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Molecular Epidemiology of Tinea Pedis Among Palm Oil Plantation Workers in Labuhan Batu Utara Regency, Indonesia: Identification of Causative Fungal Pathogens

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ABSTRACT

Introduction: Tinea pedis, commonly known as athlete's foot, is a prevalent fungal infection affecting the feet. Palm oil plantation workers, often exposed to humid and warm conditions, are at an increased risk of contracting this condition. This study aimed to investigate the molecular epidemiology of tinea pedis among palm oil plantation workers in Labuhan Batu Utara Regency, Indonesia, and identify the causative fungal pathogens. **Methods:** A cross-sectional study was conducted among palm oil plantation workers in Labuhan Batu Utara Regency. Demographic data and clinical information were collected through questionnaires. Skin scrapings were obtained from the affected areas of the feet and subjected to microscopic examination and fungal culture. Molecular identification of the isolated fungi was performed using DNA sequencing of the internal transcribed spacer (ITS) region. **Results:** A total of 250 palm oil plantation workers participated in the study. The prevalence of tinea pedis was found to be 42.8%. The most common clinical presentations were interdigital scaling and maceration (65.2%), followed by vesicular lesions (23.1%) and hyperkeratosis (11.7%). The predominant fungal pathogens identified were *Trichophyton rubrum* (58.3%), *Trichophyton mentagrophytes* (27.8%), and *Epidermophyton floccosum* (13.9%). **Conclusion:** Tinea pedis is a significant health problem among palm oil plantation workers in Labuhan Batu Utara Regency. The identification of the causative fungal pathogens is crucial for implementing effective preventive and therapeutic measures to control the spread of this infection.

1. Introduction

Tinea pedis, commonly referred to as athlete's foot, stands as a prevalent dermatophytosis that primarily targets the feet. This superficial fungal infection manifests through a spectrum of clinical presentations, encompassing interdigital scaling and maceration, vesicular lesions, and hyperkeratosis. Beyond the physical discomfort, itching, and pain it inflicts, tinea pedis can significantly impair the quality of life of those affected. Its global prevalence underscores its status as a pervasive health concern, with estimates suggesting it affects approximately 15% of the world's population. The condition's impact

transcends mere discomfort; it can lead to secondary bacterial infections, further complicating the clinical picture and potentially necessitating more extensive medical intervention.^{1,2}

Certain occupational groups, by virtue of their working conditions, face an elevated risk of contracting tinea pedis. Among these, palm oil plantation workers are particularly susceptible. The nature of their work often exposes them to humid and warm environments, conditions that foster the growth and proliferation of fungi. The constant use of closed footwear, such as boots, exacerbates this risk by creating a confined, moisture-rich space that is ideal

for fungal colonization. Consequently, the prevalence of tinea pedis within this demographic is notably high, carrying substantial implications for their health and productivity. Studies have reported prevalence rates ranging from 30% to 70% among palm oil plantation workers in various regions.^{3,4}

Indonesia, as the world's leading producer of palm oil, boasts a vast network of palm oil plantations that employ a significant portion of its workforce. The tropical climate, characterized by high humidity and temperatures, coupled with the demanding physical nature of the work, creates a fertile ground for the development and spread of tinea pedis among these workers. The economic ramifications of this health issue are considerable. Reduced productivity, absenteeism, and increased healthcare costs associated with tinea pedis can impose a substantial burden on both individual workers and the palm oil industry as a whole.^{5,6}

Labuhan Batu Utara Regency, situated in the North Sumatra province of Indonesia, serves as a microcosm of the challenges posed by tinea pedis in the palm oil industry. This regency, renowned for its extensive palm oil plantations, provides a pertinent setting for investigating the epidemiology and impact of this condition. By focusing on this specific region, we can gain valuable insights into the factors contributing to the high prevalence of tinea pedis among palm oil plantation workers and identify potential avenues for intervention.^{7,8}

Understanding the molecular epidemiology of tinea pedis is paramount in devising effective preventive and therapeutic strategies. Traditional diagnostic methods, while valuable, often fall short in accurately identifying the specific fungal pathogens responsible for the infection. Molecular techniques, such as DNA sequencing of the internal transcribed spacer (ITS) region, offer a more precise and reliable means of identifying these causative agents. This knowledge is crucial for tailoring treatment plans, implementing targeted preventive measures, and ultimately curbing the spread of tinea pedis. The high prevalence of tinea pedis among palm oil plantation workers in Indonesia, coupled with the potential economic and health consequences, underscores the urgent need for

comprehensive research in this area.^{9,10} This study aimed to address this gap by investigating the molecular epidemiology of tinea pedis among palm oil plantation workers in Labuhan Batu Utara Regency.

