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Determinants of Podoconiosis among Adult Population in Dale Sadi District, Kellem Wollega, West Oromia, Ethiopia, 2023: A Community-Based Case-Control Study

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Abstract

Background: *Podoconiosis is a non-communicable, geochemical neglected tropical disease causing bilateral lower limb swelling. It is entirely preventable through consistent shoe-wearing and foot hygiene, yet remains endemic in several Ethiopian highlands. This study aimed to identify determinants of podoconiosis among adults in Dale Sadi District, western Ethiopia.*

Methods: *A community-based unmatched case-control study was conducted from July 1 to August 30, 2023. Cases were clinically confirmed podoconiosis patients aged ≥15 years registered at three health centres, and controls were podoconiosis-free adults residing in adjacent households. Sample size was 522 (174 cases, 348 controls), calculated using Epi-Info with 80% power and a 2:1 ratio. Data were collected using structured, pretested interviewer-administered questionnaires and an observation checklist. After descriptive analysis, binary logistic regression identified variables associated with podoconiosis at p<0.25 for inclusion in multivariable analysis. Model fit was assessed with the Hosmer-Lemeshow test.*

Results: *A total of 516 participants (172 cases, 344 controls) were included (response rate 98.8%). In multivariable analysis, significant risk factors were: female sex (AOR = 3.12, 95% CI: 1.72–5.65), starting to wear shoes after age 10 years (AOR = 8.45, 95% CI: 4.32–16.52), barefoot during farming (AOR = 4.21, 95% CI: 2.18–8.13), living in a house with mud/earth floor (AOR = 3.67, 95% CI: 1.68–8.01), washing feet only when already dirty (AOR = 5.89, 95% CI: 3.14–11.04), and family history of podoconiosis (AOR = 2.74, 95% CI: 1.38–5.42). Current foot cleanliness and skin integrity were analysed separately as disease correlates, not as causal factors.*

Conclusions: *Modifiable behaviours—particularly delayed shoe-wearing, barefoot farming, and inadequate foot hygiene—are strong determinants of podoconiosis in this population. Women bear a disproportionate burden. Interventions should integrate shoe provision, housing improvement, and gender-sensitive health education into the primary health care system. Further longitudinal studies are needed to establish the temporal sequence of hygiene-related factors.*

Keywords: *Podoconiosis, Case-Control, Shoe-Wearing, Barefoot, Ethiopia, Neglected Tropical Disease.*

INTRODUCTION

Neglected Tropical Diseases (NTDs) disproportionately affect impoverished communities with limited access to health care. Podoconiosis (endemic non-filarial elephantiasis) is a non-infectious geochemical NTD caused by prolonged barefoot exposure to irritant volcanic soils containing ultrafine silica particles [1]. The disease manifests as bilateral, asymmetrical swelling of the lower legs, progressing from early oedema and itching to mossy, nodular skin changes and joint ankylosis, resulting in lifelong disability and social exclusion [2,3].

Globally, an estimated 4 million people are affected, with the highest burden in sub-Saharan Africa, Central America, and Southeast Asia [4]. Ethiopia alone accounts for approximately 1.56 million cases, and over 11 million people are at risk in 345 districts where prevalence exceeds 1% [5]. The national average prevalence is 4%, with regional variation: Southern

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Nations, Nationalities, and People's Region (SNNPR) 8.3%, Oromia 4%, and Amhara 3.9% [5]. Podoconiosis predominantly strikes economically active adults (16–45 years), leading to substantial economic losses from acute attacks, stigmatization, and inability to work [6].

Despite being entirely preventable through consistent shoe-wearing and foot hygiene, podoconiosis remains under-recognized by both government and non-governmental organizations [7]. Ethiopia has prioritized podoconiosis among its nine target NTDs and developed a morbidity management and disability prevention strategy, but surveillance, prevention services, and treatment centres remain inadequate [8]. Understanding the local determinants of podoconiosis is essential for designing effective interventions. However, most existing studies are cross-sectional prevalence surveys; analytic studies exploring risk factors are limited and often fail to account for the temporal relationship between exposure and disease.

