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CLINICAL AND EPIDEMIOLOGICAL CHARACTERISTICS AND ETIOLOGICAL FACTORS OF LONG BONE FRACTURES OF THE LOWER LEG

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Abstract

Fractures of the long bones of the lower leg, mainly involving the tibia and fibula, represent one of the most clinically significant groups of traumatic skeletal injuries. The tibia is especially vulnerable because of its subcutaneous anatomical position, limited soft-tissue coverage, and direct exposure to external mechanical forces. Tibial shaft fractures are widely regarded as one of the most common long-bone fractures and are frequently associated with high-energy trauma, road traffic accidents, occupational injuries, sports-related trauma, falls, and direct blows. The clinical relevance of these fractures is determined not only by their frequency, but also by the high risk of open injury, soft-tissue damage, compartment syndrome, infection, delayed union, malunion, nonunion, and long-term functional disability. Epidemiological studies show that tibial shaft fractures occur more commonly in males, especially young and economically active individuals, although falls and low-energy mechanisms become increasingly important among older patients. The incidence of tibial shaft fractures has been reported at approximately 16,9 per 100,000 population per year in one population-based study, with higher rates among men than women.

The aim of this article is to analyze the clinical-epidemiological characteristics and etiological factors of lower leg long bone fractures, with particular attention to age, sex, mechanism of injury, fracture morphology, soft-tissue involvement, and public health implications. A review of available literature demonstrates that

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the burden of these fractures is closely linked to trauma patterns, road safety, occupational exposure, sports activity, and demographic changes. Understanding the epidemiology and causative mechanisms of these injuries is essential for prevention, early diagnosis, treatment planning, and rehabilitation.

Keywords: Tibial fracture, fibular fracture, lower leg trauma, epidemiology, etiology, open fracture, road traffic accident, clinical characteristics.

Introduction

Long bone fractures of the lower leg are among the most important problems in modern traumatology and orthopedics. The lower leg consists primarily of two long bones: the tibia and the fibula. The tibia is the main weight-bearing bone, while the fibula provides lateral stability and serves as an attachment site for muscles and ligaments. Because of its superficial anatomical location, especially along the anteromedial surface, the tibia is poorly protected by soft tissues. This anatomical feature explains why tibial fractures are often accompanied by skin damage, open wounds, contamination, and a higher risk of infectious complications [1.2].

Among all lower limb injuries, fractures of the tibia and fibula occupy a special place because they affect walking, standing, working capacity, and general quality of life. Even when the fracture itself is treated successfully, recovery may be prolonged because the lower leg is exposed to constant mechanical loading. The patient often requires immobilization, surgical fixation, wound care, repeated radiological monitoring, physiotherapy, and gradual return to weight bearing. In severe cases, especially in open fractures, the treatment process may last for months and may require several surgical interventions [3.4].

The clinical-epidemiological importance of lower leg long bone fractures is also related to their occurrence in socially active age groups. Many patients are young adults injured in road traffic accidents, industrial trauma, sports injuries, or falls

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from height. This creates not only a medical problem, but also a social and economic burden because patients may temporarily or permanently lose their ability to work. At the same time, elderly patients represent another vulnerable group, in whom low-energy falls may cause fractures due to osteoporosis, reduced muscle strength, impaired balance, and chronic comorbid diseases.

Modern literature confirms that tibial shaft fractures are among the most common long-bone fractures and are clinically important due to the risk of compartment syndrome and open injury. In addition, population-based studies indicate that the incidence, age distribution, and mechanisms of tibial shaft fractures vary depending on sex, lifestyle, transport systems, occupational risk, and healthcare organization. For example, Larsen et al. reported an incidence of 16,9 tibial shaft fractures per 100,000 persons per year; males had a higher incidence than females, and the peak frequency differed between men and women.

Therefore, studying the clinical and epidemiological features of lower leg long bone fractures is essential for improving prevention, optimizing trauma care, reducing complications, and planning rehabilitation.

Aim of the Study

The aim of this article is to analyze the clinical-epidemiological characteristics and etiological factors of long bone fractures of the lower leg, with emphasis on tibial and fibular fractures, their distribution by age and sex, mechanisms of injury, clinical presentation, fracture type, and associated soft-tissue complications.