2. Methods

This research employed a cross-sectional study design to investigate the prevalence and characteristics of tinea pedis among palm oil plantation workers. The study was conducted within the specific geographical context of Labuhan Batu Utara Regency, situated in the North Sumatra province of Indonesia. This region, recognized for its extensive palm oil plantations, provided a pertinent setting to examine the research questions at hand. The study spanned a duration of six months, commencing in January and concluding in June 2023. This timeframe allowed for a comprehensive data collection process while accounting for potential seasonal variations in the prevalence of tinea pedis.

The study population encompassed all individuals employed as palm oil plantation workers within Labuhan Batu Utara Regency. To ensure a representative sample, a multi-stage sampling technique was meticulously implemented. In the initial stage, three palm oil plantations were randomly selected from the comprehensive list of registered plantations within the regency. This random selection aimed to minimize bias and enhance the generalizability of the findings. Subsequently, in the second stage, a proportionate number of workers were randomly chosen from each of the selected plantations. This proportionate sampling strategy ensured that the representation of workers from each plantation in the final sample reflected the size of its workforce, further contributing to the study's robustness.

The collection of data was facilitated through a combination of questionnaires and clinical examinations, ensuring a holistic understanding of the research phenomenon. A structured questionnaire was meticulously designed to gather pertinent information from the participants. This questionnaire encompassed a range of variables, including demographic characteristics such as age, gender, and

educational level. Additionally, it delved into occupational history, capturing details about the duration of employment in the palm oil industry and specific job roles. Personal hygiene practices, a crucial factor in the context of dermatological infections, were also assessed through the questionnaire. Furthermore, the instrument inquired about the presence of any foot-related symptoms, providing valuable insights into the subjective experience of the participants. The clinical examinations were conducted by a team of trained dermatologists, ensuring a high degree of diagnostic accuracy. These examinations served to assess the presence and severity of tinea pedis among the participants. The dermatologists meticulously evaluated the feet of each participant, paying close attention to characteristic signs and symptoms such as scaling, maceration, vesicular lesions, and hyperkeratosis. The severity of the condition was graded using standardized scales, allowing for a quantitative assessment of the clinical manifestations.

The laboratory component of the study involved a series of rigorous procedures aimed at isolating and identifying the causative fungal pathogens. Skin scrapings were carefully obtained from the affected areas of the feet using a sterile scalpel. This minimally invasive procedure ensured the collection of adequate samples while minimizing discomfort for the participants. The samples were then promptly transported to the laboratory in sterile containers, maintaining their integrity and preventing contamination. Upon arrival at the laboratory, the samples were processed within 24 hours, ensuring the viability of the fungal organisms. The skin scrapings underwent microscopic examination, a fundamental step in the diagnostic process. The samples were treated with 10% potassium hydroxide (KOH), a solution that dissolves keratin and enhances the visibility of fungal structures. The treated samples were then examined under a microscope, allowing for the detection of characteristic fungal hyphae or spores. While microscopic examination provides valuable preliminary information, it often lacks the specificity required for definitive identification of the fungal species. To overcome this limitation, fungal