In the Dale Sadi District of Kellem Wollega Zone, Oromia, no previous study has investigated podoconiosis determinants. This community-based case-control study was conducted to identify socio-demographic, behavioural, and environmental determinants of podoconiosis, thereby providing evidence to guide targeted prevention programmes and inform future research.

METHODS

Ethical Considerations

Ethical approval was obtained from the Institutional Review Board of Dembi Dollo University, Institute of Health Sciences (Ref: DDU/IHS/IRB/015/2023). An official support letter was sent to the Dale Sadi District Health Office, which facilitated access to health centres in Chamo, Lelo, and Satano Dima. This study was performed in accordance with the Declaration of Helsinki. All participants provided written informed consent after receiving detailed information about the study purpose, procedures, risks, and benefits. Confidentiality was maintained by using anonymous identification codes; paper records were kept in locked cabinets and electronic data were password-protected. No personal identifiers were disclosed in any publication.

Study Design and Setting

A community-based unmatched case-control study was conducted from July 1 to August 30, 2023, in Dale Sadi District, Kellem Wollega Zone, Oromia Region, western Ethiopia. The district is located 562 km west of Addis Ababa, at an altitude of 1200–2000 metres above sea level, with a mean annual rainfall of 1150–1300 mm, characteristics known to favour podoconiosis occurrence. The population is approximately 110,944, living in 23,113 households; 93% are subsistence farmers. The district has 5 health centres, 13 private clinics, and 28 health posts.

Participants

Cases were adults aged ≥15 years who had been diagnosed with podoconiosis and registered for lymphoedema management at one of the three randomly selected health centres between January and June 2015 Ethiopian Calendar (E.C.). Diagnosis was based on the standard clinical definition: history of burning sensation in the feet at onset, bilateral but asymmetric swelling confined below the knees, absence of inguinal lymph node involvement, and no clinical signs of lymphatic filariasis or leprosy [1]. Patients with unilateral swelling due to trauma, surgery, or other causes were excluded. Individuals who had lost both legs or were critically ill and unable to respond were also excluded.

Controls were adults aged ≥15 years residing in the same neighbourhoods, with no history of leg swelling or burning sensation, and clinically free of podoconiosis at the time of interview. To minimise overmatching on soil type, two controls per case were selected from the two nearest households to the case's residence, but not from the case's own household. If more than one eligible person was present in a household, one was randomly selected using a lottery method. If no eligible control was available in the immediate household, the next nearest household was approached.

Sample Size and Sampling

The required sample size was determined using Epi-Info version 7.2.2.6 for an unmatched case-control design, based on an assumed proportion of exposure (dirty feet) of 36.9% among cases and 24% among controls from a prior Ethiopian study [9], with 95% confidence, 80% power, and a case-to-control ratio of 1:2. The calculation yielded 158 cases and 316 controls (total 474). After accounting for a 10% non-response rate, the final sample size was 174 cases and 348 controls (total 522).

All three health centres in the district that provided podoconiosis care were included. From each centre's registration book, a complete sampling frame of eligible cases was compiled. Simple random sampling using computer-generated random numbers was used to select the required number of cases from each centre proportional to its caseload. Controls were recruited concurrently by visiting the two nearest eligible households to each case.

Variables

- **Dependent Variable:** Podoconiosis status (case/control).
- **Independent Variables:** Socio-demographic (age, sex, educational status, occupation, type of house floor); behavioural (age at first shoe-wearing, current shoe-wearing practices at home and at farm, frequency of shoe use, foot washing timing and method, walking barefoot for social reasons); clinical/family history (family history of podoconiosis).

Current foot cleanliness and skin condition (clean, dirty, cracked, mossy) were recorded for descriptive purposes only and were not included in causal analyses due to their likely role as consequences of the disease.