Materials and Methods

This article is based on a narrative review and analytical interpretation of current scientific literature devoted to fractures of the tibia and fibula. The reviewed sources included epidemiological studies, clinical reviews, orthopedic trauma references, and recent publications on lower limb fractures. Particular attention

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was paid to the incidence of tibial shaft fractures, common injury mechanisms, age and sex distribution, clinical manifestations, fracture morphology, and complications.

The main inclusion criteria for literature analysis were: publications discussing tibial and fibular fractures, lower limb long bone trauma, epidemiology of tibial shaft fractures, mechanisms of injury, open fractures, and clinical outcomes. Preference was given to peer-reviewed articles, orthopedic trauma references, and population-based studies.

The analysis focused on the following parameters:

age and sex distribution of patients; mechanism of injury; anatomical localization of fractures; open or closed nature of injury; fracture morphology; associated soft-tissue damage; clinical symptoms; complications; and preventive implications.

Anatomical and Clinical Background

The tibia is the second largest long bone in the human body and the principal weight-bearing bone of the lower leg. Its medial and anterior surfaces are located directly under the skin, which makes the bone vulnerable to direct trauma. The fibula is thinner and bears much less axial load, but it plays an important role in ankle stability and muscle attachment. In many injuries, fractures of the tibia and fibula occur together, especially when the trauma mechanism involves twisting, bending, crushing, or high-energy impact [1.4].

The anatomical features of the tibia determine the clinical behavior of its fractures. First, the limited soft-tissue envelope increases the risk of open fractures. Second, the blood supply of the tibial shaft may be compromised after severe injury, contributing to delayed union or nonunion. Third, swelling inside the fascial compartments of the lower leg may lead to acute compartment syndrome, which is a surgical emergency. Tibial shaft fractures are known to be strongly associated with compartment syndrome, and timely recognition is essential to prevent irreversible muscle and nerve damage [5.6].

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Clinically, patients with lower leg long bone fractures usually present with pain, swelling, deformity, inability to bear weight, abnormal mobility, local tenderness, and sometimes visible bone exposure in open fractures. Neurovascular examination is mandatory, because injury to vessels or nerves may seriously worsen the prognosis. Evaluation of skin condition is also crucial, especially in high-energy trauma, where extensive soft-tissue damage may be present even when the wound appears small.

Epidemiological Characteristics

The epidemiology of lower leg long bone fractures is influenced by demographic, geographical, social, occupational, and transport-related factors. In countries or regions with high rates of road traffic accidents, tibial and fibular fractures are frequently caused by motorcycle, automobile, pedestrian, and bicycle injuries. In industrial or agricultural settings, occupational injuries also contribute significantly. In children and adolescents, sports injuries and falls are important causes, whereas in older adults low-energy falls become more prominent [4.6].

Population studies show that tibial shaft fractures occur more often in men than in women. This is usually explained by greater exposure of men to traffic accidents, occupational risks, high-energy activities, and contact sports. Larsen et al. reported that the incidence of tibial shaft fractures was 21,5 per 100,000 per year in males and 12,3 per 100,000 per year in females. The same study found that males had the highest frequency between 10 and 20 years of age, while females had the highest frequency between 30 and 40 years of age [6.7].

Another important epidemiological feature is the age-dependent mechanism of trauma. In young patients, fractures are commonly associated with high-energy trauma, including road traffic accidents, sports injuries, and falls from height. In elderly patients, fractures may occur after simple falls due to osteoporosis, poor balance, and reduced protective reflexes. Recent global analyses of lower

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extremity fractures indicate that falls are a leading cause of lower extremity fracture burden, followed by road injuries and mechanical forces.

Open fractures are a particularly important subgroup. The tibia has a high risk of open injury because it is subcutaneous and poorly covered by muscles. Some trauma references report a high institutional variation in the proportion of open tibial fractures, depending on the population and trauma center profile. Open fractures are especially common after high-energy trauma and are often associated with contamination, bone loss, vascular damage, and soft-tissue defects.