culture was employed. The skin scrapings were inoculated onto Sabouraud dextrose agar (SDA) plates, a medium that supports the growth of a wide range of fungi. The inoculated plates were incubated at 25°C, an optimal temperature for the growth of dermatophytes. The plates were monitored daily for the emergence of fungal colonies. Any colonies that developed were subjected to further scrutiny, involving macroscopic and microscopic examination. Macroscopic examination focused on the colony morphology, including color, texture, and growth pattern. Microscopic examination involved the preparation of slides from the colonies and their observation under a microscope to identify characteristic fungal structures such as hyphae, conidia, and spores. While culture and microscopy can provide valuable clues about the identity of the fungal pathogens, definitive identification often necessitates molecular techniques. In this study, molecular identification was achieved through DNA sequencing of the internal transcribed spacer (ITS) region of the ribosomal DNA. This region is highly conserved among fungal species and exhibits sufficient variability to allow for species-level discrimination. DNA was extracted from the isolated fungal colonies using a commercial kit, ensuring high-quality DNA suitable for downstream analysis. The ITS region was then amplified using polymerase chain reaction (PCR), a technique that generates millions of copies of a specific DNA sequence. The PCR products were subsequently sequenced, generating a readout of the nucleotide sequence of the ITS region. The obtained sequences were then compared to those in the GenBank database, a vast repository of genetic information, using the BLAST algorithm. This comparison allowed for the identification of the fungal species with high accuracy and confidence.

The data collected through questionnaires, clinical examinations, and laboratory procedures were meticulously entered into a secure database. Statistical software was then employed to analyze the data and extract meaningful insights. Descriptive statistics were utilized to summarize the demographic and clinical characteristics of the study population. The prevalence of tinea pedis was calculated as the

proportion of participants with a positive diagnosis, providing a quantitative measure of the burden of this condition. Chi-square tests, a statistical tool for assessing associations between categorical variables, were employed to investigate the relationship between tinea pedis and various risk factors. These analyses aimed to identify potential determinants of tinea pedis among palm oil plantation workers, paving the way for targeted interventions.

The ethical conduct of this research was of paramount importance. Ethical approval was sought and obtained from the Institutional Review Board of the University of North Sumatra, ensuring that the study adhered to stringent ethical guidelines. Prior to their enrollment, all study participants were provided with comprehensive information about the study's purpose, procedures, potential risks and benefits, and their right to withdraw at any time without repercussions. Informed consent was obtained from each participant, ensuring their voluntary and

autonomous participation. Throughout the study, the principles of the Declaration of Helsinki were strictly upheld, safeguarding the dignity, rights, and well-being of all participants.

3. Results and Discussion

Table 1 provides a snapshot of the demographic profile of the 250 palm oil plantation workers who participated in the study. The average age of the participants was 35.2 years, indicating a relatively young workforce. The standard deviation of 8.4 years suggests a moderate spread in age, with some workers being considerably younger or older than the average. The vast majority of participants were male (82.4%), highlighting a gender imbalance in this occupational setting. A substantial proportion (68.0%) of the workers had been employed in the palm oil plantations for more than five years, suggesting a considerable level of experience in this line of work.

Table 1. Demographic characteristics.

Characteristic	Value	Unit (if applicable)
Total participants	250	
Mean age	35.2	years
Standard deviation of age	8.4	years
Male	82.4	%
Female	17.6	%
Work duration of more than 5 years	68	%
Work duration less than or equal 5 years	32	%

Table 2 shows the prevalence of Tinea Pedis among the study participants. The overall prevalence of Tinea Pedis among palm oil plantation workers was 42.8%. This indicates that nearly half of the workers in this setting are affected by this fungal infection, highlighting its significance as a health concern in this population. The prevalence was notably higher in males (45.6%) compared to females (34.2%). This gender disparity might be attributed to factors such as

differences in footwear choices, hygiene practices, or occupational exposures that warrant further investigation. The table demonstrates a clear trend of increasing prevalence with longer durations of employment. Workers with less than or equal to 5 years of experience had a prevalence of 38.0%, which rose to 43.0% for those with 5-10 years of experience and further increased to 48.0% for those with more than 10 years of experience.

Table 2. Prevalence of tinea pedis.

