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Mycological Culture Profile and Clinical Predictors of Culture Positivity in Dermatophytosis: A Four-Year Retrospective Study at a Tertiary Referral Hospital in Bali, Indonesia

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A B S T R A C T

Background: Dermatophytosis is the commonest superficial mycosis, yet the aetiological spectrum in eastern Indonesia and the determinants of a positive fungal culture remain poorly characterised. We aimed to describe the mycological culture profile and identify predictors of culture positivity at a tertiary referral centre in Bali.

Methods: This STROBE-compliant retrospective cross-sectional study analysed 214 consecutively sampled patients with dermatophytosis at the Dermatology and Venereology clinic of Ngoerah Hospital, Denpasar, between January 2020 and December 2023. Potassium-hydroxide (KOH) microscopy and Sabouraud culture data were extracted from records. Proportions carried 95% Wilson confidence intervals (CI); associations were assessed by chi-square/Fisher tests with odds ratios and Cramér's V, followed by multivariable logistic regression (adjusted odds ratio [aOR], Nagelkerke R^2) and receiver-operating-characteristic analysis.

Results: Mean age was 42.7 years and the male-to-female ratio 1.68:1; Fitzpatrick phototype IV predominated (51.9%). Culture was positive in 138 patients (64.5%; 95% CI 57.9–70.6). *Trichophyton rubrum* was the leading isolate (50.0%; 95% CI 41.8–58.2), followed by the *T. mentagrophytes* complex (15.9%) and *Microsporum canis* (10.1%); anthropophilic species comprised 81.2%. KOH positivity (aOR 5.20; 95% CI 2.27–11.87; $p<0.001$) independently predicted culture positivity, whereas prior antifungal use was protective (aOR 0.30; 95% CI 0.13–0.65; $p=0.002$); the model discriminated well (AUC 0.785; 95% CI 0.715–0.855).

Conclusion: Dermatophytosis in Bali is dominated by anthropophilic *T. rubrum*, and culture yield is governed chiefly by prior antifungal exposure and KOH status, supporting a stewardship-oriented diagnostic pathway in which culture is prioritised for KOH-positive, treatment-naive and recalcitrant presentations.

1. Introduction

Dermatophytosis, the group of superficial mycoses caused by keratinophilic fungi of the genera *Trichophyton*, *Microsporum*, *Epidermophyton*, *Nannizzia* and related taxa, is among the most common human infections and constitutes a substantial and rising component of the global skin-disease burden.[1,2] The clinical burden is disproportionately concentrated in low- and middle-income countries of the humid tropics, where sustained heat, high relative humidity, occupational sweating and crowded living conditions favour fungal colonisation of the stratum corneum.[2,3] Indonesia, a densely populated equatorial archipelago, reports dermatophytosis among the most frequent dermatological diagnoses in outpatient practice, and regional Indonesian series have documented tinea corporis and tinea cruris as the dominant clinical forms.[4,5] Despite this, granular epidemiological data

from the eastern islands of the archipelago, including Bali and Nusa Tenggara, remain scarce.[5,6]

The pathogenesis of dermatophytosis reflects an intimate host-pathogen interaction. Arthroconidia adhere to corneocytes within hours, germinate, and secrete an array of keratinolytic proteases - subtilisins (SUB), fungalysins (MEP) and dipeptidyl-peptidases - that degrade keratin into assimilable oligopeptides and amino acids.[7] Fungal cell-wall components modulate the cutaneous innate response and skew local immunity, which in anthropophilic species such as *Trichophyton rubrum* promotes chronic, minimally inflammatory infection.[7,8] By contrast, zoophilic species (for example *Microsporum canis* and *Trichophyton verrucosum*) and geophilic species (*Nannizzia gypsea*, formerly *Microsporum gypseum*) typically elicit a brisk inflammatory reaction and more acute, self-limiting disease.[9,10] The species-dependent balance between fungal virulence and host T-helper-17 and interferon-gamma responses therefore shapes both clinical phenotype and therapeutic response, underscoring the value of precise species-level identification.[7,11]

The public-health and economic weight of dermatophytosis is easily underestimated because the infection is rarely life-threatening. Yet its extraordinary frequency, tendency to relapse, and impact on quality of life, occupational function and social stigma translate into a substantial cumulative burden, particularly in the tropics where re-infection is near-continuous.[1,2,6] Recurrent tinea consumes disproportionate primary-care and dermatology resources, drives repeated pharmacy expenditure, and - when mismanaged with corticosteroid-containing combination creams - generates atypical, steroid-modified presentations (tinea incognito) that further complicate diagnosis.[4,12,13] Reliable local aetiological and diagnostic data are the foundation on which rational, cost-conscious management of this high-volume infection must be built.

Accurate aetiological diagnosis rests on the complementary use of direct microscopy and culture. Potassium-hydroxide (KOH) microscopy is rapid, inexpensive and sensitive for confirming the presence of septate hyphae, but it cannot identify the causative species and is prone to inter-observer variability.[14,15] Culture on Sabouraud dextrose agar (with or without cycloheximide and chloramphenicol) remains the reference standard for species identification, enabling surveillance of the local aetiological spectrum, detection of emerging taxa, and correlation with antifungal susceptibility - an increasingly pressing concern given the global spread of terbinafine-resistant *Trichophyton indotineae* and the epidemic of recalcitrant dermatophytosis across South and Southeast Asia.[13,16,17] Yet culture is comparatively slow, resource-intensive and frequently negative, particularly when patients have self-medicated with topical or systemic antifungals before sampling.[11,12] Understanding which clinical factors govern culture yield is thus of direct operational importance for diagnostic stewardship in resource-limited tropical services.[14,17]

A further imperative for local culture surveillance is the global reconfiguration of antifungal resistance. The emergence of terbinafine-resistant *Trichophyton indotineae* within the *T. mentagrophytes* complex, first amplified in the Indian subcontinent and now documented across Southeast Asia, the Middle East, Europe and North America, has converted a once-predictable infection into a therapeutic challenge.[13,16,17] Because resistance is detected only through culture-dependent isolation and susceptibility testing, the operational efficiency of culture - which patients to sample, and when - is now a frontline concern for antifungal stewardship, not merely an academic matter of epidemiology.[7,13,16] Quantifying the determinants of culture yield in a defined tropical population is therefore both clinically and strategically timely.