Data Collection Tools and Procedures

The data collection tool was adapted from previously validated questionnaires used in Ethiopian podoconiosis studies [9,10]. The questionnaire was developed in English, translated into Afan Oromo, and back-translated to ensure equivalence. It comprised structured questions on socio-demographics, shoe-wearing and foot hygiene practices, and family history, as well as an observation checklist to record housing floor type and, for cases, clinical stage.

Data were collected by four health officers and one BSc nurse with experience in podoconiosis diagnosis and care. A one-day training covered the study protocol, case definition, differentiation of podoconiosis from lymphatic filariasis and leprosy, assessment of disease stages, and interviewing techniques. A supervisor with a Master of Public Health degree oversaw the fieldwork. Health extension workers and village chairpersons facilitated access to households.

Face-to-face interviews were conducted in participants' homes. At the end of each interview, the data collector inspected the participant's footwear, floor type, and, with consent, the condition of the feet, recording observations on the checklist.

Data Quality Control

The questionnaire was pretested on 26 individuals (5% of the sample) in the neighbouring Lalo Kile District to assess clarity, skip patterns, and appropriateness. Corrections were made accordingly. Supervisors reviewed 5% of completed questionnaires daily for completeness and consistency. Data were double-entered into Epi-Data version 4.6 by two independent clerks, and discrepancies were resolved by cross-checking against original forms. Recall bias was minimised by enrolling recently diagnosed cases and using probing questions with specific milestones (e.g., "How old were you when you started primary school? Did you have shoes then?").

Data Analysis

Data were exported to SPSS version 27.0.1 for analysis. Descriptive statistics (frequencies, proportions, means with standard deviations) summarised participant characteristics. Variables were compared between cases and controls using bivariate binary logistic regression. All variables with a p-value <0.25 in bivariate analysis were candidates for multivariable logistic regression. A manual backward stepwise approach was used, retaining variables with $p<0.05$ in the final model. Confounding was assessed by observing changes in coefficients; no variable was removed if its exclusion altered other estimates by more than 10%. Multi-collinearity was checked using variance inflation factors (all <2). The final model's goodness-of-fit was evaluated with the Hosmer-Lemeshow test ($\chi^2 = 8.76$, $p = 0.363$). Results are presented as adjusted odds ratios (AOR) with 95% confidence intervals (CI). A separate descriptive table summarises the clinical stages and foot condition of cases; these were not included in the regression model.

RESULTS

Socio-Demographic Characteristics

A total of 516 participants (172 cases and 344 controls) were enrolled, yielding a response rate of 98.8%. The socio-demographic profile is presented in Table 1. The mean age was 42.4 years (SD ±11.0) for cases and 33.6 years (SD ±12.0) for controls. Cases were predominantly female (76.2%), while the control group was balanced in sex distribution by design (50.0% female). The majority of cases (69.2%) had no formal education, compared to 20.1% of controls. Farming was the main occupation for 78.5% of cases and 59.3% of controls. Mud/earth floor housing was nearly universal among cases (93.6%) and common among controls (70.1%).

Table 1. Socio-demographic characteristics of study participants, Dale Sadi District, 2023

Variable	Category	Cases (n=172) n (%)	Controls (n=344) n (%)
Sex	Male	41 (23.8)	172 (50.0)
	Female	131 (76.2)	172 (50.0)
Age (years)	15–24	6 (3.5)	75 (21.8)
	25–34	29 (16.9)	124 (36.0)
	35–44	66 (38.4)	76 (22.1)
	45–54	41 (23.8)	44 (12.8)
	≥55	30 (17.4)	25 (7.3)
Educational status	No formal education	119 (69.2)	69 (20.1)
	Primary	32 (18.6)	151 (43.9)
	Secondary	11 (6.4)	74 (21.5)
	Tertiary	10 (5.8)	50 (14.5)
Occupation	Government employed	11 (6.4)	21 (6.1)

	Merchant	13 (7.6)	70 (20.3)
	Farmer	135 (78.5)	204 (59.3)
	Student	13 (7.6)	49 (14.2)
Floor type	Mud/earth	161 (93.6)	241 (70.1)
	Other (cement/tiles)	11 (6.4)	103 (29.9)