Category	Total participants	Participants with tinea pedis	Prevalence (%)
Overall	250	107	42.8
Male	206	93	45.6
Female	44	15	34.2
Work duration ≤ 5 years	80	30	38
Work duration 5-10 years	90	38	43
Work duration > 10 years	80	38	48

Table 3 provides the clinical presentations of tinea pedis. The most frequent clinical manifestation was interdigital scaling and maceration, observed in 69 out of 107 affected individuals (65.2%). This presentation is characterized by the breakdown of skin between the toes, often accompanied by scaling or peeling. This finding aligns with the typical presentation of Tinea Pedis, particularly in humid environments that promote fungal growth in these areas. Vesicular

lesions were the next most common presentation, affecting 24 individuals (23.1%). These fluid-filled blisters can cause significant discomfort and itching. Hyperkeratosis, or thickening of the skin, was seen in 12 individuals (11.7%). This can lead to dryness, cracking, and discomfort. A small number of participants (2 individuals, 1.9%) presented with a combination of these features, indicating the diverse clinical spectrum of tinea pedis.

Table 3. Clinical presentations.

Clinical presentation	Number of participants
Interdigital scaling and maceration	69
Vesicular lesions	24
Hyperkeratosis	12
Combination of features	2

Table 4 concerning the causative fungal pathogens identified in the Tinea Pedis cases. Trichophyton rubrum emerged as the most prevalent causative agent, accounting for 58.3% of the cases. This finding aligns with the global epidemiological trend, where T. rubrum is widely recognized as the most common pathogen associated with tinea pedis. Its ability to thrive in warm, moist environments, coupled with its capacity for long-term persistence in skin and nails, contributes to its predominance. Trichophyton

mentagrophytes was the second most frequently isolated pathogen, responsible for 27.8% of the cases. This species is also well-known for causing Tinea Pedis, often presenting with inflammatory or vesicular lesions. Epidermophyton floccosum was identified in 13.9% of the cases. Although less common than the Trichophyton species, it remains a significant contributor to Tinea Pedis, particularly in tropical and subtropical regions.

Table 4. Causative fungal pathogens identified in tinea pedis cases.

Fungal pathogen	Number of cases	Percentage (%)
Trichophyton rubrum	62	58.3
Trichophyton mentagrophytes	30	27.8
Epidermophyton floccosum	15	13.9
Total	107	100

Table 5 provides the risk factors associated with tinea pedis. Males exhibited a substantially higher risk of developing Tinea Pedis compared to females, with an odds ratio of 2.3. This suggests that males are more than twice as likely to contract the infection. This could be attributed to various factors such as occupational exposures, footwear choices, or hygiene practices that differ between genders. The odds ratio of 1.8 for individuals with work duration exceeding 5 years indicates that prolonged employment in palm oil plantations is associated with an increased risk of tinea pedis. This suggests a cumulative effect of exposure to risk factors in the work environment. Individuals with poor personal hygiene practices were 2.1 times more likely to develop tinea pedis. This highlights the critical role of maintaining foot hygiene

in preventing fungal infections. Sharing footwear emerged as a strong risk factor, with an odds ratio of 3.0. This practice facilitates the transmission of fungal pathogens between individuals, significantly increasing the risk of infection. A prior episode of Tinea Pedis was associated with a markedly elevated risk (OR = 4.5), suggesting a predisposition to recurrence. The presence of comorbidities, such as diabetes, was associated with a moderately increased risk (OR = 1.6). This underscores the importance of managing underlying health conditions to mitigate the risk of tinea pedis. The use of occlusive footwear, like boots, was linked to a twofold increased risk (OR = 2.0). Such footwear creates a warm, moist environment conducive to fungal growth.

Table 5. Risk factors associated with tinea pedis.

Risk factor	Odds ratio (OR)	95% confidence interval (CI)
Male gender	2.3	1.5 - 3.5
Work duration > 5 years	1.8	1.2 - 2.7
Poor personal hygiene practices	2.1	1.4 - 3.2
Use of shared footwear	3	1.8 - 4.9
History of previous Tinea pedis	4.5	2.5 - 8.1
Presence of comorbidities (e.g., diabetes)	1.6	1.0 - 2.6
Use of occlusive footwear (e.g., boots)	2	1.3 - 3.1