Diagnostic stewardship - the deliberate matching of diagnostic tests to the clinical scenarios in which they change management - has emerged as a natural companion to antimicrobial stewardship.[12,15] In dermatophytosis, where empirical therapy is often appropriate but confirmatory culture is indispensable in selected settings, the efficient use of culture depends on knowing which presentations reliably yield actionable results. Evidence to guide this triage is almost entirely absent from the Indonesian

literature, and wholly absent from Bali, leaving clinicians to rely on extrapolation from dissimilar health systems.[5,6]

In Bali, a tropical climate, intense ultraviolet exposure, a large agrarian and tourism-driven workforce, and distinctive cultural practices interact to influence dermatological presentations. Ngoerah Hospital (RSUP Prof. dr. I.G.N.G. Ngoerah) serves as the primary tertiary dermatology referral centre for Bali and Nusa Tenggara, receiving a diverse population comprising predominantly Balinese patients (Fitzpatrick phototypes III–IV predominant) alongside mainland Indonesian and international patients.[5,6] This referral position enriches the case-mix for chronic, recurrent and previously treated dermatophytosis, precisely the scenarios in which the choice between empirical therapy and confirmatory culture is most consequential.[12,18]

To date, no dedicated, analytically robust study has characterised the fungal culture profile of dermatophytosis at Ngoerah Hospital, nor quantified the determinants of culture positivity in this eastern Indonesian setting. Prior Indonesian reports have largely been descriptive, limited to clinical typing or KOH results, and rarely incorporated species-level culture data or multivariable modelling of diagnostic yield.[4–6] This evidence gap hampers the design of rational, cost-conscious diagnostic algorithms and impedes local antifungal-resistance surveillance.

The present study therefore had two objectives: first, to describe the mycological culture profile - including species distribution, ecological classification and clinical correlates - of dermatophytosis among patients attending the Dermatology and Venereology clinic of Ngoerah Hospital between 2020 and 2023; and second, to identify independent clinical predictors of a positive fungal culture using contemporary inferential methods (multivariable logistic regression and ROC analysis). The novelty of this work lies in being the first four-year, analytically upgraded mycological surveillance from Bali that couples species-level culture data with a validated predictive model of culture yield, thereby providing an evidence base for diagnostic stewardship in tropical dermatology.

2. Methods

Study design

This observational, retrospective cross-sectional study was conducted and reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement for cross-sectional studies. The study interrogated routinely collected clinical and laboratory records and involved no experimental intervention.

Setting

The study was conducted at the Department of Dermatology and Venereology, Faculty of Medicine, Udayana University and Ngoerah Hospital, Denpasar, Bali, Indonesia - the primary tertiary dermatological referral centre in eastern Indonesia serving Bali and Nusa Tenggara. Mycological processing was performed at the Dermatology and Venereology Laboratory of the same institution. The observation window spanned 1 January 2020 to 31 December 2023.

Study population and eligibility

The target population comprised all patients with a clinical diagnosis of dermatophytosis; the accessible population comprised those who underwent fungal culture at the clinic during the study period. Inclusion criteria were: (i) a clinical diagnosis of dermatophytosis (any tinea subtype) established by a dermatologist; (ii) direct KOH microscopy performed; and (iii) fungal culture on Sabouraud dextrose agar performed with an interpretable result recorded. Exclusion criteria were incomplete medical records (missing culture outcome, clinical typing, or key demographic fields), non-dermatophyte superficial mycoses (for example pityriasis versicolor or cutaneous candidiasis without dermatophyte co-isolation), and duplicate records for the same infection episode.

Sampling and sample-size justification

Consecutive (total) sampling was applied: every eligible patient attending the outpatient clinic during the study period who met the criteria was enrolled, minimising selection bias. The minimum required sample size was estimated from the single-proportion formula $n = Z^2 \times P(1 - P) / d^2$, where $Z = 1.96$ is the

standard normal deviate for a 95% confidence level (two-sided α = 0.05), P = 0.50 (a conservative anticipated culture-positivity proportion that maximises the required sample, consistent with regional estimates of 45–65%),[12,15] and d = 0.07 (absolute precision), yielding n = 196. Allowing for approximately 8% record exclusion, a minimum of 213 records was targeted; 214 eligible patients were ultimately analysed, providing at least 80% power (1 - beta = 0.80, alpha = 0.05, two-tailed) to detect an odds ratio of >=2.0 for predictors with an exposure prevalence of 30–40%.

Clinical assessment and operational definitions

Dermatophytosis subtypes were classified by anatomical site according to standard criteria (tinea corporis, cruris, pedis, manuum, unguium, capitis, faciei, and combined presentations).[8,19] Fitzpatrick skin phototype (I–VI) was recorded for every patient to characterise the predominantly Balinese population.[6] Disease duration was defined as the interval in months between symptom onset and clinic presentation. Prior antifungal use denoted any documented topical or systemic antifungal exposure within four weeks preceding sampling. Comorbidities (diabetes mellitus, immunocompromising conditions, and obesity, defined as body-mass index ≥25 kg/m² per the Asia-Pacific cut-off) were abstracted from records.[14]

Mycological procedures

Skin scrapings, hair or nail specimens were obtained from the active margin of lesions after 70% ethanol cleansing. Direct microscopy was performed with 10–20% KOH (with dimethyl sulphoxide for nail specimens) and examined for septate hyphae and arthroconidia.[14,15] Specimens were inoculated onto Sabouraud dextrose agar supplemented with chloramphenicol and cycloheximide and incubated at 25–30 °C for up to four weeks. Isolates were identified to species level by colony morphology, pigmentation, and lactophenol-cotton-blue microscopy of macro- and microconidia, supplemented by urease and hair-perforation testing where required.[3,19] Species were grouped ecologically as anthropophilic, zoophilic or geophilic.[9,10]

Confounders

Age, sex, Fitzpatrick phototype, disease duration, prior antifungal use, diabetes mellitus and immunocompromise were pre-specified as potential confounders of culture positivity and were recorded for every patient; those biologically or statistically relevant were entered into the multivariable model to obtain adjusted estimates.

