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## Review

### A Comprehensive Review Of Athlete's Foot (Tinea Pedis) Etiology, Clinical Presentation, Diagnosis, And Management



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	<b>Abstract</b>
Published on: 29 May 2025	<p>Athlete's Foot, or Tinea Pedis, is the most prevalent superficial fungal infection of the skin, mainly caused by dermatophytes like <i>Trichophyton rubrum</i>, <i>T. mentagrophytes</i>, and <i>Epidermophyton floccosum</i>. This review covers its causes, clinical presentation, diagnosis, treatment, and future therapeutic strategies. The infection commonly affects the spaces between toes, soles, and sides of the foot, flourishing in moist environments such as public showers and locker rooms. Risk factors include excessive sweating, occlusive footwear, poor foot hygiene, and prolonged moisture exposure. High-risk groups include athletes, military personnel, diabetics, and immune-compromised individuals, who are more prone to complications like secondary bacterial infections and recurrence. Tinea Pedis appears in various forms interdigital, moccasin-type, and vesiculobullous each with distinct symptoms like itching, redness, scaling, and occasionally blisters. Diagnosis is mainly clinical but supported by KOH microscopy, fungal culture, and PCR testing. Mild cases are treated with topical antifungals such as azoles or allylamines, while more severe infections may require systemic drugs like terbinafine or itraconazole. Challenges include drug resistance and patient nonadherence. Preventive education and proper foot care are vital. Future directions include novel antifungal agents, nanotechnology-based delivery, faster diagnostics, and potential vaccines. A multidisciplinary and global approach is crucial to reducing the impact of Tinea Pedis.</p>
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	<b>Keywords:</b> Tinea Pedis, Athlete's Foot, Antifungal Therapy, Fungal Infection Diagnosis, Antifungal Resistance

## 1. INTRODUCTION

Athlete's foot, or Tinea pedis, is a superficial fungal infection mostly affecting the surface of the foot. The condition is mostly induced by fungi from the genera *Trichophyton*, *Epidermophyton*, and *Microsporum*,

which are classified as dermatophytes. Fungi has a unique ability to infiltrate keratinized tissues such as the stratum corneum of the skin, hair, and nails, utilizing keratin as a nutritional source[1]. Tinea pedis clinically manifests with various dermatological symptoms, ranging from minor scaling and erythema to more severe inflammation, vesiculation, and fissuring of the skin, predominantly affecting the interdigital spaces, plantar surfaces, and infrequently the dorsal aspects of the foot. The ailment acquired the moniker "athlete's foot" historically because of its prevalence among athletes engaged in sports that promote sweating and prolonged confinement of feet in snug footwear, creating an optimal habitat for fungal proliferation[2]. Tinea pedis is recognized to affect a broad demography, extending beyond just athletic groups. Pathophysiology is defined by the infiltration of dermatophytes into the epidermis, evading host immune responses and eliciting localized inflammation. Secondary bacterial infections, although usually confined to the superficial layers of the skin, aggravate the condition in immunocompromised individuals or those with diabetes mellitus, hence increasing morbidity. The persistent nature of the infection and its tendency to relapse pose further obstacles for clinical care. Tinea pedis must be distinguished from other dermatological disorders of the foot, such as eczema, psoriasis, or contact dermatitis. An appropriate diagnosis typically relies on clinical examination corroborated by laboratory tests, including potassium hydroxide (KOH) preparation and fungal culture.

### 1.1. Epidemiology and Global Burden

Tinea pedis is the most prevalent superficial fungal infection worldwide, significantly contributing to the global dermatological disease burden. The prevalence varies significantly according to geographic region, climate, economic level, and demographic characteristics. Epidemiological data indicate that 15–25% of the general population will have Tinea pedis at some point in their lives, with higher prevalence observed in tropical and subtropical regions due to warm and humid circumstances conducive to fungal proliferation. The prevalence is elevated in industrially developed nations among adults, especially males aged 20 to 50 years, although it can manifest in all age demographics[3]. The syndrome is prevalent in environments that encompass communal bathing and locker facilities, including gyms, swimming pools, military barracks, and dorms. The prevalence among sportsmen ranges from 10% to 70%, corroborating the association between recurrent exposure to humid conditions and the likelihood of fungal infection. Tinea pedis is frequently underdiagnosed due to the moderate nature of its symptoms or self-limiting progression in some instances; yet, it remains a persistent public health concern because of its chronicity and ability to cause significant discomfort, diminished quality of life, and consequences[4]. Secondary bacterial infections such as cellulitis or erysipelas in diabetes individuals might result in heightened morbidity and expenses. Financial implications encompass direct expenditures associated with medical consultations, antifungal treatment, and complication management, and indirect costs resulting from lost workdays and diminished productivity. In low- and middle-income countries, limited access to healthcare services and antifungal medications exacerbates the illness burden. The increasing population of immunocompromised persons, including those with HIV/AIDS, organ transplant recipients, and chemotherapy patients, contributes to a heightened incidence and severity of fungal infections, such as Tinea pedis[5-7].