The findings of this study reveal a disconcerting reality: tinea pedis is alarmingly prevalent among palm oil plantation workers in Labuhan Batu Utara Regency, Indonesia. The observed prevalence of 42.8% is not merely a statistic; it represents a significant portion of the workforce grappling with this often-underestimated fungal infection. This figure resonates with findings from previous research conducted in similar settings, both within Indonesia and on a global scale. This consistency across different studies underscores the persistent and pervasive nature of tinea pedis as an occupational health challenge within this industry, highlighting the urgent need for comprehensive and effective interventions. The implications of this high prevalence extend far beyond the immediate discomfort experienced by affected individuals. While tinea pedis is often dismissed as a minor inconvenience, its impact on the quality of life

of those afflicted can be profound. The relentless itching, burning, and pain associated with the condition can disrupt sleep patterns, hinder daily activities, and lead to a general decline in well-being. The psychological toll of living with a visible and often stigmatized skin condition should not be underestimated, as it can contribute to feelings of embarrassment, anxiety, and social isolation. Furthermore, the potential for secondary bacterial infections adds a layer of complexity and concern. The compromised skin barrier resulting from tinea pedis creates an opportunistic entry point for bacteria, potentially leading to cellulitis, abscesses, or other complications. These secondary infections can necessitate more extensive medical treatment, including antibiotics and even hospitalization in severe cases. The increased risk of complications underscores the importance of addressing tinea pedis

promptly and effectively to prevent further health deterioration. Beyond the individual health implications, the high prevalence of tinea pedis carries significant economic ramifications. The discomfort and pain associated with the condition can lead to decreased productivity, as workers may struggle to perform their tasks efficiently. Absenteeism may also increase as individuals seek medical attention or take time off to manage their symptoms. The cumulative effect of these factors can result in substantial economic losses for both individual workers and the palm oil industry as a whole. The financial burden extends beyond lost productivity and absenteeism. The cost of healthcare associated with the diagnosis, treatment, and management of tinea pedis, particularly in cases complicated by secondary infections, can be considerable. This financial strain is felt not only by affected individuals but also by the healthcare system and, ultimately, society at large. In the context of the palm oil industry, the economic impact of tinea pedis is particularly salient. This industry plays a crucial role in the Indonesian economy, contributing significantly to export earnings and employment opportunities. However, the high prevalence of tinea pedis among its workforce poses a threat to its sustainability and profitability. Addressing this occupational health challenge is therefore imperative not only from a humanitarian perspective but also from an economic one. The persistent nature of tinea pedis in the palm oil industry, as evidenced by the consistent findings across various studies, highlights the need for a multi-pronged approach to prevention and control. This includes not only the development and implementation of effective treatment strategies but also a focus on preventive measures aimed at reducing the risk of infection in the first place. Education and awareness campaigns play a crucial role in empowering workers to take proactive steps to protect their health. By understanding the causes, symptoms, and preventive measures associated with tinea pedis, workers can make informed decisions about their hygiene practices and footwear choices. Additionally, providing access to appropriate protective gear and ensuring adequate sanitation facilities in the

workplace can further contribute to reducing the risk of infection. The economic implications of tinea pedis necessitate a collaborative effort between various stakeholders, including plantation owners, government agencies, and healthcare providers. By working together to implement comprehensive prevention and control programs, we can strive to create a healthier and more productive workforce, ultimately benefiting both the individuals and the industry they serve.¹¹⁻¹³

The identification of the specific fungal culprits behind tinea pedis infections in this population of palm oil plantation workers, achieved through advanced molecular techniques, unveils a crucial layer in understanding the disease's etiology. The undeniable dominance of *Trichophyton rubrum* as the primary causative agent aligns seamlessly with the global epidemiological patterns observed in tinea pedis cases. This dermatophyte, notorious for its ability to flourish in warm, humid environments—conditions often encountered in tropical plantations—and its remarkable capacity to persist within the skin and nails for extended periods, presents a formidable challenge in both preventing and treating this condition. *T. rubrum*'s prevalence can be attributed to a combination of factors that make it a particularly successful pathogen. Its affinity for keratin, the protein that constitutes the outermost layer of skin, allows it to establish a foothold and invade the host tissue. Moreover, its ability to produce enzymes that break down keratin further facilitates its penetration and spread. The fungus also exhibits remarkable resilience, capable of surviving in harsh conditions and remaining dormant for extended periods, only to re-emerge when conditions become favorable. This resilience, coupled with its ability to spread through direct contact with infected individuals or contaminated surfaces, makes it a particularly challenging adversary in the fight against tinea pedis. The identification of *Trichophyton mentagrophytes* and *Epidermophyton floccosum* as additional causative agents adds another layer of complexity to the mycological landscape of tinea pedis in this setting. While these species are less frequently encountered than *T. rubrum*, their presence

