barefoot running abruptly (Hollander et al., 2019). Conversely, rapid changes in running style have been associated with an increased risk of stress related injuries due to insufficient time for tissue adaptation. Prospective research also suggests that injury rates between barefoot and shod runners may converge over time when appropriate adaptation strategies are followed, indicating that the initial transition phase plays a significant role in shaping outcomes (Altman & Davis, 2016). Collectively, these findings emphasize that the effects of barefoot running cannot be fully understood without considering the temporal

Journal of Molecular Science
Volume 36 Issue 2, Year of Publication 2026, Page 595-605
Journal of Molecular Science DoI-10.004687/1000-9035.2026.069

dimension of adaptation, as both benefits and risks are closely tied to how the transition is managed.

DISCUSSION:

The interpretation of the findings indicates that barefoot running does not function as a universal solution for injury prevention but instead alters the biomechanical pathways through which forces are distributed across the lower extremities, thereby influencing the type and location of injuries experienced by runners. The observed reduction in certain injuries, particularly those affecting the knee, can be attributed to the shift in foot strike pattern and the associated decrease in impact transients during ground contact. This modification reduces the magnitude of forces transmitted to proximal joints, which may lower the likelihood of repetitive stress injuries in the knee region (Lieberman et al., 2010). However, this apparent benefit is accompanied by an increased mechanical demand on distal structures, particularly the foot and ankle complex, where forces are absorbed more actively through muscular and tendinous mechanisms. As a result, barefoot running has been associated with a higher incidence of injuries such as metatarsal stress fractures and Achilles tendinopathy, especially in individuals who lack adequate conditioning or transition too rapidly (Ridge et al., 2013). This dual outcome highlights that barefoot running does not eliminate injury risk but redistributes it, reinforcing the importance of understanding injury mechanisms in relation to biomechanical adaptations rather than evaluating outcomes in isolation.

The concept of biomechanical tradeoffs further clarifies this relationship, as the reduction in knee loading is counterbalanced by increased stress on the foot and ankle structures. Studies examining joint kinetics have demonstrated that barefoot running reduces knee joint moments while simultaneously increasing plantarflexor demand, resulting in greater reliance on the calf muscles and Achilles tendon for shock absorption and propulsion (Fuller et al., 2016). This redistribution of mechanical work reflects a shift from passive to active load management, where the musculoskeletal system assumes a greater role in stabilizing and absorbing forces. While this may enhance functional strength and proprioceptive engagement over time, it also increases the risk of overload in tissues that may not be sufficiently adapted to handle these demands. Comparative analyses have shown that such trade offs are inherent to changes in running mechanics and cannot be entirely avoided, as improvements in one aspect of biomechanical efficiency often result in increased strain elsewhere in the kinetic chain (Hall et al., 2013). Consequently, the evaluation of barefoot running must consider these compensatory mechanisms rather than focusing solely on isolated benefits.

From a practical perspective, the findings suggest that barefoot running may be beneficial for certain individuals but is not universally appropriate for all runners. Those who may benefit include individuals with a history of knee related injuries, as the reduced loading at the knee joint could potentially alleviate symptoms and improve running comfort. Additionally, runners who are willing to adopt a gradual and structured transition process may experience improved neuromuscular control and foot strength over time (Hollander et al., 2019). Conversely, individuals with pre existing conditions affecting the foot or Achilles tendon, as well as those who lack adequate strength or attempt an abrupt transition, may be at a higher risk of injury. Evidence indicates that improper adaptation is a significant factor contributing to injury incidence in barefoot running, emphasizing the need for progressive training protocols and individualized approaches (Warne & Gruber, 2017). These considerations highlight that the effectiveness of barefoot running is highly dependent on context, including the runner's physical condition, training habits, and adherence to appropriate transition strategies.

When compared with previous studies, the present findings align with the broader consensus that barefoot running produces meaningful changes in biomechanics but does not conclusively reduce overall injury rates. Earlier systematic reviews and comparative studies have similarly reported that while barefoot or minimalist running may lower impact forces and alter movement patterns, these changes are accompanied by a shift in injury distribution rather than a reduction in total injury incidence (Perkins et al., 2014; Altman & Davis, 2016). Furthermore, research examining injury patterns across different running conditions has consistently demonstrated variability in outcomes, reflecting the influence of individual differences and methodological diversity (Ryan et al., 2014). The consistency of these observations across multiple studies strengthens the argument that the relationship between running style and injury risk is complex and multifactorial. Overall, the findings contribute to the existing body of knowledge by reinforcing the need for a balanced and integrative perspective that considers both the benefits and limitations of barefoot running within the broader context of recreational running practices.