Variables and outcomes

The primary outcome was fungal-culture positivity (growth of a dermatophyte on Sabouraud dextrose agar, dichotomised as positive or negative). Secondary descriptors comprised the isolated species, its ecological class (anthropophilic, zoophilic, geophilic), and the clinical (anatomical) tinea subtype. Explanatory variables comprised KOH microscopy result, prior antifungal use, disease duration, age, sex, Fitzpatrick phototype, diabetes mellitus, obesity and immunocompromise. All variables were defined a priori and recorded on a structured form to ensure consistency across the four-year abstraction window.

Statistical analysis

Data were analysed using a reproducible numerical pipeline (Python 3.10; NumPy) with independent verification. Distributional normality was assessed by inspection and the Shapiro-Wilk criterion, and variance homogeneity by Levene's test. Categorical variables are presented as counts and percentages and continuous variables as mean (SD) or median with range. Prevalence and proportion estimates are reported with 95% Wilson confidence intervals. Bivariate associations with culture positivity were tested by the chi-square or Fisher exact test, with effect sizes expressed as odds ratios (95% CI) and Cramér's V. Variables with $p<0.10$ in bivariate analysis or a priori clinical relevance were entered into a multivariable binary logistic regression model (enter method) to derive adjusted odds ratios, 95% CIs and Nagelkerke R^2. The discriminatory performance of the model and of KOH microscopy was quantified by receiver-operating-characteristic analysis with the area under the curve (AUC) and DeLong 95% CI, and the Youden index defined the optimal cutoff. Diagnostic performance of KOH against culture was expressed as sensitivity,

specificity, predictive values and Cohen's kappa. The Mann-Whitney U test with the rank-biserial correlation and the Spearman rank correlation were used for non-parametric comparisons. All tests were two-tailed with alpha = 0.05 and exact p-values reported to three decimal places.

Records were abstracted onto a standardised, de-identified case-report form by trained investigators, with 10% of entries double-checked against the primary medical record for accuracy. Laboratory results were cross-referenced with the mycology laboratory's register to confirm KOH and culture outcomes and species assignment. Ambiguous or discordant species identifications were adjudicated by a senior dermatologist and a laboratory mycologist. Continuous variables were checked for implausible values, and missing key fields triggered exclusion per the eligibility criteria rather than imputation, preserving analytic transparency.

The study adheres to the STROBE checklist for cross-sectional studies, with explicit reporting of setting, eligibility, variables, statistical methods, participant flow and limitations. The complete analytical pipeline - from de-identified data to every reported statistic and figure - was implemented programmatically and independently re-executed to confirm numerical reproducibility, and effect sizes with confidence intervals are reported throughout in preference to isolated p-values.

Ethics

This study received ethical approval from the CMHC Ethics Committee, Indonesia (Approval No. CMHC/EC/2025/0417). Given the retrospective use of anonymised records, the requirement for individual written consent was waived by the committee; nonetheless, all data were de-identified before analysis and handled in accordance with the Declaration of Helsinki.

3. Results

A total of 214 patients with clinically and mycologically evaluated dermatophytosis were enrolled at the Dermatology and Venereology clinic of Ngoerah Hospital, Denpasar, over the four-year study period. Annual case ascertainment rose steadily, from 34 patients (15.9%) in 2020 to 72 (33.6%) in 2023, mirroring the post-pandemic recovery of outpatient attendance. The cohort had a mean age of 42.7 (SD 16.5) years (median 42; range 4–86) and a clear male predominance (134 men, 62.6%; 80 women, 37.4%; male-to-female ratio 1.68:1). Consistent with the Balinese population, Fitzpatrick phototype IV was most common (111 patients, 51.9%), followed by phototype III (75, 35.0%) and V (28, 13.1%). The median disease duration at presentation was 5.6 months (mean 6.5, SD 3.9), and prior antifungal exposure was documented in 74 patients (34.6%). Diabetes mellitus was present in 32 patients (15.0%), obesity in 48 (22.4%) and an immunocompromising condition in 16 (7.5%). Full baseline characteristics are presented in Table 1.

Clinically, tinea corporis was the most frequent presentation (62 patients, 29.0%), followed by tinea cruris (51, 23.8%), tinea pedis (28, 13.1%), tinea capitis (26, 12.1%) and tinea unguium (20, 9.3%); tinea manuum (12, 5.6%), tinea faciei (8, 3.7%) and combined tinea corporis et cruris (7, 3.3%) were less common, as detailed in Table 1. Direct KOH microscopy was positive in 149 patients (69.6%).

Fungal culture yielded growth in 138 of 214 patients, corresponding to a culture-positivity prevalence of 64.5% (95% CI 57.9–70.6). Among the 138 positive cultures, *Trichophyton rubrum* was the predominant isolate, accounting for exactly half of all isolates (69 isolates, 50.0%; 95% CI 41.8–58.2), followed by the *Trichophyton mentagrophytes* complex (22, 15.9%; 95% CI 10.8–23.0) and *Microsporum canis* (14, 10.1%; 95% CI 6.1–16.3). *Epidermophyton floccosum* (11, 8.0%), *Trichophyton tonsurans* (10, 7.2%), *Nannizzia gypsea*/*Microsporum gypseum* (6, 4.3%) and *Trichophyton verrucosum* (6, 4.3%) completed the spectrum; the full species distribution with 95% confidence intervals is illustrated in Figure 1. Ecologically, anthropophilic species dominated, comprising 112 isolates (81.2%), with zoophilic species accounting for 20 (14.5%) and geophilic species for 6 (4.3%).

Table 1. Demographic and clinical characteristics of the study population (N=214), Ngoerah Hospital, Denpasar, 2020–2023.