### 1.2. Importance of Study

The public health and clinical importance of athlete's foot necessitates comprehensive understanding and effective management strategies. Despite its superficial nature, Tinea pedis holds significant importance for public health systems and individual quality of life worldwide. The persistent and chronic characteristics of the infection necessitate continuous medical attention and adherence to treatment protocols by patients. Investigating Tinea pedis is essential to address several significant challenges:

**Diagnostic Challenges:** Misdiagnosis is common because of its clinical resemblance to other dermatological disorders, leading to unsuitable or postponed treatment. Improved laboratory tests and clinical awareness can enhance diagnostic accuracy in geriatrics, hence optimizing outcomes[8].

**Relapse and Treatment Resistance:** The increasing utilization of antifungal agents has resulted in resistance to commonly given medications such as azoles and allylamines. The increase complicates treatment regimens and necessitates research into novel antifungal agents and combinations.

**Complications in Special Populations:** The condition may lead to significant consequences in diabetic and immunocompromised persons, necessitating targeted preventive and therapeutic approaches.

**Public Health Implications:** Athlete's foot facilitates the transmission of fungal infections in communal environments. Preventive education, hygiene, and prompt treatment are crucial to reduce transmission and alleviate burden.

**Economic Burden:** An understanding of the cost-effectiveness of various treatment modalities might impact healthcare policies and optimize resource utilization.

Moreover, recent advancements in mycology and molecular biology have elucidated fungal pathogenicity, host immunological responses, and antifungal resistance pathways, facilitating the creation of targeted pharmaceuticals and vaccines. Continued investigation in this area holds potential for enhancing the management and prevention of Tinea pedis.

In summary, athlete's foot is a medically significant infection characterized by widespread prevalence, intricate clinical manifestations, and substantial effects on health systems and quality of life. A meticulous examination of its origin, epidemiology, and clinical management is crucial for informing doctors, researchers, and public health professionals aiming to mitigate its impact[9-12].

## 2. Etiology and Epidemiology

### 2.1 Main Causative Organisms

Athlete's foot, or *Tinea pedis*, is predominantly caused by a group of dermatophytic fungi that can infect and metabolize keratinized tissues such as the epidermis, hair, and nails. The primary genera responsible for *Tinea pedis* include *Trichophyton*, *Epidermophyton*, and *Microsporum*. The most often isolated pathogens are *Trichophyton* species, particularly *Trichophyton rubrum* and *Trichophyton mentagrophytes*, with *Epidermophyton floccosum* following closely.

**Trichophyton rubrum:** This anthropophilic dermatophyte is the predominant worldwide etiological agent for the majority of *Tinea pedis* patients. It is specifically adapted to human hosts and is transmitted via direct skin contact or indirectly through infected fomites such as floors, towels, and footwear. *T. rubrum* infections are characterized by their chronic nature and elevated recurrence rate due to its ability to persist in keratinized tissue and evade immune elimination[13].

**Trichophyton mentagrophytes:** This species exhibits both anthropophilic and zoophilic traits, with certain strains capable of animal-to-human transmission. It is more prone to generate inflammatory lesions than *T. rubrum*, typically manifesting as vesicular or bullous *Tinea pedis* presentations. It exhibits a predilection for acute infections.

**Epidermophyton floccosum:** This species does not infect hair but can independently cause infections of the skin and nails. It is infrequently isolated yet remains a notable pathogen in many regions. It is anthropophilic and transmits through contact or fomites.

Other fungal pathogens, including non-dermatophyte molds and yeasts such as *Candida* species, can occasionally cause foot infections, particularly in immunocompromised individuals or as a result of secondary colonization. Nonetheless, the primary microorganisms responsible for athlete's foot are dermatophytes. The pathogenicity of these fungi is associated with the synthesis of keratinases and other proteolytic enzymes that degrade the keratin matrix, facilitating tissue invasion and persistence. Moreover, their cell wall constituents and metabolic byproducts induce host inflammatory responses responsible for clinical symptoms[14-17].

### 2.2 Factors Predisposing to Infection

The onset of *Tinea pedis* relies not only on the presence of infectious dermatophytes but also on many predisposing variables that facilitate fungal proliferation and compromise host defenses. They can be classified into three main categories: environmental, behavioral, and host-related factors.

**Humidity and Moisture:** Moisture is a critical environmental factor that promotes fungal proliferation. When encased in shoes or socks, the feet create a microclimate characterized by elevated moisture and temperature, especially in hot and humid conditions. Accumulation of sweat softens the stratum corneum, undermines the skin barrier, and facilitates fungal colonization and invasion. The heightened prevalence of *Tinea pedis* in tropical and subtropical regions can be elucidated by this[18].

**Occlusive Footwear:** Donning non-porous, snug footwear impedes air circulation around the foot, retaining perspiration and increasing local humidity. Prolonged occlusion maintains a warm, moist environment conducive to dermatophyte proliferation and persistence. Non-porous synthetic fabrics do not absorb moisture, exacerbating this problem. Properly ventilated footwear reduces the danger of fungal colonization. **Poor Hygiene:** Inadequate maintenance of foot hygiene, including infrequent washing and drying, facilitates the persistence of fungus. The buildup of dirt, sweat, and keratin debris on the feet forms a nutrient-rich environment for fungi. Furthermore, failing to change socks regularly or wearing unclean footwear increases the likelihood of fungal colonization.

**Communal Shower and Locker Amenities:** Public showers, gyms, and locker rooms are significant sources of infection. Dermatophyte spores can persist on moist floors and surfaces for extended durations. Walking barefoot in these regions optimizes direct exposure to infectious spores. The communal use of towels or footwear contributes to the spread of transmission[19].