CONCLUSION:

The findings of the present study indicate that barefoot running cannot be regarded as a universally safer alternative to conventional shod running, as its effects on injury risk are complex and context dependent. While barefoot running promotes biomechanical adaptations such as a forefoot or

Journal of Molecular Science
Volume 36 Issue 2, Year of Publication 2026, Page 595-605
DoI-10.004687/1000-9035.2026.069

midfoot strike pattern and reduced impact transients, these changes do not eliminate mechanical stress but instead alter its distribution across the lower extremities. Evidence suggests that reduced loading at the knee joint may contribute to a lower incidence of certain knee related injuries; however, this benefit is accompanied by increased stress on the foot and ankle structures, particularly the metatarsals and Achilles tendon (Lieberman et al., 2010; Ridge et al., 2013). This redistribution of mechanical load highlights that injury risk is not removed but shifted, with different running conditions predisposing individuals to distinct injury profiles. Furthermore, the role of adaptation emerges as a critical determinant of outcomes, as runners who transition gradually demonstrate more favorable biomechanical adjustments and lower injury incidence compared to those who adopt barefoot running abruptly (Hollander et al., 2019). The overall evidence therefore supports the conclusion that barefoot running represents an alternative running strategy with specific advantages and limitations rather than a definitive solution for injury prevention. A balanced and individualized approach is essential when considering its application in recreational running.

RECOMMENDATIONS:

Based on the findings, it is recommended that individuals who choose to adopt barefoot running should follow a gradual and structured transition protocol to allow sufficient time for neuromuscular and musculoskeletal adaptation. Sudden changes in running style have been associated with an increased risk of stress related injuries, particularly in the foot and ankle region, emphasizing the importance of progressive exposure and controlled training increments (Warne & Gruber, 2017). Incorporating targeted strengthening exercises for the intrinsic foot muscles and calf complex is also advisable, as enhanced muscular capacity can improve shock absorption and reduce the likelihood of overload injuries. Additionally, barefoot running may be more effectively utilized as a supplementary training method rather than a complete replacement for shod running, allowing runners to benefit from improved proprioception and muscle activation without excessive strain. From a research perspective, there is a need for more comprehensive longitudinal studies that examine the long term effects of barefoot running on injury risk, as current evidence is largely based on short term observations and may not fully capture adaptation over time (Perkins et al., 2014). These recommendations aim to promote safer implementation and encourage a more evidence based approach to running practices.

LIMITATIONS:

The present study is subject to several limitations that should be considered when interpreting the findings. One of the primary limitations is the lack of long term data within the existing literature, as many studies focus on short duration interventions or observational analyses that do not fully account for the effects of prolonged adaptation. This restricts the ability to draw definitive conclusions regarding the sustained impact of barefoot running on injury risk over extended periods. Additionally, there is considerable variability in study designs, including differences in sample size, participant characteristics, and methodological approaches, which contributes to inconsistencies in reported outcomes and limits the comparability of findings across studies (Altman & Davis, 2016). Another important limitation relates to individual differences in biomechanics, training history, and physical conditioning, which influence how runners respond to changes in footwear and running style. Such variability makes it difficult to generalize results to all populations, particularly when considering the diverse nature of recreational runners. These limitations highlight the need for more standardized research frameworks and emphasize caution in interpreting and applying current evidence.

REFERENCES:

1. Lieberman, D. E., Venkadesan, M., Werbel, W. A., Daoud, A. I., D'Andrea, S., Davis, I. S., Mang'Eni, R. O., & Pitsiladis, Y. (2010). Foot strike patterns and collision forces in habitually barefoot versus shod runners. *Nature, 463*(7280), 531–535. https://doi.org/10.1038/nature08723
2. Ridge, S. T., Johnson, A. W., Mitchell, U. H., Hunter, I., Robinson, E., Rich, B. S., & Brown, S. D. (2013). Foot bone marrow edema after a 10-week transition to minimalist running shoes. *Medicine & Science in Sports & Exercise, 45*(7), 1363–1368. https://doi.org/10.1249/MSS.0b013e3182874769
3. Perkins, K. P., Hanney, W. J., & Rothschild, C. E. (2014). The risks and benefits of running barefoot or in minimalist shoes: A systematic review. *Sports Health, 6*(6), 475–480. https://doi.org/10.1177/1941738114546846
4. Hollander, K., Liebl, D., Meining, S., Mattes, K., & Willwacher, S. (2019). Adaptation of running biomechanics to repeated barefoot running: A randomized controlled study. *The American Journal of Sports Medicine, 47*(8), 1975–1983.
5. Altman, A. R., & Davis, I. S. (2016). Prospective comparison of running injuries between shod and barefoot runners. *British Journal of Sports Medicine, 50*(8), 476–480.
6. Divert, C., Mornieux, G., Baur, H., Mayer, F., & Belli, A. (2005). Mechanical comparison of barefoot and shod running. *International Journal of Sports Medicine, 26*(7), 593–598.
7. Hatala, K. G., Dingwall, H. L., Wunderlich, R. E., & Richmond, B. G. (2013). Variation in foot strike patterns during running among habitually barefoot populations. *PLOS ONE, 8*(1), e52548.
8. Hanson, N. J., Berg, K., Deka, P., Meendering, J. R., & Ryan, C. (2011). Oxygen cost of running barefoot vs. shod. *International Journal of Sports Medicine, 32*(6), 401–406.
9. Kerrigan, D. C., Franz, J. R., Keenan, G. S., Dicharry, J., Della Croce, U., & Wilder, R. P. (2009). The effect of running shoes on lower extremity joint torques. *PM&R,*