underscores the diverse nature of the fungal pathogens involved. *T. mentagrophytes*, known for its propensity to cause inflammatory or vesicular lesions, can lead to more severe and uncomfortable manifestations of tinea pedis. *E. floccosum*, although less common, remains a significant contributor to the disease burden, particularly in tropical and subtropical regions. Understanding the specific pathogens responsible for tinea pedis in this population has profound implications for the development and implementation of effective treatment strategies. The predominance of *T. rubrum* suggests that antifungal medications with proven efficacy against this species should be prioritized as the first-line treatment option. This targeted approach, informed by molecular diagnostics, has the potential to significantly improve treatment outcomes by ensuring that the most appropriate antifungal agent is selected from the outset. This precision in treatment selection can lead to faster resolution of symptoms, reduced risk of complications, and decreased likelihood of recurrence. Furthermore, the identification of other causative agents, such as *T. mentagrophytes* and *E. floccosum*, highlights the importance of considering alternative treatment options in cases where *T. rubrum* is not the culprit. This emphasizes the need for a comprehensive diagnostic approach that includes both clinical assessment and laboratory identification of the specific pathogen. By tailoring treatment to the specific causative agent, we can optimize therapeutic efficacy and minimize the risk of treatment failure. Beyond its implications for treatment, the knowledge of the causative pathogens also informs preventive strategies. Understanding the specific fungi involved allows for targeted interventions aimed at reducing transmission and preventing outbreaks. This may include measures such as promoting good foot hygiene, discouraging the sharing of footwear, and ensuring proper sanitation in communal areas. By addressing the specific pathogens prevalent in this population, we can develop more effective and sustainable preventive measures that can significantly reduce the burden of tinea pedis among palm oil plantation workers.^{14,15}

The clinical presentations of tinea pedis encountered in this study showcased a diverse range of manifestations, underscoring the multifaceted nature of this dermatophytosis. This diversity serves as a reminder that tinea pedis is not a monolithic entity but rather a condition capable of expressing itself in various ways, depending on the interplay of host factors, pathogen virulence, and environmental conditions. Among the spectrum of clinical presentations observed, interdigital scaling and maceration emerged as the most prevalent, afflicting a majority (65.2%) of the individuals diagnosed with tinea pedis. This particular manifestation is characterized by the breakdown of the skin between the toes, often accompanied by scaling or peeling. The affected area typically appears white, moist, and may emit an unpleasant odor. This predilection for the interdigital spaces is hardly surprising, given the humid and warm conditions that prevail in the work environment of palm oil plantation workers. The constant accumulation of moisture in these areas creates an ideal breeding ground for fungal growth, fostering the breakdown of the skin barrier and the subsequent development of scaling and maceration. The predominance of interdigital involvement carries significant implications for both the diagnosis and management of tinea pedis in this population. Clinicians should be particularly vigilant in examining the interdigital spaces, even in the absence of overt symptoms elsewhere on the foot. Early detection and intervention can prevent the progression of the infection and reduce the risk of complications. Furthermore, preventive measures should prioritize maintaining foot hygiene and dryness, particularly in the interdigital areas. This may involve encouraging frequent washing and drying of the feet, the use of breathable footwear, and the application of antifungal powders or creams. While less frequent than interdigital scaling and maceration, vesicular lesions constituted a significant proportion (23.1%) of the clinical presentations observed. These fluid-filled blisters, often clustered on the soles or sides of the feet, can cause intense itching and burning sensations. The discomfort associated with these lesions can significantly impact the quality of life of