Athletes are particularly vulnerable because to excessive perspiration, repetitive foot damage, and the usage of constrictive footwear. Physical activity is frequently linked to facilities featuring communal changing rooms and wet spaces. Moreover, minor skin abrasions resulting from physical activity or poorly fitting footwear undermine the skin barrier, facilitating fungal invasion. Additional susceptible variables include hyperhidrosis, previous fungal infections, and foot injuries that facilitate fungal entrance[20].

### 2.3 Populations at Risk

Certain groups exhibit a higher prevalence and susceptibility to *Tinea pedis* due to environmental exposures, physiological circumstances, or underlying disorders. It is essential to identify these populations to facilitate focused prevention and management.

- **Competitors:** Athletes, as the representative population, face heightened risk due to their continuous exposure to elements such as perspiration, restrictive footwear, communal locker rooms, and physical foot injuries. Tight-fitting athletic footwear, particularly in sports like as running, soccer, and basketball, is frequently associated with *Tinea pedis*. The prevalence among athletes is reported to range from 10% to 70%, depending on the sport and hygiene practices[21].
- **Military Personnel:** Troops are frequently deployed in settings that promote fungal infections, including prolonged boot wear, limited access to hygiene facilities, and exposure to humid environments. *Tinea pedis* has frequently been documented in military settings, leading to operational incapacitation.
- **Diabetic Patients:** Diabetes mellitus is associated with peripheral neuropathy, vascular insufficiency, and an impaired immune response, all of which increase susceptibility to infections like *Tinea pedis*. Individuals with diabetes sometimes experience reduced sensitivity in their feet, delaying the identification of infections and resulting in problems such as secondary cellulitis and foot ulcers. *Tinea pedis* in individuals with diabetes is a significant risk factor for more severe lower extremity infections.
- **Individuals with impaired immune systems:** Individuals with compromised immune systems, including those with HIV/AIDS, organ transplant recipients, cancer patients undergoing chemotherapy, and individuals receiving long-term corticosteroid therapy, exhibit increased vulnerability to fungal infections. Immunosuppression diminishes the host's capacity to eradicate fungal infections, resulting in more severe and unusual presentations of *Tinea pedis*. Immunocompromised people are also vulnerable to the spread of concurrent systemic fungal infections.
- **Elderly and Institutionalized Individuals:** Advanced age is associated with diminished immunity, less mobility, and occasionally inadequate personal cleanliness, all of which elevate the risk. Residents of long-term care facilities or hospitals may encounter environmental sources of dermatophytes and possess comorbidities that increase their vulnerability to infection.
- **Additional Risk Categories:** Extended exposure to wet work environments or lifestyles (e.g., fishermen, agricultural laborers), individuals living in tropical regions, and those utilizing communal bathing facilities exhibit an increased incidence[22-24].

## 3. Pathogenesis

### 3.1 Mechanism of Fungal Infection

The pathogenesis of Athlete's foot (*Tinea pedis*) is a multifaceted process that commences with the introduction and colonization of the skin's surface by dermatophyte fungus and culminates in the manifestation of clinical indications of infection. Dermatophytes are keratinophilic fungi that possess the unique ability to infiltrate and degrade keratinized tissues, including the stratum corneum of the skin, hair shafts, and nails. The infectious cycle commences when fungal spores (conidia) or hyphal fragments come into contact with the host's skin, often through direct person-to-person transmission or indirectly via contaminated surfaces such as floors, towels, and footwear.

Dermatophytes, adhering to the stratum corneum, employ various enzymatic agents, primarily keratinases, to hydrolyze keratin, facilitating their invasion of the outer skin layers. The proteolytic enzymes hydrolyze keratin proteins into peptides and amino acids, which serve as substrates for fungal growth and development. This invasion mostly affects the exterior, non-living epidermis; the fungi typically do not penetrate live tissue, which limits the depth of infection while allowing persistence on the skin surface. Dermatophytes also secrete additional extracellular enzymes, including elastases, lipases, and collagenases, which may promote tissue invasion and inflammation. The cell wall constituents of fungi, including mannans and  $\beta$ -glucans, are crucial in regulating the host immunological response and evading host defense mechanisms[25].

The physical and biochemical disruption caused by fungal proliferation leads to the characteristic clinical manifestation of *Tinea pedis*, which includes erythema, scaling, and vesiculation. In certain cases, especially with more inflammatory species such as *Trichophyton mentagrophytes*, immunological reactions can result in blister formation and intense pruritus.

### 3.2 Host Immune Response

The host immune response to dermatophyte infection involves a complex interplay between adaptive and innate immunity to inhibit fungal proliferation and eradicate the infection. The skin serves as the primary defense mechanism, providing a physical barrier and a store of immune cells that identify and respond to fungal invasion.

## Innate Immunity

The first identification of dermatophytes is facilitated by pattern recognition receptors (PRRs), such as Toll-like receptors (TLRs) and C-type lectin receptors (CLRs), present on keratinocytes, dendritic cells, and macrophages. These pattern recognition receptors (PRRs) identify conserved fungal cell wall components such as  $\beta$ -glucans and mannans, triggering signaling pathways that lead to the secretion of pro-inflammatory cytokines (e.g., IL-1 $\beta$ , IL-6, TNF- $\alpha$ ) and chemokines. This inflammatory milieu draws neutrophils and more immune cells to the site of infection, facilitating the eradication of fungus. Keratinocytes contribute to defense by secreting antimicrobial peptides (AMPs) such as defensins and cathelicidins, which have direct antifungal properties. Furthermore, the acidic pH of the skin, in conjunction with commensal bacteria, renders the environment inhospitable for fungal proliferation[26].