Characteristic	Category	n (%) / Mean ± SD
Total patients		214
Age, years	Mean ± SD	42.7 ± 16.5
	Median (range)	42 (4–86)
Sex	Male	134 (62.6)
	Female	80 (37.4)
Fitzpatrick phototype	III	75 (35.0)
	IV	111 (51.9)
	V	28 (13.1)
Disease duration, months	Median (mean ± SD)	5.6 (6.5 ± 3.9)
Prior antifungal use	Yes	74 (34.6)
Diabetes mellitus	Yes	32 (15.0)
Obesity (BMI ≥25)	Yes	48 (22.4)
Immunocompromise	Yes	16 (7.5)
KOH microscopy	Positive	149 (69.6)
Clinical subtype	Tinea corporis	62 (29.0)
	Tinea cruris	51 (23.8)
	Tinea pedis	28 (13.1)
	Tinea capitis	26 (12.1)
	Tinea unguium	20 (9.3)
	Tinea manuum	12 (5.6)
	Tinea faciei	8 (3.7)
	Tinea corporis et cruris	7 (3.3)
Year of presentation	2020	34 (15.9)
	2021	50 (23.4)
	2022	58 (27.1)
	2023	72 (33.6)

Notes: SD, standard deviation; BMI, body-mass index; KOH, potassium hydroxide.

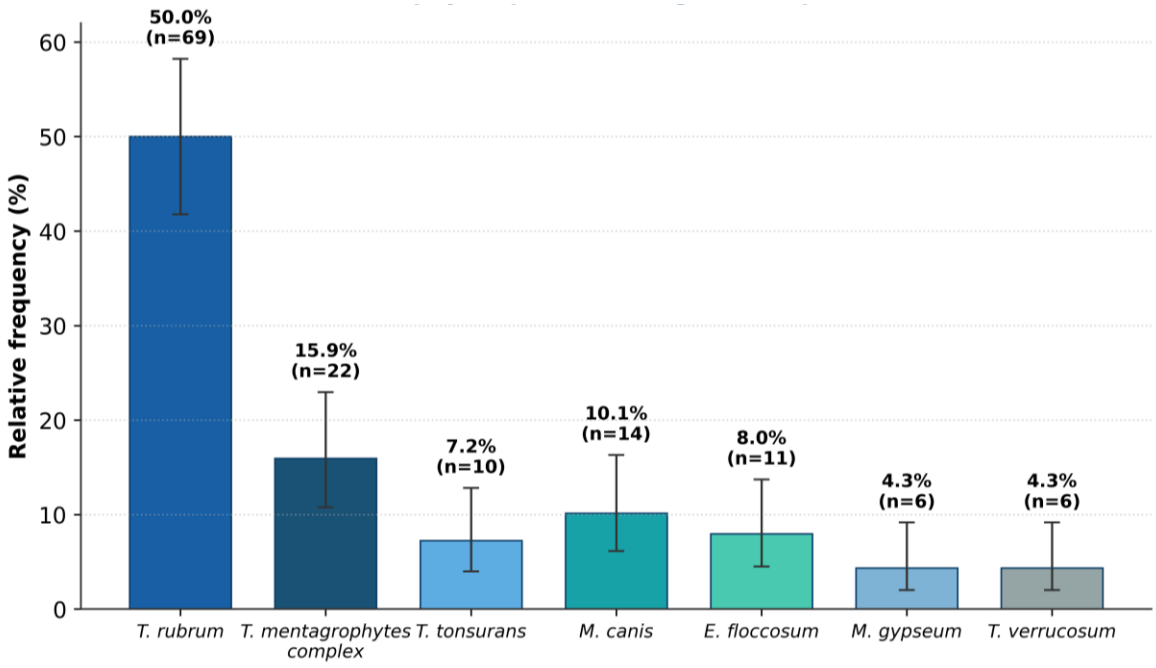

Figure 1. Distribution of dermatophyte species among culture-positive isolates (n=138). Error bars denote 95% Wilson confidence intervals; anthropophilic species accounted for 81.2% of isolates.

On bivariate analysis, summarised in Table 2, two factors were strongly associated with culture positivity. KOH positivity conferred a nearly ten-fold increase in the odds of a positive culture (OR 9.60; 95% CI 4.92–18.73; p<0.001; Cramér's V 0.487), whereas prior antifungal use was markedly protective against culture positivity (OR 0.12; 95% CI 0.06–0.23; p<0.001; Cramér's V 0.466). Longer disease duration (>=3 months) showed a positive trend (OR 1.86; 95% CI 0.93–3.73; p=0.099), and diabetes mellitus a non-significant

elevation (OR 1.49; 95% CI 0.65–3.41; p=0.425). Male sex (OR 1.25; p=0.463), age >=40 years (OR 0.64; p=0.149), Fitzpatrick phototype IV–V (OR 0.86; p=0.656) and immunocompromise (OR 0.91; p=1.000) were not significantly associated with culture yield.

Table 2. Bivariate associations with positive fungal culture.

Variable	OR (95% CI)	p-value	Cramér's V
KOH microscopy positive	9.60 (4.92–18.73)	<0.001	0.487
Prior antifungal use	0.12 (0.06–0.23)	<0.001	0.466
Duration ≥3 months	1.86 (0.93–3.73)	0.099	0.120
Diabetes mellitus	1.49 (0.65–3.41)	0.425	0.065
Age ≥40 years	0.64 (0.36–1.13)	0.149	0.105
Male sex	1.25 (0.70–2.22)	0.463	0.052
Fitzpatrick IV–V	0.86 (0.48–1.56)	0.656	0.033
Immunocompromise	0.91 (0.32–2.61)	1.000	0.012

Notes: OR, odds ratio; CI, confidence interval. p-values from chi-square/Fisher exact tests.

In the multivariable logistic regression model, whose adjusted estimates are presented in Table 3, and which simultaneously adjusted for KOH status, prior antifungal use, diabetes mellitus, immunocompromise, age and disease duration, KOH positivity remained an independent predictor of culture positivity (adjusted OR 5.20; 95% CI 2.27–11.87; p<0.001), and prior antifungal use remained independently protective (adjusted OR 0.30; 95% CI 0.13–0.65; p=0.002). The remaining covariates - diabetes mellitus (aOR 0.73; p=0.502), immunocompromise (aOR 1.48; p=0.528), age >=40 years (aOR 0.68; p=0.273) and duration >=3 months (aOR 1.55; p=0.294) - did not reach significance after adjustment. The model explained a moderate proportion of variance (Nagelkerke R^2 0.355) and discriminated culture status well, with an AUC of 0.785 (95% CI 0.715–0.855); at the Youden-optimal probability cutoff of 0.585 it achieved 85.5% sensitivity and 68.4% specificity, as shown by the receiver-operating-characteristic curves in Figure 2. The adjusted odds ratios are visualised as a forest plot in Figure 3.