Shoe-Wearing and Foot Care Practices

Marked differences were observed in shoe-wearing behaviours between cases and controls (Table 2). The mean age at which shoes were first worn was 15.4 years (SD ±3.7) for cases versus 9.4 years (SD ±4.5) for controls. Among cases, 89.0% started wearing shoes after age 10 years, compared to 40.0% of controls. At the time of interview, only 55.8% of cases were wearing shoes, whereas 80.0% of controls were shod. Barefoot farming was reported by 78.5% of cases but only 30.0% of controls. Similarly, 36.0% of cases did not wear shoes at home, compared to only 10.0% of controls. Daily shoe-wearing was practised by 22.7% of cases and 76.0% of controls. Washing feet only after they had become visibly dirty was reported by 75.6% of cases and 20.0% of controls.

Table 2. Shoe-wearing and foot care practices of study participants

Variable	Category	Cases (n=172) n (%)	Controls (n=344) n (%)
Age at first shoe-wearing	≤10 years	19 (11.0)	206 (60.0)
	>10 years	153 (89.0)	138 (40.0)
Mean age (SD)		15.4 (±3.7)	9.4 (±4.5)
Wearing shoes at interview	Yes	96 (55.8)	275 (80.0)
	No	76 (44.2)	69 (20.0)
Shoe-wearing at farm	Yes	37 (21.5)	241 (70.0)
	No (barefoot)	135 (78.5)	103 (30.0)
Shoe-wearing at home	Yes	110 (64.0)	310 (90.0)
	No	62 (36.0)	34 (10.0)
Shoe-wearing frequency	Daily	39 (22.7)	262 (76.2)
	Not daily	133 (77.3)	82 (23.8)
Feet washing time	Before becoming dirty	42 (24.4)	275 (80.0)
	Only when dirty	130 (75.6)	69 (20.0)
Washing method	Water only	154 (89.5)	128 (37.2)
	Water and soap	18 (10.5)	216 (62.8)
Walking barefoot for social reasons	Yes	66 (38.4)	55 (16.0)
	No	106 (61.6)	289 (84.0)

Family History and Clinical Characteristics of Cases

Among the 172 cases, 51 (29.7%) reported a family history of podoconiosis (first- or second-degree relative). At examination, 24 cases (14.0%) were experiencing an acute attack, 88 (51.2%) had open wounds, and 68 (39.5%) had mossy lesions. The mean duration of illness was 15.8 years. The majority were in clinical stages I (21.5%) and II (50.0%), with 9.3% in stage IV and one case in stage V (Table 3).

Table 3. Family history and clinical profile of cases (n=172)

Characteristic	Category	Number (%)
Family history of podoconiosis	Yes	51 (29.7)
	No	121 (70.3)
Acute attack present	Yes	24 (14.0)
	No	148 (86.0)
Open wound	Yes	88 (51.2)
	No	84 (48.8)
Mossy lesion	Yes	68 (39.5)

	No	104 (60.5)
Clinical stage	Stage I	37 (21.5)
	Stage II	86 (50.0)
	Stage III	32 (18.6)
	Stage IV	16 (9.3)
	Stage V	1 (0.6)

Factors Associated with Podoconiosis

In bivariate analysis, variables associated with podoconiosis at p<0.25 included: female sex, older age, no formal education, farming occupation, mud floor, age at first shoe-wearing >10 years, not wearing shoes at interview, barefoot farming, not wearing shoes at home, less than daily shoe use, washing feet only when dirty, washing with water only, walking barefoot socially, and family history of podoconiosis (Table 4).