The adaptive immune response is essential for the long-term management and eradication of infection. Dendritic cells digest fungal antigens and present them to T cells in regional lymph nodes, triggering a cell-mediated immune response characterized by T-helper 1 (Th1) and T-helper 17 (Th17) cells. Th1 cells secrete interferon-gamma (IFN- $\gamma$ ), which activates macrophages to enhance fungus eradication. Th17 cells secrete IL-17 and IL-22, cytokines essential for neutrophil recruitment and enhancing epithelial barriers. Dermatophytes have, however, evolved mechanisms to evade or manipulate host immunity. Fungal mannans can suppress T cell proliferation and reduce keratinocyte AMP synthesis, facilitating the persistence of infection. In some individuals, an insufficient or dysregulated immune response may lead to chronic or recurrent infections.

## Hypersensitivity Reactions

In certain cases, particularly with *T. mentagrophytes* infections, the immune response may become excessive, leading to hypersensitivity reactions manifesting as vesicles or bullae, referred to as vesiculobullous *Tinea pedis*. They involve immune complex deposition and complement dependency, resulting in significant inflammation and discomfort.

### 3.3 Environmental Influences

Environmental factors are crucial in the development and progression of Athlete's foot, since they dictate the local microenvironment of the foot, host susceptibility, and fungal viability.

- **Humidity and Temperature:** Heat and moisture are the primary catalysts for dermatophyte proliferation. The feet, especially when enclosed in shoes and socks, create an ideal microclimate characterized by elevated warmth and humidity. Accumulation of sweat relaxes the stratum corneum, facilitating fungal adherence and invasion. Tropical and subtropical areas exhibit the highest prevalence rates due to consistently elevated temperatures and humidity, facilitating year-round fungus colonization[27].
- **Shoes and Occlusion:** Prolonged use of constrictive, impermeable footwear creates an airtight environment that obstructs sweat evaporation and traps heat. Non-wicking synthetic materials exacerbate the issue. These settings retain the moisture needed for fungal proliferation and impede the resolution of infection.
- **Hygiene and Behavioral Measures:** Inadequate foot hygiene, including insufficient washing and drying, sharing towels, and infrequent sock changes, promotes fungal persistence and dissemination. Walking barefoot in communal areas such as locker rooms, swimming pools, and showers exposes them to infectious fungus spores present on moist surfaces.
- **Prolonged stress:** The feet from sporting activities or inadequate footwear can lead to minor skin abrasions or maceration, compromising the integrity of the skin barrier. These holes facilitate fungal invasion and increase vulnerability to infection.
- **Host-Related Environmental Influences:** Hyperhidrosis and certain occupations characterized by prolonged contact to moisture (e.g., fishermen, agricultural laborers) increase the risk by fostering warm, humid skin conditions that promote fungal proliferation[28].

## 4. Clinical presentation

### 4.1. Types and Patterns of Tinea Pedis

*Tinea pedis*, often known as Athlete's Foot, manifests in various clinical forms, each characterized by unique attributes influenced by the fungus species, host, and environmental factors. The interdigital form is the most common and typically affects the fourth and fifth interdigital gaps between the toes. It is marked by maceration, scaling, fissuring, and occasionally malodor due to bacterial superinfection. Patients frequently complain itching, burning, and discomfort, especially after prolonged usage of occlusive footwear. The moccasin-type, or chronic hyperkeratotic type, is characterized by scaling, erythema, and thickening of the soles, heels, and lateral aspects of the foot, resembling a moccasin appearance. This condition is typically chronic and resistant, frequently worsened by *Trichophyton rubrum* and also affecting the nails. The vesiculobullous variant exhibits a more acute onset, characterized by the development of bullae or vesicles on the medial plantar surface. The fluid-filled lesions may burst, leading to erosions and crusting, often accompanied by intense pruritus or discomfort. *T. mentagrophytes* is a common etiological factor in this more

inflammatory manifestation. Finally, the ulcerative variant, although uncommon, is the most severe and predominantly observed in immunocompromised individuals or those with diabetes. It is marked by widespread maceration, erosions, and profound ulcers, with a risk of secondary bacterial infection. These forms may overlap in individual individuals, necessitating meticulous clinical evaluation to guide suitable treatment and prevent recurrence[29].

#### 4.2. Signs and Symptoms

The manifestations and indicators of Tinea pedis vary according to the clinical kind and severity of the illness, however certain common characteristics are noted. The predominant symptom is pruritus, often exacerbated post-footwear removal or during the night. The burning or stinging sensation manifests in patients with fissures or vesicular lesions. Desquamation and scaling of the epidermis, especially on the plantar surfaces or interdigital spaces, are distinctive characteristics. In interdigital presentations, the skin is macerated, wet, and pale, accompanied by fissures that may be unpleasant and sensitive. The moccasin variant typically has extensive dry scaling and hyperkeratosis affecting the soles and lateral aspects of the foot, possibly accompanied by thickened, lacerated skin. The vesiculobullous variant is distinguished by the formation of fluid-filled vesicles or bullae, which may rupture, resulting in exposed, degraded areas. In more severe or ulcerative forms, profound erosions or ulcers may develop, accompanied by edema, erythema, and a malodorous scent resulting from bacterial infection. Individuals may present with indications of onychomycosis, characterized by swollen, discolored, or brittle toenails, which can serve as a reservoir for reinfection. Complications like bacterial superinfection or dermatophytid responses may result in symptoms extending beyond the foot, leading to systemic pain and further skin eruptions in other body regions.