Table 1. General clinical and epidemiological characteristics of lower leg long bone fractures

Parameter	Typical finding	Clinical significance
Main bones involved	Tibia, fibula, or both	Determines stability, treatment method, and rehabilitation
Most vulnerable bone	Tibia	Subcutaneous location increases risk of open fracture
Common age group	Young adults; elderly patients in fall-related injuries	Different prevention strategies are required
Sex distribution	More common in males	Linked to higher exposure to traffic, sport, and occupational trauma
Common mechanism	Road traffic accidents, falls, sports trauma, direct blow	Helps predict fracture pattern and soft-tissue damage
Frequent clinical signs	Pain, swelling, deformity, inability to bear weight	Basis for early clinical diagnosis
Serious complications	Open wound, infection, compartment syndrome, delayed union, nonunion	Require urgent recognition and specialized management
Diagnostic basis	Clinical examination and radiography	CT may be needed for complex intra-articular or comminuted injuries

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Etiological Factors

The etiology of lower leg long bone fractures is multifactorial. The immediate cause is usually mechanical force exceeding the strength of the bone. However, the type of force, direction of impact, patient age, bone quality, and protective conditions determine the final fracture pattern.

Road traffic accidents are one of the most important causes of tibial and fibular fractures, especially in young and middle-aged adults. Motorcyclists, cyclists, pedestrians, and car occupants may sustain direct impact injuries, twisting trauma, or crushing injuries. High-energy road trauma often produces comminuted fractures, segmental fractures, open fractures, and severe soft-tissue damage [7.8].

Falls are another major etiological factor. In young individuals, falls from height may generate high-energy trauma, while in elderly individuals even a fall from standing height may cause fracture. The role of falls is particularly important in older populations because osteoporosis, sarcopenia, visual impairment, neurological disorders, and polypharmacy increase the risk of falling and reduce bone resistance.

Sports injuries commonly occur during football, skiing, running, jumping, combat sports, and other activities involving sudden twisting, collision, or direct impact. These injuries may cause spiral, oblique, or transverse fractures depending on the mechanism. In adolescents and young adults, sports-related fractures may be associated with high physical activity and insufficient protective equipment [9.10].

Occupational trauma includes injuries sustained in construction, agriculture, mining, manufacturing, transport, and heavy machinery work. These fractures may occur due to falling objects, machinery accidents, falls from height, or crushing trauma. Occupational fractures are clinically important because they may be associated with contamination and combined injuries [9].

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Direct violence or assault may also cause fractures, especially transverse or comminuted patterns. In children, non-accidental injury must be considered when the history is inconsistent with the fracture pattern.

Pathological fractures are less common but clinically significant. They occur when bone strength is reduced by tumors, infection, metabolic bone disease, osteoporosis, chronic kidney disease-mineral bone disorder, or long-term medication effects. In such cases, even low-energy trauma may cause fracture.

Table 2. Main etiological factors and expected fracture characteristics

Etiological factor	Typical mechanism	Expected fracture pattern	Risk level for soft-tissue injury
Road traffic accident	High-energy direct impact, crushing, twisting	Comminuted, segmental, open fractures	High
Fall from height	Axial loading and bending force	Spiral, oblique, comminuted fractures	Moderate to high
Simple fall in elderly	Low-energy trauma with weak bone structure	Simple or metaphyseal fracture	Low to moderate
Sports injury	Rotation, collision, sudden loading	Spiral or oblique fracture	Usually moderate
Occupational injury	Heavy object impact, machinery trauma	Open, crushed, comminuted fracture	High
Direct blow or assault	Localized bending force	Transverse or comminuted fracture	Moderate
Pathological bone weakness	Minimal trauma	Variable, often low-energy fracture	Depends on underlying disease