Journal of Molecular Science
Volume 36 Issue 2, Year of Publication 2026, Page 595-605
DoI-10.004687/1000-9035.2026.069

1(12), 1058–1063.
10. Fuller, J. T., Buckley, J. D., Tsiros, M. D., Brown, N. A., & Thewlis, D. (2016). Redistribution of mechanical work at the knee and ankle during running in minimalist shoes. *Journal of Athletic Training, 51*(10), 794–802.
11. Yong, J. R., Silder, A., & Delp, S. L. (2014). Differences in muscle activity between natural forefoot and rearfoot strikers during running. *Journal of Biomechanics, 47*(15), 3593–3597.
12. Futrell, E. E., Jamison, S. T., Tenforde, A. S., & Davis, I. S. (2018). Relationships between cadence, footstrike, and vertical load rates in runners. *Medicine & Science in Sports & Exercise, 50*(9), 1837–1841.
13. Warne, J. P., & Gruber, A. H. (2017). Transitioning to barefoot running: Effects on foot strike, mechanics, and injury risk. *Sports Medicine, 47*(9), 1647–1659.
14. Daoud, A. I., Geissler, G. J., Wang, F., Saretsky, J., Daoud, Y. A., & Lieberman, D. E. (2012). Foot strike and injury rates in endurance runners. *Medicine & Science in Sports & Exercise, 44*(7), 1325–1334.
15. Squadrone, R., & Gallozzi, C. (2009). Biomechanical and physiological comparison of barefoot and two shod conditions in experienced runners. *Journal of Sports Medicine and Physical Fitness, 49*(1), 6–13.
16. Bonacci, J., Saunders, P. U., Hicks, A., Rantalainen, T., Vicenzino, B. G., & Spratford, W. (2013). Running in a minimalist and lightweight shoe is not the same as running barefoot. *British Journal of Sports Medicine, 47*(6), 387–392.
17. Hall, J. P. L., Barton, C., Jones, P. R., & Morrissey, D. (2013). The biomechanical differences between barefoot and shod running. *Journal of Foot and Ankle Research, 6*(1), 1–9.
18. Tam, N., Tucker, R., Santos-Concejero, J., Prins, D., & Lamberts, R. P. (2014). Running economy in barefoot vs. shod conditions. *Journal of Science and Medicine in Sport, 17*(4), 401–405.
19. Gruber, A. H., Silvernail, J. F., Brueggemann, P., Rohr, E., & Hamill, J. (2013). Footfall patterns during barefoot running on different surfaces. *Journal of Applied Biomechanics, 29*(5), 529–535.
20. Shih, Y., Lin, K., & Shiang, T. (2013). Is the foot striking pattern more important than footwear condition in running? *Gait & Posture, 38*(3), 490–494.
21. Goss, D. L., & Gross, M. T. (2012). Relationships among self-reported shoe type, footstrike pattern, and injury incidence. *US Army Medical Department Journal*, 25–30.
22. Ryan, M. B., Elashi, M., Taunton, J. E., Clement, D. B., & McKenzie, D. C. (2014). Examining injury risk in runners using minimalist footwear. *British Journal of Sports Medicine, 48*(16), 1257–1262.
23. Hryvniak, D., Dicharry, J., & Wilder, R. (2014). Barefoot running survey: Evidence from the field. *Journal of Sport and Health Science, 3*(2), 131–136. https://doi.org/10.1016/j.jshs.2014.03.008
24. Jahn, V. S., Correia, C. K., Dell'Antonio, E., Mochizuki, L., & Ruschel, C. (2020). Biomechanics of shod and barefoot running: A literature review. *Revista Brasileira de Medicina do Esporte, 26*(6), 1–6.
25. Lorenz, D. S., & Pontillo, M. (2012). Is there evidence to support a forefoot strike pattern in barefoot runners? *Sports Health, 4*(6), 480–484.