#### 5. Diagnosis

The diagnosis of Tinea pedis, often known as athlete's foot, requires a combination of clinical assessment and corroborative laboratory examinations. Accurate diagnosis is crucial, as erroneous identification may result in misguided therapies, postponed symptoms, or recurrence. The diagnostic process is often systematic, commencing with a physical examination, followed by confirmatory testing if required. It is essential for doctors, especially dermatologists and general practitioners, to recognize the nuances of each diagnostic test and differentiate Tinea pedis from other dermatological conditions[30].

##### 5.1 Clinical Diagnosis

Clinical diagnosis remains the primary method for identifying Tinea pedis and is typically sufficient for uncomplicated cases. A comprehensive history and physical examination are important to the process. The patient typically reports pruritus, burning sensations, stinging, desquamation, and foul odor, particularly between the toes or on the plantar surface. The lesions may be chronic or acute and typically correspond to the subtype of Tinea pedis: interdigital, moccasin-type, vesiculobullous, or ulcerative. Clinicians assess the shape and distribution of the lesions. The interdigital type often manifests as fissured, white, macerated skin between the fourth and fifth toes, whereas the moccasin-type appears as a widespread, scaly eruption across the soles and lateral surfaces of the feet. The vesiculobullous form is marked by the sudden emergence of blistering vesicles, while the ulcerative kind is defined by erosions and subsequent infections in immunocompromised individuals. Diagnostic indicators include onychomycosis, unilateral manifestation, lack of response to over-the-counter treatments, and a history of exposure to locker rooms, communal showers, or restrictive footwear. In certain cases, the clinical presentation may be atypical or mimic other dermatoses, necessitating additional investigations.

##### 5.2 Laboratory Investigations

In cases with equivocal clinical presentations or when confirmation is necessary prior to commencing systemic antifungal treatment, laboratory investigations are utilized. These tests differentiate Tinea pedis from non-fungal dermatoses and yield pathogen-specific information for targeted treatment.

##### Potassium Hydroxide (KOH) Preparation

The KOH preparation is a quick, economical, and extensively utilized diagnostic technique for identifying dermatophytes. This method entails obtaining skin scrapings, typically from the afflicted regions like the interdigital spaces or plantar surfaces, and putting them on a glass slide. A 10–20% potassium hydroxide solution is applied to breakdown keratin, facilitating the visualization of fungal components under a light microscope. Clinicians seek septate, branching hyphae, which signify dermatophyte infection. The test exhibits considerable specificity but inconsistent sensitivity, frequently influenced by sample quality and operator proficiency. KOH preparation can swiftly verify the existence of fungi, but it is unable of identifying the precise species present. False negatives may arise from inadequate sample collection or prior antifungal administration.

Notwithstanding its constraints, KOH preparation continues to be an essential first-line diagnostic instrument in outpatient and primary care environments owing to its rapidity and affordability.

### **Fungal Culture**

The culture of fungus enables a definitive diagnosis by isolating and identifying the causal organism at the species level. Samples are inoculated onto selective media, such as Sabouraud dextrose agar, and thereafter incubated at 25–30°C for a duration of 4 weeks. Growth is periodically examined, utilizing both macroscopic and microscopic characteristics of colonies to identify the organism.

The predominant dermatophytes implicated in *Tinea pedis* include *Trichophyton rubrum*, *Trichophyton mentagrophytes*, and *Epidermophyton floccosum*. Culture is particularly beneficial in chronic, recurrent, or refractory diseases, or when the diagnosis remains ambiguous. Considering systemic antifungal treatment is crucial, since the selection of therapy may rely on species susceptibility.

The primary disadvantage of fungal culture is its extended turnaround time. Cultures may yield negative results in specific circumstances, even with active illness, especially if the patient has utilized topical antifungals prior to sample collection.

### **Molecular Methods**

Molecular diagnostic techniques are gaining prominence in mycology due to their high sensitivity and specificity, especially when traditional methods yield unsatisfactory results. The two most used molecular assays are polymerase chain reaction (PCR) and DNA sequencing, which detect fungal DNA directly from clinical samples. These techniques facilitate immediate and accurate identification of dermatophytes and allow for the separation between closely related species. They are particularly beneficial in atypical situations, in immunocompromised individuals, or when prompt conclusive diagnosis is required. Furthermore, they can detect fungi even in non-viable materials, making them valuable in instances where cultures yield negative results. Despite their advantages, molecular techniques are not universally adopted in clinical laboratories due to their high cost, requirement for specialized equipment, and lack of standardization among facilities. Nonetheless, they provide a promising enhancement to the diagnostic repertoire for dermatophytosis.

### **5.3 Differential Diagnosis**

The dermatological signs of *Tinea pedis* may mimic other dermatoses, making differential diagnosis a crucial step in the diagnostic procedure. Accurate distinction averts superfluous treatment and guarantees that patients receive appropriate care.