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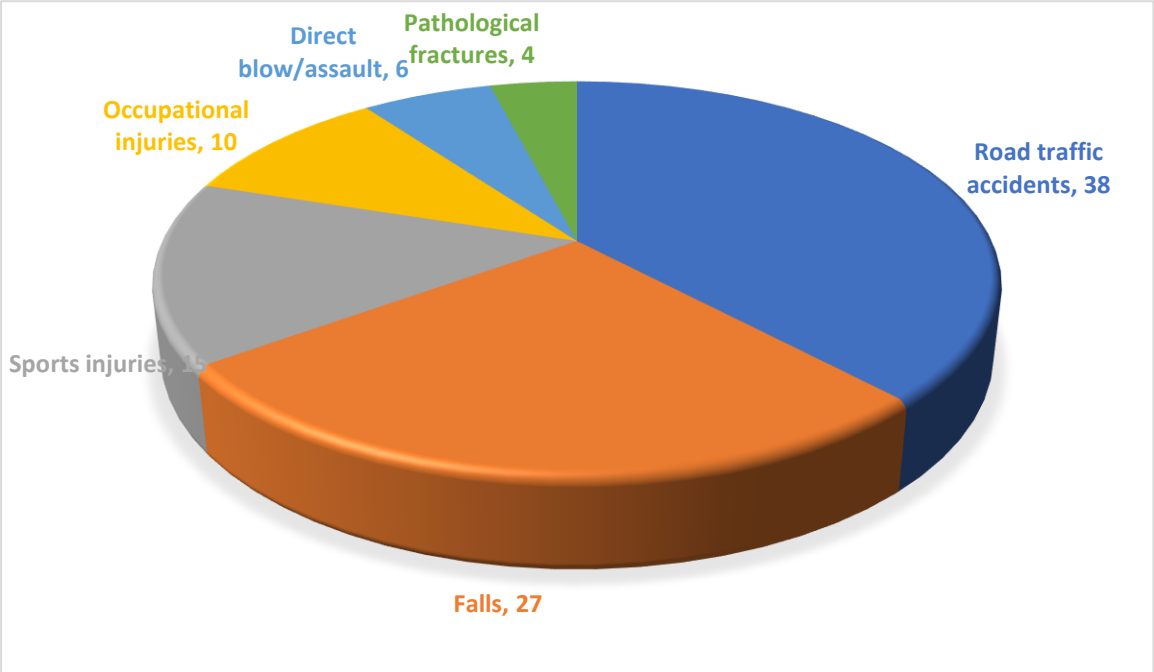

Figure 1. Approximate distribution of etiological factors in lower leg long bone fractures

The proposed diagram demonstrates that road traffic accidents represent the largest etiological group, accounting for approximately 38% of lower leg long bone fractures. Falls form the second largest group, with an estimated share of 27%. Sports injuries and occupational trauma are also clinically important, especially among young and economically active patients. Direct assault and pathological fractures account for smaller proportions, but their clinical relevance remains high because they may require specific diagnostic and therapeutic approaches.

Clinical Characteristics. The clinical presentation of lower leg long bone fractures depends on the severity of trauma, fracture location, degree of displacement, involvement of the fibula, soft-tissue damage, and neurovascular

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status. The most common symptoms are severe pain, swelling, inability to stand or walk, visible deformity, shortening or angulation of the limb, tenderness at the fracture site, and abnormal mobility. In closed fractures, skin integrity remains preserved, but swelling, bruising, and tension of soft tissues may be marked. In open fractures, the wound communicates with the fracture site, and bone fragments may be visible [8].

Pain is usually acute and increases with movement or palpation. The patient often holds the limb in a protective position. Swelling develops rapidly, especially after high-energy trauma, and may make clinical assessment difficult. Deformity suggests displacement, angulation, or shortening. Crepitus should not be intentionally elicited because unnecessary manipulation may worsen soft-tissue injury.

One of the most dangerous clinical conditions associated with tibial shaft fractures is acute compartment syndrome. It occurs when pressure within the fascial compartments rises and compromises tissue perfusion. Early signs include severe pain disproportionate to the injury, pain with passive stretch, tense swelling, sensory changes, and later motor weakness. Because delayed diagnosis can lead to necrosis, contracture, infection, amputation, or death, careful monitoring is essential in high-risk fractures.

Open fractures require special attention. The wound size may underestimate the depth and severity of injury. A small puncture wound may still communicate with a contaminated fracture site. Open tibial fractures are associated with a greater risk of infection, delayed union, nonunion, and need for repeated surgery. Therefore, early antibiotic therapy, tetanus prophylaxis, surgical debridement, stabilization, and soft-tissue coverage are central principles of management.

Fracture Morphology and Classification. Fracture morphology reflects the direction and magnitude of the traumatic force. Transverse fractures are usually caused by direct bending forces. Oblique fractures occur when force is applied at

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an angle. Spiral fractures are typical of rotational trauma. Comminuted fractures result from high-energy injury and are characterized by multiple fragments. Segmental fractures involve two separate fracture lines creating an isolated bone segment and are often associated with severe trauma.