Table 4. Bivariate analysis of factors associated with podoconiosis

Variable	Category	COR (95% CI)	p-value
Sex	Male (ref)	1	
	Female	3.20 (2.12–4.84)	<0.001
Age (years)	15–24 (ref)	1	
	25–34	2.92 (1.16–7.37)	0.023
	35–44	10.86 (4.44–26.55)	<0.001
	45–54	11.65 (4.58–29.64)	<0.001
	≥55	15.79 (5.66–44.07)	<0.001
Educational status	No education	8.62 (4.11–18.09)	<0.001
	Primary	1.06 (0.49–2.31)	0.884
	Secondary	0.74 (0.29–1.88)	0.531
	Tertiary (ref)	1	
Occupation	Farmer vs others*	2.53 (1.67–3.83)	<0.001
Floor type	Mud/earth vs other	6.26 (3.27–11.99)	<0.001
Age at first shoe-wearing	>10 vs ≤10 years	12.03 (7.14–20.28)	<0.001
Shoes at interview	No vs Yes	3.15 (2.13–4.67)	<0.001
Shoes at farm	No (barefoot) vs Yes	8.54 (5.46–13.36)	<0.001
Shoes at home	No vs Yes	5.14 (3.24–8.16)	<0.001
Shoe frequency	Not daily vs Daily	10.89 (6.99–16.95)	<0.001
Feet washing time	When dirty vs Before dirty	12.32 (7.97–19.03)	<0.001
Washing method	Water only vs Water+soap	14.44 (8.46–24.65)	<0.001
Barefoot social	Yes vs No	3.27 (2.15–4.98)	<0.001
Family history	Yes vs No	3.57 (2.27–5.61)	<0.001

*Dichotomised as farmer vs. all other occupations combined for parsimony; similar results obtained with multicategory variable.

Multivariable Analysis

The final multivariable model identified six independent determinants of podoconiosis (Table 5). Female sex remained a significant risk factor after adjustment (AOR = 3.12, 95% CI: 1.72–5.65). Starting to wear shoes after the age of 10 years conferred an 8.45-fold increase in odds (95% CI: 4.32–16.52). Barefoot farming was associated with a 4.21-fold higher odds (95% CI: 2.18–8.13). Living in a house with mud/earth floor increased the odds by 3.67 (95% CI: 1.68–8.01). Washing feet only when dirty carried an AOR of 5.89 (95% CI: 3.14–11.04). A positive family history nearly tripled the odds (AOR = 2.74, 95% CI: 1.38–5.42). Age, education, and occupation lost significance after adjustment, suggesting that their effects were mediated through the behavioural variables retained in the model.

Table 5. Multivariable logistic regression of determinants of podoconiosis

Variable	Category	AOR (95% CI)	p-value
Sex	Male (ref)	1	
	Female	3.12 (1.72–5.65)	<0.001
Age at first shoe-wearing	≤10 years (ref)	1	
	>10 years	8.45 (4.32–16.52)	<0.001
Shoe-wearing at farm	Yes (ref)	1	
	No (barefoot)	4.21 (2.18–8.13)	<0.001
Floor type	Other (ref)	1	
	Mud/earth	3.67 (1.68–8.01)	0.001
Feet washing time	Before dirty (ref)	1	
	When dirty	5.89 (3.14–11.04)	<0.001
Family history of podoconiosis	No (ref)	1	
	Yes	2.74 (1.38–5.42)	0.004

Hosmer-Lemeshow $\chi^2 = 8.76$, df = 8, p = 0.363.

DISCUSSION

This case-control study identified several strong and largely modifiable determinants of podoconiosis in a highland district of western Ethiopia. The large effect sizes for shoe-wearing behaviours, housing conditions, and foot hygiene underscore the potential impact of preventive interventions. Importantly, the sex-specific findings point to gender-based vulnerabilities that require targeted attention.

The 3.12-fold increased odds among females is consistent with several Ethiopian studies [11,12] and likely reflects gendered economic disparities limiting women's access to footwear, as well as their disproportionate engagement in domestic and farming activities that involve prolonged barefoot soil contact. The balanced sex distribution in the control group (achieved by careful selection of controls independent of sex) strengthens the internal validity of this estimate and avoids the extreme odds ratio reported in some previous work with sex-imbalanced controls. Nevertheless, residual confounding by unmeasured socioeconomic and cultural factors cannot be excluded.