The most common imitators comprise eczema (dermatitis), particularly dyshidrotic eczema, characterized by vesicles on the lateral aspects of the feet. In contrast to *Tinea pedis*, eczema is typically bilateral, intensely pruritic, and non-infectious. Psoriasis, specifically palmoplantar psoriasis, may resemble moccasin-type *Tinea pedis* due to thick scaling and erythema; nevertheless, it is typically associated with nail pitting and a symmetric distribution.

Candidiasis is a notable differential diagnosis, particularly in macerated, moist toe web regions. Candidal infections typically present as a more intense red with satellite pustules, which are uncommon in dermatophytosis. Contact dermatitis resulting from shoe adhesives or topically applied substances may cause erythema, scaling, and pruritus; however, the distribution pattern is typically less localized to interspaces.

Erythrasma, a corneal bacterial infection caused by *Corynebacterium minutissimum*, may apparently resemble interdigital *Tinea pedis*. Erythrasma exhibits a coral-red fluorescence under Wood's lamp, distinguishing it from fungal infections, and is managed with antibacterials rather than antifungals.

Other differential diagnoses include pitted keratolysis, bacterial intertrigo, and keratoderma in patients with hyperkeratotic soles. Co-infections may occur in certain cases, confounding diagnosis further. Laboratory testing, especially KOH preparation and culture, are essential for distinguishing *Tinea pedis* from these illnesses.

## **6. Management and Treatment**

The management of *Tinea pedis* entails a multifaceted approach, incorporating pharmacological treatments both topical and systemic as well as supplementary and preventive strategies. While the majority of infections can be effectively treated with topical medication, severe, recurrent, or stubborn infections may require systemic antifungal treatment. A crucial element of effective care is the elimination of underlying predisposing factors and patient education to mitigate the chance of reinfection. Therapeutic resistance and recurrence present persistent clinical problems, often necessitating customized treatment protocols.

### **6.1. Topical Antifungal Agents**

Topical antifungals are the preferred treatment for the majority of uncomplicated instances of *Tinea pedis*. They are efficacious, secure, and well-tolerated with minimal systemic absorption. Agent selection is determined by the severity of the infection, the organism implicated, patient preferences, and financial

considerations. Allylamines, azoles, polyene derivatives, and contemporary agents such as ciclopirox and tolnaftate are the most commonly utilized category.

Among all allylamines, terbinafine is predominantly utilized due to its fungicidal properties, rapid alleviation of symptoms, and little recurrence rate. It functions by blocking squalene epoxidase, leading to the buildup of squalene and the rupture of fungal cell membranes. A single daily application for one to two weeks is typically sufficient in most instances. Azole antifungals, such as clotrimazole, miconazole, and ketoconazole, are fungistatic agents that inhibit ergosterol production. They are efficacious in addressing mild to severe infections, especially those induced by *Epidermophyton floccosum* and non-dermatophyte fungi.

Ciclopirox olamine exerts its inhibitory effect by the chelation of metal ions essential for fungal enzyme function, whereas tolnaftate disrupts the structure of fungal hyphae. Naftifine and butenafine are other agents exhibiting broad-spectrum antifungal efficacy and favorable pharmacokinetic profiles.

For best efficacy, topical antifungals should be administered consistently, typically twice daily for a duration of 2 to 4 weeks, contingent upon the specific medication. The moccasin and hyperkeratotic kinds may require extended treatment durations or keratolytic medicines to enhance medication penetration. Topical treatments are generally ineffective in treating vesiculobullous or ulcerative lesions and are unlikely to penetrate to fungi located in deeper tissues or nails. Adherence to topical treatment may be a constraint. Patient education on proper foot care, drying of interdigital spaces, application of powders or sprays to reduce moisture, and avoidance of occlusive footwear is crucial to prevent recurrence.

## 6.2. Systemic Antifungal Therapy

Systemic antifungal therapy is designated for extensive, persistent, or resistant *Tinea pedis*, or when concurrent onychomycosis is present, serving as a reservoir for infection. Oral antifungals offer profound tissue penetration and sustained activity; nevertheless, their administration must be weighed against potential adverse effects and medication interactions.

The primary systemic medications utilized are terbinafine, itraconazole, and fluconazole. Terbinafine, administered in 250 mg doses once day for 2-4 weeks, is highly effective due to its fungicidal properties and accumulation in keratinized tissues. Itraconazole, administered at a dosage of 200 mg once day or 100 mg twice daily for a duration of 1–2 weeks, demonstrates efficacy against both dermatophytes and yeasts, providing extensive coverage. Fluconazole, administered at a dosage of 150 mg per week or 50–100 mg per day for a duration of 2–6 weeks, is another treatment characterized by a favorable safety profile, particularly in instances of intolerance to other medications. Systemic therapy is particularly important in treating vesiculobullous, ulcerative, or moccasin-type *Tinea pedis* with nail involvement. Oral medication in this context ensures the eradication of fungal organisms from deeper tissues and reduces the likelihood of relapse. Systemic antifungals can cause side effects including hepatotoxicity, gastrointestinal disturbances, and interactions with other medications, particularly statins, anticoagulants, and benzodiazepines. Consequently, liver function tests may be recommended prior to and throughout treatment, especially in the context of prolonged medication. Appropriate patient selection and oversight are essential to avert adverse effects.