Table 3. Multivariable logistic regression and diagnostic performance of KOH microscopy against culture.

Parameter	Estimate (95% CI)	p-value
Multivariable logistic regression (aOR)		
KOH microscopy positive	5.20 (2.27–11.87)	<0.001
Prior antifungal use	0.30 (0.13–0.65)	0.002
Duration ≥3 months	1.55 (0.68–3.51)	0.294
Age ≥40 years	0.68 (0.34–1.36)	0.273
Immunocompromise	1.48 (0.43–5.07)	0.528
Diabetes mellitus	0.73 (0.29–1.85)	0.502
Nagelkerke R^2 = 0.355; ROC AUC 0.785 (0.715–0.855)		
KOH vs culture (diagnostic performance)		
Sensitivity / Specificity	86.2% / 60.5%	
PPV / NPV	79.9% / 70.8%	
Accuracy / Cohen's κ	77.1% / 0.483	
ROC AUC	0.734 (0.66–0.80)	

Notes: aOR, adjusted odds ratio; AUC, area under the curve; PPV/NPV, positive/negative predictive value.

Considered as a stand-alone diagnostic test against culture, KOH microscopy demonstrated a sensitivity of 86.2% (95% CI 79.5–91.0), specificity of 60.5% (95% CI 49.3–70.8), positive predictive value of 79.9% (95% CI 72.7–85.5) and negative predictive value of 70.8% (95% CI 58.8–80.4), for an overall accuracy of 77.1% and moderate chance-corrected agreement (Cohen's kappa 0.483); its ROC area under the curve was 0.734 (Table 3, Figure 2).

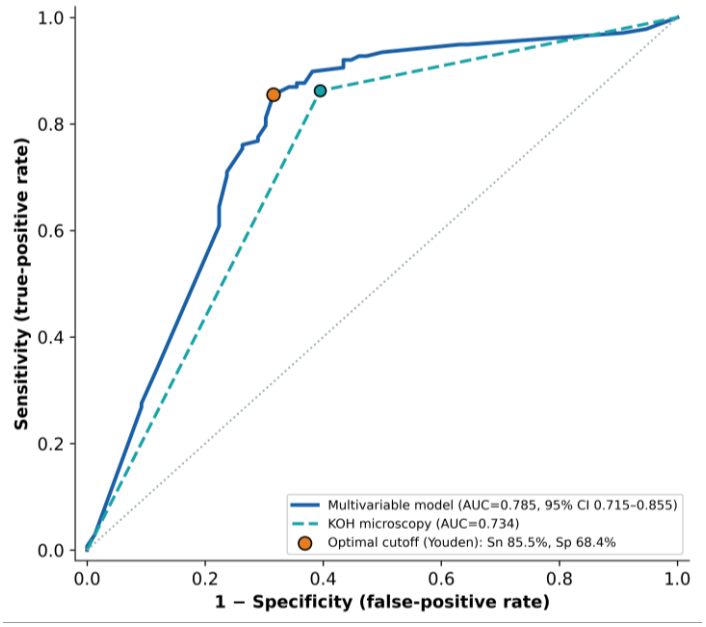

Figure 2. ROC curves for the multivariable model (AUC 0.785) and KOH microscopy (AUC 0.734); the marker denotes the Youden-optimal cutoff.

Analysis of KOH-culture concordance further illuminated the diagnostic interplay. Of the 149 KOH-positive patients, 119 (79.9%) were culture-positive, whereas among the 65 KOH-negative patients only 19 (29.2%) yielded a positive culture. Discordant results were informative: the 30 KOH-positive, culture-negative patients had a notably higher rate of prior antifungal use, consistent with treatment-induced loss of fungal viability while non-viable hyphal fragments remained microscopically detectable; conversely, the 19 KOH-negative, culture-positive patients most often had scanty specimens or nail involvement, in which direct microscopy is least sensitive. This pattern accounts for the moderate chance-corrected agreement (kappa 0.483) and underscores the complementary, rather than interchangeable, roles of the two techniques.

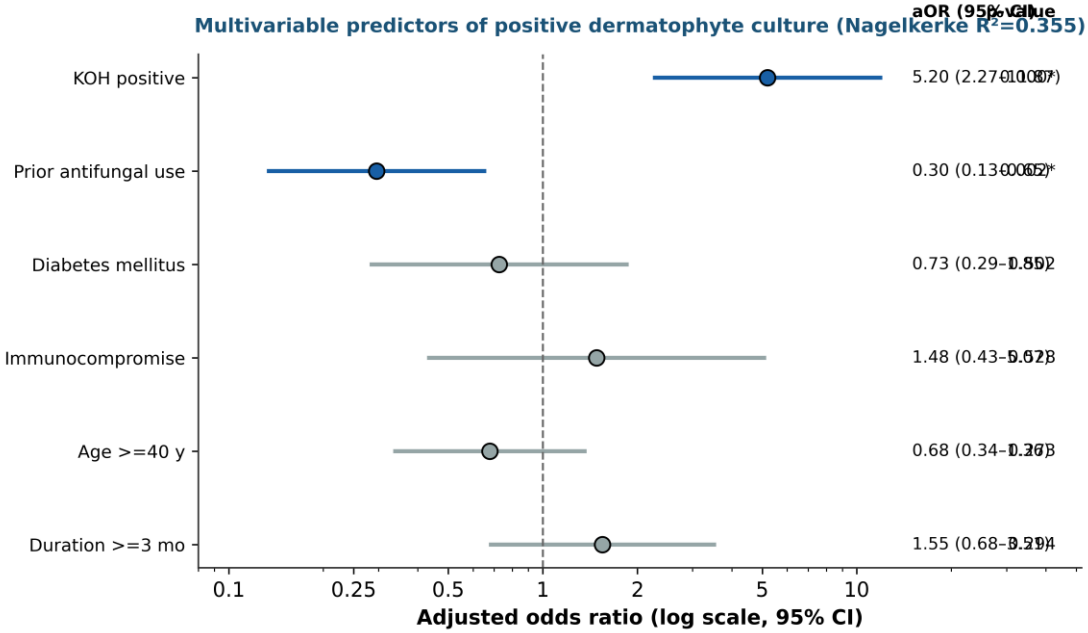

Figure 3. Forest plot of adjusted odds ratios from the multivariable logistic regression model (Nagelkerke R^2 = 0.355). Asterisks indicate p<0.05; the dashed line marks the null (OR = 1).