The AO/OTA classification is widely used to describe tibial shaft fractures. AO-type 42 fractures refer to tibial shaft injuries. In a population-based study, AO type 42-A1 was reported as the most common tibial shaft fracture type, representing 34% of all tibial shaft fractures. Classification is important because it helps standardize communication among clinicians, predict stability, guide treatment choice, and compare outcomes in research [9.10].

Open fractures are often classified using the Gustilo-Anderson system, which considers wound size, contamination, soft-tissue damage, periosteal stripping, and vascular injury. Higher-grade open fractures have worse prognosis and require more complex management.

Diagnostic Approach. Diagnosis begins with history and physical examination. The physician should clarify the mechanism of injury, time of trauma, pain intensity, ability to bear weight, presence of open wounds, associated injuries, and previous diseases affecting bone quality. In high-energy trauma, the patient must be evaluated according to trauma principles because lower leg fractures may be part of polytrauma.

Plain radiography remains the first-line imaging method. Standard anteroposterior and lateral views of the tibia and fibula should include both the knee and ankle joints. This is necessary because associated injuries may be missed if imaging is limited only to the fracture site. Orthopedic trauma references emphasize that diagnosis of tibial shaft fractures is confirmed by radiographs including adjacent joints.

Computed tomography is useful in complex fractures, intra-articular extension, plateau or pilon involvement, and preoperative planning. Magnetic resonance

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imaging is not routinely required for acute shaft fractures but may be useful in stress fractures, occult injuries, ligamentous injury, or pathological lesions. Laboratory tests may be needed in open fractures, polytrauma, suspected infection, or metabolic bone disease.

Discussion

The analysis of clinical and epidemiological characteristics of lower leg long bone fractures demonstrates that these injuries are not homogeneous. Their features differ depending on patient age, sex, trauma mechanism, bone quality, and socioeconomic context. Young male patients are more frequently affected by high-energy trauma, especially road traffic accidents and sports injuries. In contrast, elderly patients often sustain fractures after falls, where bone fragility plays a major role.

The tibia is more clinically vulnerable than many other long bones because of its anatomical position. Its subcutaneous surface explains the high risk of open fractures and soft-tissue complications. This makes tibial fractures a complex problem requiring cooperation between traumatologists, orthopedic surgeons, emergency physicians, radiologists, rehabilitation specialists, and sometimes plastic surgeons.

The etiological structure of these fractures also has important implications for healthcare planning. A high proportion of road traffic injuries indicates the need for trauma prevention policies and emergency care readiness. A high proportion of fall-related fractures indicates the need for geriatric prevention and osteoporosis management. Occupational injuries point to the need for workplace safety. Thus, epidemiological analysis is not only descriptive but also preventive.

Clinically, the early period after injury is decisive. Delayed diagnosis of open fracture, vascular injury, or compartment syndrome may lead to severe consequences. Therefore, every patient with a suspected tibial or fibular fracture

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should undergo careful clinical examination, radiographic assessment, neurovascular evaluation, and repeated monitoring when swelling is significant.
The literature also shows that tibial shaft fractures are common enough to represent a significant burden for orthopedic trauma services. Their management may include conservative immobilization, intramedullary nailing, plate fixation, external fixation, wound debridement, and staged reconstruction depending on fracture type and soft-tissue condition. Although treatment methods are beyond the main focus of this article, epidemiological and etiological understanding is essential for choosing the correct therapeutic strategy.

Conclusion

Long bone fractures of the lower leg, particularly tibial and fibular fractures, represent a major clinical and public health problem. They are common traumatic injuries with a broad etiological spectrum that includes road traffic accidents, falls, sports injuries, occupational trauma, direct blows, and pathological bone weakness. The tibia is especially vulnerable due to its superficial anatomical location and limited soft-tissue protection, which increases the risk of open fractures, contamination, infection, delayed union, and compartment syndrome.
Epidemiologically, these fractures occur more often in males and frequently affect young, socially active individuals. However, elderly patients represent another important risk group because of fall-related and osteoporotic fractures. The mechanism of injury strongly influences fracture morphology, soft-tissue damage, treatment complexity, and prognosis.
A comprehensive understanding of the clinical and epidemiological characteristics of lower leg long bone fractures allows physicians to improve early diagnosis, prevent complications, choose appropriate treatment tactics, and develop targeted prevention programs. Road safety, fall prevention, workplace protection, and sports injury prevention should be regarded as key directions for reducing the burden of these injuries.

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