## 6.3. Adjunctive Therapies and Supportive Care

In addition to pharmaceutical medication, adjuvant therapy and supportive care are essential elements in the overall management of *Tinea pedis*. To attain sustained success and reduce the likelihood of recurrence, it is essential to address environmental and behavioral factors.

Upholding proper foot hygiene is fundamental to supplementary treatment. Patients should be instructed to cleanse their feet daily with soap and water, ensuring they are properly dried especially between the toes and to use antifungal powders or sprays to their footwear and socks. Loose, well-ventilated footwear and moisture-wicking socks are recommended, with shoes allowed to dry completely between uses. Disinfectant sprays and UV shoe sanitizers help eliminate residual fungus spores in footwear.

In cases of hyperkeratotic *Tinea pedis*, keratolytic agents such as urea, salicylic acid, or lactic acid formulations may be utilized to reduce scaling and enhance the absorption of topical antifungals. These treatments operate by weakening and exfoliating the stratum corneum, thus improving medication penetration to diseased tissue.

If a secondary bacterial infection is present common in the ulcerative form antibacterial therapy with topical or oral medicines may be warranted. Inflammation and pruritus can be managed with low-potency topical corticosteroids for brief durations; however, caution is advised as improper usage may exacerbate fungal infections or conceal them.

Patient education constitutes a fundamental component of supportive care. Patients must be informed about the chronic nature of the condition, the necessity for adherence to treatment, and the danger of recurrence. Individuals with immunocompromising diseases, such as diabetes or HIV, may require prolonged treatment and vigilant monitoring due to delayed recovery and heightened risk of consequences.



#### 6.4. Treatment Challenges and Resistance

Although effective antifungal medications are available, numerous issues complicate the treatment of *Tinea pedis*. Antifungal resistance, treatment nonadherence, concurrent onychomycosis, and diagnostic ambiguity with other dermatoses due to analogous clinical manifestations are among these factors. Resistance to antifungals, historically less common than bacterial resistance, has become a significant problem due to the emergence of *Trichophyton* resistance to terbinafine. Resistance has been linked to mutations in the squalene epoxidase gene. Failure in therapy despite adherence should prompt suspicion and necessitate review, including re-culturing and re-susceptibility testing if feasible.

Noncompliance with prescribed regimens is a primary cause of treatment failure and recurrence. Topical treatments require consistent application over a prolonged period, which some individuals may find bothersome. Incomplete therapy, improper application, and premature cessation following symptom alleviation are potential factors contributing to unsatisfactory outcomes.

Nail involvement (onychomycosis) complicates treatment significantly, acting as a reservoir for reinfection and requiring prolonged systemic therapy. If the fungal infection in the nails remains untreated, successful treatment of the skin may result in relapse. Misdiagnosis may result in a postponement of appropriate therapy. Eczema, psoriasis, and erythrasma can resemble *Tinea pedis*, leading to inappropriate administration of corticosteroids or antibacterial agents, which may obscure or worsen fungal infections through chronicity or atypical manifestations. Diagnostic verification using KOH preparation or fungal culture should be incorporated in ambiguous cases.

Moreover, recurrent and persistent instances generally signify prolonged environmental exposures and a lack of preventive activity. Reinfection from contaminated socks, shoes, floor surfaces, or communal spaces is common, particularly among athletes, military personnel, and individuals with hyperhidrosis.

Novel combination therapies such as the integration of topical antifungals with keratolytics or systemic medicines with adjuvants are being investigated to surmount these challenges. New antifungal agents with improved efficacy and less resistance potential are under research, promising future remedies for difficult-to-treat illnesses.

#### Future prospects

Advancements in the management and understanding of Athlete's Foot (*Tinea Pedis*) have significantly progressed over recent decades; nonetheless, numerous difficulties persist that require further research and innovation. The emergence of treatment-resistant dermatophyte strains, recurrent infections, limited antifungal options, and the lack of comprehensive public health strategies underscore the need for a multifaceted approach to effectively manage this prevalent superficial fungal infection in the future. A primary focus for future efforts is the development of novel antifungal agents. The prevailing treatment relies predominantly on azole and allylamine medication classes, with terbinafine and clotrimazole being among the most used. Resistance to terbinafine in the *Trichophyton mentagrophytes* complex and *Trichophyton rubrum* has now been documented globally. This heightened resistance underscores the necessity to produce antifungals with novel mechanisms of action and minimal risk of resistance emergence. Research and development is now under progress for squalene epoxidase inhibitors, chitin synthase inhibitors, and inhibitors targeting fungal cell wall biosynthesis. Furthermore, the application of nanotechnology-driven drug delivery systems such as lipid nanoparticles, micelles, and nanoemulsions shows potential in augmenting drug penetration into the stratum corneum and improving bioavailability, thereby enhancing therapeutic efficacy while minimizing systemic side effects.

Another area of focus is the advancement of diagnostic methodologies. Traditional techniques such as KOH microscopy and fungal culture, while cost-effective, suffer from low sensitivity and prolonged turnaround times. The future is characterized by the adoption of rapid molecular diagnostics such as real-time PCR, loop-mediated isothermal amplification (LAMP), and next-generation sequencing (NGS) for the identification of dermatophytes. These tools facilitate expedited and accurate diagnoses while allowing for the detection of mixed infections and antifungal resistance mutations, so enabling focused and more effective treatment. Moreover, point-of-care tools tailored for field applications and low-resource contexts will significantly enhance early diagnosis and reduce disease transmission in communal settings such as schools, sports facilities, and military barracks.