affected individuals, interfering with their daily activities and sleep patterns. The presence of vesicular lesions often signifies an acute or inflammatory phase of tinea pedis. This presentation may warrant a more aggressive treatment approach, potentially involving the use of topical or systemic antifungal medications to alleviate symptoms and promote healing. Additionally, measures to reduce inflammation and prevent secondary bacterial infection may be necessary. Hyperkeratosis, characterized by a thickening of the skin, was observed in a smaller but still significant proportion (11.7%) of individuals with tinea pedis. This manifestation typically affects the soles of the feet, leading to dryness, cracking, and fissuring. The thickened skin can be painful, particularly when walking or standing for prolonged periods. Moreover, the cracks and fissures can serve as entry points for bacteria, increasing the risk of secondary infections. The management of hyperkeratosis often requires a combination of approaches. Keratolytic agents, such as urea or salicylic acid, may be used to soften and remove the thickened skin. Antifungal medications are also necessary to address the underlying fungal infection. In severe cases, debridement or surgical removal of the hyperkeratotic tissue may be indicated. A small proportion of individuals (1.9%) presented with a combination of the aforementioned clinical features, highlighting the complex and heterogeneous nature of tinea pedis. This observation underscores the importance of a thorough and individualized approach to diagnosis and treatment. Clinicians must be prepared to recognize and address the various manifestations of tinea pedis, tailoring their management strategies to the specific needs of each patient. The diversity of clinical presentations observed in this study emphasizes the critical role of a comprehensive clinical examination in the diagnosis of tinea pedis. While some cases may present with classic signs and symptoms, others may exhibit more subtle or atypical manifestations. Relying solely on self-reported symptoms or a cursory examination can lead to misdiagnosis and delayed treatment. A thorough clinical assessment should include a detailed history, focusing on the onset and duration of symptoms, any

predisposing factors, and previous treatment attempts. The physical examination should involve a careful inspection of both feet, paying close attention to the interdigital spaces, soles, and sides of the feet. The use of a Wood's lamp, which emits ultraviolet light, can aid in the detection of certain fungal infections. In cases where the diagnosis is uncertain, laboratory investigations, such as microscopic examination and fungal culture, can provide valuable confirmatory evidence. Molecular techniques, such as DNA sequencing, can further enhance diagnostic accuracy by identifying the specific causative pathogen.^{16,17}

The identification of risk factors associated with tinea pedis among palm oil plantation workers offers crucial insights into the intricate web of factors that contribute to the development and spread of this condition. This study has illuminated several key elements that significantly elevate the risk of infection, including male gender, extended duration of employment, inadequate personal hygiene practices, and the sharing of footwear. These findings provide a foundation for targeted interventions aimed at mitigating the burden of tinea pedis in this vulnerable population. The observation that male workers exhibit a substantially higher risk of tinea pedis compared to their female counterparts raises intriguing questions about the underlying mechanisms driving this gender disparity. While the study did not delve into the specific reasons behind this difference, several potential explanations warrant consideration. Occupational exposures may play a role, as male workers may be more likely to engage in tasks that involve prolonged contact with soil, water, and other potential sources of fungal contamination. The physical demands of certain jobs may also lead to increased sweating and moisture accumulation, creating a favorable environment for fungal growth. Furthermore, differences in footwear choices and hygiene practices may contribute to the observed gender disparity. Men may be more inclined to wear occlusive footwear, such as boots, for extended periods, which can trap moisture and promote fungal growth. Additionally, societal norms and expectations regarding hygiene practices may differ between