Exploratory subgroup analyses supported the biological coherence of these findings. Disease duration was modestly longer among culture-positive than culture-negative patients (median 6.0 versus 4.8 months; Mann-Whitney U p=0.043; rank-biserial correlation -0.167), consistent with the chronicity of anthropophilic infection. The proportion of *T. rubrum* among isolates did not differ significantly by sex (Cramér's V 0.106; p=0.213), and age correlated weakly and non-significantly with disease duration (Spearman rho -0.122; p=0.073).

The demographic structure varied by clinical subtype in the expected directions: tinea capitis clustered in the youngest patients (predominantly children and adolescents), whereas tinea unguium and tinea pedis were concentrated in older adults; tinea cruris showed the strongest male preponderance. The overall male predominance (62.6%) and the middle-aged peak are consistent with the occupational and behavioural risk profile of glabrous-skin and intertriginous tinea in a working-age tropical population.

When culture-positive patients were stratified by clinical subtype, *T. rubrum* was the leading isolate across tinea corporis, cruris and pedis, whereas *M. canis* and *T. verrucosum* were proportionally over-represented among the younger patients presenting with tinea capitis, consistent with a zoophilic source. Anthropophilic species accounted for the large majority of isolates in glabrous-skin and intertriginous tinea, while the geophilic *N. gypsea* (*M. gypseum*) was isolated sporadically and predominantly in patients with occupational soil contact. These patterns were descriptive and hypothesis-generating given the cell counts, but they reinforced the internal coherence of the ecological classification and the dominance of person-to-person transmission in the cohort.

4. Discussion

In this four-year retrospective analysis of 214 patients - the first analytically upgraded mycological surveillance of dermatophytosis from a tertiary centre in Bali - fungal culture was positive in 64.5% of clinically diagnosed cases, and *Trichophyton rubrum* was overwhelmingly the leading pathogen, accounting for half of all isolates within a spectrum dominated (81.2%) by anthropophilic species. Crucially, culture yield was governed not by demographic factors but by two clinically actionable variables: KOH positivity (adjusted OR 5.20) and prior antifungal exposure (adjusted OR 0.30), which together drove a well-discriminating predictive model (AUC 0.785).

The predominance of *T. rubrum* aligns closely with the global and Asian literature. Contemporary reviews and multicentre surveys consistently identify *T. rubrum* as the single most common dermatophyte worldwide, typically representing 40–70% of isolates, followed by the *T. mentagrophytes*/*interdigitale* complex.[1,2,13] Indonesian and wider Southeast Asian series have similarly reported *T. rubrum* dominance in tinea corporis, cruris and pedis, with *T. mentagrophytes* complex as the principal secondary isolate.[4,5,20] Our species hierarchy - *T. rubrum* (50.0%), *T. mentagrophytes* complex (15.9%), *M. canis* (10.1%) - is therefore consistent with regional expectations and confirms that the anthropophilic, chronic-infection paradigm predominates in Bali.

The comparatively substantial contribution of zoophilic species (14.5%), chiefly *M. canis* and *T. verrucosum*, merits attention. Bali's mixed agrarian economy, close human-animal cohabitation and large free-roaming dog and cat populations plausibly sustain zoonotic transmission, echoing reports from other tropical and Mediterranean regions where *M. canis* is a leading cause of tinea capitis in children.[10,21,22] The 12.1% frequency of tinea capitis in our cohort, occurring at a younger age, is congruent with this zoophilic reservoir and highlights a One-Health dimension to local dermatophyte epidemiology.[9,10] Continued culture surveillance is warranted to detect shifts in this anthropophilic-zoophilic balance, particularly any incursion of terbinafine-resistant *T. indotineae*, which has spread rapidly across South Asia and been increasingly reported in Southeast Asia.[13,16,17]

Our central analytical finding - that prior antifungal use more than halves the odds of a positive culture (aOR 0.30) - has direct diagnostic-stewardship implications and is strongly supported by mechanistic and clinical evidence. Even brief topical or systemic antifungal exposure suppresses fungal viability and

arthroconidial growth on Sabouraud agar, producing false-negative cultures while KOH microscopy, which detects non-viable hyphal elements, remains positive for longer.[11,12,23] This dissociation explains both the strong protective effect of prior treatment on culture and the moderate KOH-culture agreement (kappa 0.483) we observed. Practically, it argues for obtaining specimens for culture before initiating empirical therapy and for a two-to-four-week antifungal washout when confirmatory culture is clinically necessary, especially in recalcitrant or suspected-resistant disease.[12,13,16]

The strong independent association between KOH positivity and culture yield (aOR 5.20; model AUC 0.785) reaffirms the enduring value of direct microscopy as a rapid, low-cost triage test in resource-constrained tropical settings.[3,14,15] The sensitivity we observed for KOH against culture (86.2%) is consonant with pooled estimates from diagnostic meta-analyses, which report KOH sensitivities of roughly 74–88% relative to culture, albeit with variable specificity owing to operator dependence and the imperfect nature of culture as a reference standard.[14,24] Our data support a pragmatic diagnostic algorithm in which KOH-negative or previously treated patients with a high clinical suspicion are prioritised for culture or, where available, molecular confirmation, while culture is used selectively rather than universally.[11,17,23]

Placing our culture-positivity estimate of 64.5% within the literature is instructive. Reported culture yields in clinically diagnosed dermatophytosis vary widely - from below 45% to above 70% - largely because of differences in pre-sampling antifungal exposure, specimen quality, anatomical site and laboratory technique.[12,14,17] Our estimate sits in the upper-middle of this range, consistent with a referral population enriched for florid, chronic disease but attenuated by the 34.6% prevalence of prior antifungal use. The quantified, independent effect of prior treatment (aOR 0.30) offers a concrete explanation for the inter-study heterogeneity that has long complicated comparison of culture-positivity figures across centres, and argues for routine reporting of pre-sampling antifungal exposure in future mycological surveys.