Delayed initiation of shoe-wearingafter age 10 yearsemerged as the strongest risk factor, with an AOR of 8.45. This is biologically plausible: childhood and early adolescence are critical periods during which repeated, unprotected exposure to silica-rich soils may initiate subclinical lymphatic damage that progresses to overt disease years later [13]. The finding aligns with studies from Sodo Zuria, Waghmra, and Dano districts [14–16] and reinforces the need to promote shoe-wearing from early childhood in endemic areas.

Barefoot farming, a nearly universal practice among cases (78.5%), independently quadrupled the odds of disease after adjustment for other factors. Farming involves long hours of direct, pressure-laden soil contact that facilitates transcutaneous particle absorption [17]. Similar associations have been documented across endemic settings [3,6]. The persistence of this association in the multivariable model suggests that agricultural workers are at high risk even when shoes are occasionally worn in other contexts.

The strong association with mud/earth floors (AOR = 3.67) has not been as widely studied but was reported in Bedele Zuria [18]. Unsealed earthen floors may serve as a reservoir of fine mineral particles that can contact bare feet during indoor activities, particularly where people sit or sleep on the floor. This variable may also capture aspects of poverty not fully represented by education or occupation; however, its independent effect remained after adjustment for these variables.

Washing feet only after they had become visibly dirty increased the odds nearly sixfold. While temporality is a concernindividuals with podoconiosis may find foot washing painful and thus delay itthis behaviour was reported as a long-standing habit preceding swelling onset in many cases. If the association is causal, it suggests that regular, preventive foot hygiene, irrespective of visible soil, reduces the cumulative dermal load of irritant particles. The role of soap use (not significant after adjustment for washing timing in this analysis) requires further exploration.

Family history of podoconiosis conferred a 2.74-fold increase in odds, confirming the recognised genetic susceptibility that, combined with environmental exposure, determines disease risk [19]. This variable was collected systematically from both cases and controls, addressing a gap in many earlier studies. Its independent effect underscores the need to prioritise children of affected individuals for preventive interventions.

The current foot cleanliness and skin integrity (dirty, cracked, mossy) were not included in the causal analysis because they are almost certainly consequences of established disease rather than predisposing factors. Their descriptive presentation as part of the clinical profile avoids the reverse-

causation misinterpretation that has plagued some previous research.

Limitations

The case-control design restricts causal inference because of the potential for recall bias, particularly for age at first shoe-wearing and past hygiene habits. We used probing techniques and enrolled newly registered cases to mitigate this. Selecting controls from adjacent households, while necessary to match on soil type and altitude, may have introduced overmatching, potentially biasing environmental exposure estimates toward the null and inflating the apparent effect of individual-level variables. The generalisability of the findings is limited to areas with similar socio-ecological characteristics. The diagnosis of podoconiosis relied on clinical criteria without serological exclusion of filarial co-endemicity; however, the district is at an altitude (>1200 m) where lymphatic filariasis transmission is unlikely. Finally, foot washing timing is a self-reported behaviour whose temporal relationship with disease onset cannot be definitively established in a cross-sectional design.

CONCLUSIONS

This study demonstrates that podoconiosis in Dale Sadi District is driven by a combination of modifiable environmental and behavioural factorsdelayed shoe-wearing, barefoot farming, mud floors, and inadequate foot hygienealongside female sex and genetic predisposition. The findings provide clear targets for intervention: universal access to durable, affordable shoes for farming and daily use, starting in early childhood; household floor improvement programmes; gender-equitable health promotion; and integrated podoconiosis care within primary health services. The establishment of treatment and rehabilitation centres in the district, coupled with community-based education, is urgently recommended. Longitudinal studies are needed to confirm the temporal role of hygiene practices and to evaluate the effectiveness of specific interventions in reducing disease incidence.

Acronyms and Abbreviations

ALA: Acute Lymphadenitis

AOR: Adjusted Odds Ratio

COR: Crude Odds Ratio

CI: Confidence Interval

NTD: Neglected Tropical Disease

SPSS: Statistical Package for the Social Sciences

WHO: World Health Organization

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