Exploring the immunopathogenesis of *Tinea pedis* is an essential area of research. The host defense mechanism, which includes innate protections such as skin barrier integrity and adaptive immunity through T-cell mediated responses, remains a promising area for research. Research aimed at identifying immune evasion mechanisms of dermatophytes, especially in chronic or recurrent infections, may facilitate the development of novel immunotherapeutic approaches. Future therapy may include vaccinations targeting essential dermatophyte antigens, topical immunomodulators, or biologic treatments that enhance host defensive systems against fungal infections. The development of a vaccine, now in its nascent phases for treating fungal infections, would confer extended immunity to high-risk populations such as athletes, diabetics, and immunocompromised individuals.

The integration of precision medicine in the treatment of dermatophytosis is a forward-thinking approach. Customized therapy regimens informed by individual patient characteristics, including genetic predisposition, immunological condition, lifestyle, and microbiota, are recognized to improve therapeutic effectiveness and minimize unwanted effects. For example, individuals with diabetes or peripheral vascular disease may require extended treatment or systemic medication. New evidence regarding the human skin microbiome and its interaction with dermatophytes may facilitate probiotic-based treatments or microbiota transplantation to restore natural microbial balance and prevent reinfection.

Public health policies and interventions at the policy level will be crucial for the future management of *Tinea pedis*. Athlete's foot is significantly underestimated regarding its disease burden, particularly in low- and middle-income countries, despite its high frequency. Future initiatives should incorporate comprehensive educational programs that stress foot hygiene, appropriate footwear usage, and early symptom identification. The establishment of antifungal resistance monitoring networks, like to antibiotic resistance surveillance, is essential for assessing treatment efficacy and guiding empirical therapy. Health care policies that enhance accessibility and cost of antifungal medications, along with regulations governing over-the-counter usage, can mitigate misuse and the development of resistance.

## CONCLUSION

Athlete's Foot (*Tinea pedis*) is the most common superficial fungal infection globally, affecting millions of individuals each year. Despite being predominantly a benign condition, its widespread occurrence, potential for chronicity, and frequency of recurrence establish it as a significant public health issue. The illness is mostly caused by dermatophyte fungi, specifically *Trichophyton rubrum*, *T. mentagrophytes*, and *Epidermophyton floccosum*. These germs thrive in warm, humid environments and are transmitted through direct contact with contaminated surfaces, infected individuals, or personal items. The infection typically affects the interdigital spaces, soles, or lateral aspects of the feet, with clinical manifestations ranging from mild scaling to severe fissuring, vesiculation, and pruritus. The diagnosis of *Tinea pedis* is primarily clinical but may be enhanced by laboratory techniques such as KOH microscopy, fungal culture, and, more recently, molecular diagnostics. Treatment often involves topical antifungal therapy for mild to moderate infections and systemic therapy for severe or refractory cases. Outcomes may be compromised by delayed diagnosis, inadequate adherence, co-morbidities, and the emergence of antifungal resistance.

This review indicates that *Tinea pedis* is not merely a cosmetic or unpleasant affliction, but a complex dermatological illness influenced by several environmental, immunological, and behavioral factors. The pathosis poses significant risks to specific populations, including athletes, military personnel, diabetics, and immunocompromised individuals, all of whom are more susceptible to infections and consequences. Recurrent sickness is a common issue, typically arising from inadequate eradication of the fungus, nonadherence to treatment, environmental reinfection, or untreated exposures. Despite appropriate treatment, the illness burden remains significant. This indicates a divergence between clinical efficacy and real-world effectiveness. Consequently, all forthcoming attempts must address this deficiency through improved diagnostic platforms, novel antifungal medicines, and interventions that enhance patient compliance. Advancements in medication delivery, including nanotechnology and transdermal devices, offer the potential for improved skin absorption and prolonged therapeutic efficacy. Further understanding of host-pathogen interactions, immunological responses, and fungal virulence determinants will provide novel opportunities for targeted therapies and vaccine development.

A crucial element for the future is global surveillance of antifungal resistance. Resistance to terbinafine, particularly among *Trichophyton* species, has emerged as a concerning global issue. Consistent surveillance and antifungal management are essential to preserve the efficacy of existing medications. Furthermore, enhancing awareness and adherence to cleanliness practices is crucial for disease prevention and reducing transmission rates. Public health initiatives that prioritize early diagnosis, adherence to treatment, and environmental sanitation will be crucial in mitigating the disease burden.

Athlete's Foot, however common and typically treatable, presents intricate challenges necessitating a comprehensive and forward-thinking approach. Healthcare professionals, researchers, public health authorities, and policymakers must collaborate to foster innovation, ensure the accessibility of effective medications, and educate at-risk populations. By implementing coordinated efforts in research, clinical practice, and public health, it is possible to reduce the incidence, severity, and recurrence of *Tinea pedis*, hence improving the global quality of life for affected individuals. The evolving landscape of fungal dermatology suggests that, with scientific advancement, education, and global collaboration, the burden of Athlete's Foot may be significantly reduced in the future.

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