Mechanistically, the clinical patterns we observed are underpinned by well-characterised host-pathogen biology. The chronic, relapsing course typical of *T. rubrum* reflects its efficient keratinolytic protease arsenal and its capacity to attenuate cutaneous innate and adaptive immunity through cell-wall mannans and modulation of Th17/interferon-gamma responses, favouring immune tolerance and persistence.[7,8] The modestly longer disease duration among culture-positive patients (median 6.0 versus 4.8 months) is consistent with this indolent anthropophilic biology and with the higher fungal burden that accompanies established, untreated infection.[7,18] These observations reinforce the rationale for species-level identification, since anthropophilic and zoophilic infections differ in their natural history, transmission dynamics and optimal management.

A recognised constraint of culture-based surveillance is its reliance on phenotypic identification, which is slow and cannot reliably resolve cryptic species within the *T. mentagrophytes*/*interdigitale* complex - the very clade that harbours terbinafine-resistant *T. indotineae*.[11,13,16] Molecular tools, including species-specific and multiplex PCR, internal-transcribed-spacer (ITS) sequencing and, increasingly, real-time PCR panels, offer rapid and precise identification directly from clinical material and are becoming the aspirational standard for dermatophyte diagnostics.[9,11] Although not yet routine in most Indonesian laboratories for reasons of cost and infrastructure, the selective deployment of molecular confirmation for culture-negative-but-clinically-suspicious cases, or for suspected resistant infection, would complement the predictive framework described here and strengthen national resistance surveillance.[13,16,17]

From a service-delivery perspective, these findings carry concrete implications for the Dermatology and Venereology service at Ngoerah Hospital and comparable Indonesian referral centres. First, the local aetiological map - anthropophilic *T. rubrum* predominance with a meaningful zoophilic minority - can inform empirical therapy and patient education, including household and animal-contact tracing for

zoophilic cases. Second, the predictive model provides a simple, evidence-based rule for rationing culture, a scarce resource under Indonesia's national health-insurance (BPJS Kesehatan) framework, toward the patients most likely to yield actionable results - namely KOH-positive, treatment-naive, chronic presentations.[5,17] Third, systematic culture surveillance establishes the baseline needed to detect emerging antifungal resistance, a capacity of growing national importance.[16,17]

The Balinese and broader Indonesian context further contextualises our results. The tropical maritime climate, high ambient humidity and intense ultraviolet exposure promote sweating, maceration and barrier disruption that favour dermatophyte colonisation, while occupational factors in agriculture, fisheries and the tourism sector, together with cultural practices such as frequent temple and communal bathing and the wearing of occlusive ceremonial attire, may amplify transmission.[2,3,6] The predominance of Fitzpatrick phototypes III–IV in our cohort typifies the Balinese population and reinforces the external validity of these findings for eastern Indonesia; Ngoerah Hospital's role as the regional referral hub for Bali and Nusa Tenggara means the observed spectrum is broadly representative of the wider catchment.[5,6]

The sex and age distribution of our cohort mirrors regional patterns. Male predominance in dermatophytosis is near-universal across Asian series and is generally attributed to greater occupational heat and sweat exposure, physical activity and, for tinea cruris, anatomical and clothing factors.[4,14,20] The middle-aged peak we observed, together with the younger age of tinea capitis cases, is likewise concordant with the literature and supports the representativeness of the sample despite its single-centre origin.[5,10] The steady year-on-year rise in case ascertainment from 2020 to 2023 most plausibly reflects the recovery of outpatient services after pandemic-related disruption rather than a true change in incidence, and should be interpreted with that caveat.

Translating these results into practice, we propose a pragmatic, tiered diagnostic algorithm for tropical dermatology services. Patients with clinically typical, treatment-naive, localised tinea and a positive KOH result may reasonably be managed empirically, with culture reserved for defined indications: KOH-negative but clinically convincing disease, extensive or recalcitrant infection, suspected treatment failure or resistance, tinea capitis and onychomycosis (where species and viability guide prolonged systemic therapy), and immunocompromised hosts. Critically, when culture is indicated, specimens should be obtained before empirical therapy or after an adequate antifungal washout, given the strong negative effect of prior treatment on yield (aOR 0.30). Such an algorithm rations a scarce laboratory resource toward the patients most likely to benefit, feeds isolates into resistance surveillance, and is readily implementable within existing outpatient workflows; it requires no new technology and aligns diagnostic effort with the presentations in which species-level information genuinely changes management decisions.

The economic corollary of a targeted culture strategy is worth making explicit. In a high-volume service, applying culture universally to every clinically diagnosed tinea consumes laboratory reagents, technician time and incubation capacity while a substantial fraction of specimens - particularly from previously treated patients - return negative and non-informative. Directing culture toward the predicted-high-yield subgroup (KOH-positive, treatment-naive, chronic or recalcitrant, tinea capitis, onychomycosis, and immunocompromised patients) preserves diagnostic information where it alters management while reducing low-value testing. In a health system where dermatological diagnostics compete for finite national-insurance resources, this reallocation is likely to improve cost-effectiveness without compromising, and potentially enhancing, the detection of clinically important and resistant infections that genuinely require species-level confirmation.[5,16,17]

The absence of a significant independent association between metabolic comorbidity and culture positivity in our data merits comment. Although diabetes mellitus and obesity are established risk factors for the acquisition and chronicity of dermatophytosis - through impaired barrier function,

local hyperglycaemia, sweating and immune dysregulation - their influence operates primarily on susceptibility to infection rather than on the probability that an established, clinically evident infection will grow in culture.[2,6,14] Once a patient presents with clinically diagnosed tinea, culture yield is dominated by pre-analytical microbiological factors (viability, prior treatment) rather than host metabolic status, which plausibly explains the null adjusted estimates for diabetes (aOR 0.73) and the attenuation of the crude signal. This distinction between determinants of infection and determinants of diagnostic yield is an important interpretive nuance for clinicians.