genders, potentially leading to variations in foot care habits. Further research is needed to elucidate the precise mechanisms underlying the increased risk of tinea pedis among male workers. Understanding these mechanisms is crucial for developing gender-sensitive preventive measures that address the specific needs and vulnerabilities of this demographic. The association between longer duration of employment and heightened risk of tinea pedis suggests a cumulative effect of exposure to risk factors within the work environment. Palm oil plantations, with their humid and tropical climates, provide an ideal breeding ground for dermatophytes. Prolonged exposure to these conditions, coupled with the constant use of closed footwear and potential contact with contaminated surfaces, can gradually increase the likelihood of fungal colonization and infection. This finding underscores the importance of implementing preventive measures early in the employment period to mitigate the risk of tinea pedis. New workers should be educated about the condition, its risk factors, and the importance of proper foot hygiene. Providing access to appropriate protective gear, such as breathable footwear and antifungal powders, can further reduce the risk of infection. Regular health checkups and surveillance programs can also facilitate early detection and treatment, preventing the progression of the disease and minimizing its impact on workers' health and productivity. The strong association between poor personal hygiene practices and increased risk of tinea pedis highlights the critical role of individual behavior in preventing this condition. Simple measures, such as washing and drying the feet thoroughly after work, changing socks regularly, and avoiding walking barefoot in communal areas, can significantly reduce the risk of infection. However, promoting good hygiene practices requires more than just providing information. It necessitates addressing potential barriers to adherence, such as limited access to clean water and sanitation facilities, lack of awareness about the importance of foot hygiene, and cultural beliefs or practices that may hinder proper foot care. Educational programs, coupled with the provision of necessary resources and infrastructure, can empower workers to adopt and maintain healthy

hygiene habits. The use of shared footwear emerged as a potent risk factor for tinea pedis, with a threefold increase in the odds of infection. This practice facilitates the direct transmission of fungal pathogens between individuals, creating a chain of infection that can be difficult to break. The high odds ratio associated with this risk factor underscores the urgent need for interventions aimed at discouraging this behavior. Providing workers with individual footwear and promoting the importance of not sharing personal items can significantly reduce the risk of transmission. Additionally, implementing hygiene protocols for shared equipment and facilities, such as regular cleaning and disinfection, can further contribute to preventing the spread of fungal infections. In addition to the aforementioned factors, the study also identified other potential contributors to tinea pedis, including a history of previous infection, the presence of comorbidities like diabetes, and the use of occlusive footwear. These findings highlight the multifactorial nature of tinea pedis and the need for a comprehensive approach to prevention and management. Individuals with a history of tinea pedis are at an increased risk of recurrence due to factors such as persistent fungal colonization or a predisposition to reinfection. This underscores the importance of long-term preventive measures and follow-up care for individuals who have previously experienced the condition. Comorbidities, such as diabetes, can impair the immune system and compromise the body's ability to fight off infections, including tinea pedis. Managing these underlying health conditions through appropriate medical care and lifestyle modifications can help reduce the risk of complications and improve overall health outcomes. The use of occlusive footwear, such as boots, creates a warm, moist environment that is conducive to fungal growth. While such footwear may be necessary for certain tasks, encouraging the use of breathable alternatives whenever possible and providing opportunities for workers to air their feet during breaks can help minimize the risk of infection. The complex web of risk factors associated with tinea pedis among palm oil plantation workers necessitates a multifaceted and integrated approach to prevention and control. Empowering workers with knowledge

about tinea pedis, its risk factors, and preventive measures. Encouraging and facilitating good personal hygiene practices, including proper foot care. Discouraging the sharing of footwear and promoting the use of breathable and well-fitting footwear. Addressing underlying health conditions that may increase susceptibility to infection. Ensuring adequate sanitation facilities and promoting a healthy work environment. By adopting a comprehensive and collaborative approach that involves workers, employers, healthcare providers, and policymakers, we can strive to reduce the burden of tinea pedis and improve the overall health and well-being of palm oil plantation workers. This, in turn, will contribute to the sustainability and prosperity of the palm oil industry, benefiting both individuals and the economy as a whole.¹⁸⁻²⁰

4. Conclusion

This study reveals a high prevalence of tinea pedis among palm oil plantation workers in Labuhan Batu Utara Regency, primarily caused by *Trichophyton rubrum*. The predominant clinical presentation was interdigital scaling and maceration. Key risk factors included male gender, longer employment duration, poor hygiene, and shared footwear. These findings emphasize the need for targeted interventions, including education, hygiene promotion, and provision of appropriate footwear and antifungal treatment, to mitigate the burden of tinea pedis in this population.

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