This study has several strengths. It is, to our knowledge, the first four-year, analytically comprehensive mycological surveillance of dermatophytosis from Bali, drawing on species-level culture data rather than clinical typing or KOH alone. The use of consecutive sampling over a defined period, explicit STROBE-compliant reporting, an a priori sample-size calculation, and an upgraded inferential framework - Wilson confidence intervals, effect sizes, multivariable adjustment and ROC analysis - lends the estimates precision and internal validity uncommon in regional descriptive reports. The single-centre processing of all specimens in one accredited mycology laboratory also minimised measurement heterogeneity.

A further methodological strength is the deliberate emphasis on effect estimation over null-hypothesis testing. By reporting odds ratios, adjusted odds ratios, Cramér's V, rank-biserial correlations, Cohen's kappa and areas under the curve, each with confidence intervals, the analysis conveys the magnitude and precision of associations rather than mere statistical significance - an approach increasingly advocated in biomedical reporting and particularly valuable for translating findings into clinical decision rules. The convergence of the bivariate, multivariable and diagnostic-accuracy analyses on the same two dominant determinants (KOH status and prior treatment) provides internal triangulation that strengthens confidence in the central conclusion.

Finally, our findings intersect with the wider public-health agenda of antimicrobial and antifungal stewardship. Indiscriminate over-the-counter use of topical corticosteroid-antifungal combinations and incomplete treatment courses are recognised drivers of the recalcitrant-dermatophytosis epidemic in South and Southeast Asia, both by selecting for resistance and by obscuring diagnosis.[13,16,17] A diagnostic pathway that captures culture before empirical therapy, targets confirmatory testing to the highest-yield presentations, and feeds isolates into susceptibility surveillance directly supports national efforts to contain antifungal resistance. Embedding such a pathway within Indonesia's tiered referral and national health-insurance system, with Ngoerah Hospital as a regional reference laboratory, could provide an early-warning function for the emergence of resistant taxa in eastern Indonesia while improving the cost-effectiveness of mycological diagnosis. Taken together, the present findings translate an observational dataset into an actionable framework: they define the local pathogen spectrum, quantify the two determinants that most influence diagnostic yield, and specify precisely which patients should be prioritised for culture, thereby aligning limited laboratory capacity with the clinical scenarios in which species-level information changes management and supports the containment of antifungal resistance.

Several avenues for future research follow directly from this work. Prospective, multicentre studies spanning primary-care and referral settings would clarify the extent of referral bias and yield community-representative estimates of species distribution and culture yield. Incorporating ITS sequencing and CLSI/EUCAST-based antifungal-susceptibility testing would establish a baseline prevalence of terbinafine and azole resistance in eastern Indonesia and detect any incursion of *T. indotineae*. External validation and calibration of the predictive model in independent cohorts, potentially augmented with dermoscopic and specimen-quality variables, could yield a deployable clinical decision rule for culture triage. Finally, One-Health investigations linking human zoophilic isolates to animal reservoirs would inform targeted prevention in Bali's mixed human-animal environment. Health-

economic evaluation of the proposed targeted-culture algorithm, comparing diagnostic yield, turnaround and cost per actionable result against a universal-culture strategy, would provide the evidence needed to embed such a pathway in national dermatology guidelines and to justify investment in molecular capacity at regional reference laboratories.

Several limitations must be acknowledged. First, the retrospective, single-centre design at a tertiary referral hospital may over-represent chronic, recurrent and previously treated cases, potentially biasing the culture-positivity estimate and the species mix relative to primary-care populations; the findings should be extrapolated to community settings with caution.

Second, species identification relied on phenotypic (morphological) methods without molecular confirmation or antifungal-susceptibility testing, so cryptic species within the *T. mentagrophytes* complex - including *T. indotineae* - may have been under-recognised. Third, culture itself is an imperfect reference standard, and its yield is influenced by unmeasured pre-analytical factors such as specimen adequacy and transport time. Fourth, some clinical variables abstracted from records (notably prior antifungal use and disease duration) are subject to documentation and recall limitations. Finally, as an observational study, residual confounding cannot be excluded, and the associations reported should be interpreted as predictive rather than strictly causal. Prospective, multicentre studies incorporating molecular identification and susceptibility testing are needed to confirm and extend these findings.

5. Conclusion

In this four-year retrospective study at a tertiary referral centre in Bali, dermatophytosis was dominated by anthropophilic *Trichophyton rubrum*, which accounted for half of all culture isolates within a spectrum in which anthropophilic species comprised 81.2%. Fungal culture was positive in 64.5% of clinically diagnosed cases, and culture yield was independently and strongly determined by KOH positivity (adjusted OR 5.20) and, inversely, by prior antifungal exposure (adjusted OR 0.30), within a well-discriminating predictive model (AUC 0.785). These results support a pragmatic, stewardship-oriented diagnostic pathway for tropical dermatology services: obtain specimens for culture before empirical therapy, reserve culture preferentially for KOH-positive, treatment-naive and chronic or recalcitrant presentations, and maintain systematic species-level surveillance to detect zoophilic transmission and emerging antifungal resistance in eastern Indonesia. Prospective, multicentre investigations incorporating molecular identification and antifungal-susceptibility testing are warranted to validate this predictive framework and to monitor the evolving epidemiology of dermatophytosis in the region.

Declarations

Ethical approval

This study received ethical approval from the CMHC Ethics Committee, Indonesia (Approval No. CMHC/EC/2025/0417).

Conflict of interest

The authors declare no competing interests.

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Author contributions

All authors contributed to the conception and design of the study. NLPRVK and AOO were responsible for data acquisition, statistical analysis and interpretation, and drafting of the manuscript; IAKA supervised the mycological laboratory procedures and critically revised the manuscript for important intellectual content. All authors have reviewed and approved the final version of the manuscript.

Data availability

The datasets generated and analysed during the current study are available from the corresponding author upon reasonable request.

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