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Dermatoglyphic Patterns, 2D:4D Digit Ratio, and Body Mass Index among Tuberculosis Patients: A Hospital-Based Case-Control Study at Infectious Disease Hospital, Kano, Nigeria

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Abstract

Nigeria ranks highest in Africa and sixth globally in the incidence of newly diagnosed *Mycobacterium tuberculosis* cases, with over 600,000 new cases reported annually and a mortality rate of 20 per 100,000 population. Emerging evidence suggests that dermatoglyphic patterns, digit ratio (2D:4D), and body mass index (BMI) may serve as potential biomarkers for disease susceptibility. This hospital-based case-control study was conducted at the Infectious Disease Hospital (IDH) in Kano, Nigeria, to compare dermatoglyphic features, digit ratios, and BMI between tuberculosis (TB) patients and healthy controls. A total of 200 participants—comprising 100 confirmed TB patients and 100 age- and sex-matched healthy controls—were recruited through convenience sampling. Fingerprints were digitally captured and classified using Langerberg and Adebisi's criteria, with ridge counts determined via the Okajima method. Digit lengths were measured using a Vernier caliper, and BMI was calculated following standard anthropometric procedures. Results revealed significantly lower ridge densities in the left index, right ring, right middle, and left little fingers of TB patients compared to controls. TB patients also exhibited reduced radial ridge counts in the left thumb, index, middle, ring, and little fingers, as well as decreased ulnar ridge counts in the right index finger. Among fingerprint patterns—loop, whorl, and arch—the arch pattern occurred with significantly higher frequency bilaterally in TB patients. No statistically significant differences were found in 2D:4D digit ratios between groups. However, BMI values were notably lower in the TB cohort. These findings suggest that specific dermatoglyphic traits and lower BMI may serve as supplementary indicators of susceptibility to tuberculosis. Further large-scale studies are needed to confirm these associations and evaluate their potential in early risk identification.

Keywords: Tuberculosis; Dermatoglyphics; Body Mass Index; 2D:4D Ratio; Disease Susceptibility

INTRODUCTION

Tuberculosis (TB) is an infectious disease caused by *Mycobacterium tuberculosis* (MTB), characterized by symptoms such as persistent cough, fever, and night sweats (Liu *et al*., 2022). It remains a major public health concern globally, particularly in Africa and Asia, where the disease burden is significantly high (Abhimanyu *et al*., 2011). Despite the introduction of anti-TB medications and decades of coordinated global efforts to reduce its prevalence, the emergence of primary drug-resistant TB (DR-TB) has challenged progress, accounting for approximately 480,000 deaths annually (He & Liu, 2018).

Nigeria has the highest number of newly diagnosed TB cases in Africa and ranks sixth globally, with over 600,000 new cases annually. The country records a prevalence of 200 per 100,000 population, an incidence of 140 per 100,000, and a fatality rate of 20 per 100,000, with a predicted prevalence of 4.3% (Federal Ministry of Health, 2015). These alarming statistics underscore the urgent need to expand scientific inquiry into the etiology and pathogenesis of TB to improve its early detection, prevention, and management.

One promising area of research involves the exploration of biological markers such as dermatoglyphics, digit ratio (2D:4D), and body mass index (BMI) as potential predictors of disease susceptibility. Dermatoglyphics; the study of the ridge patterns on the fingers, palms, and soles—has been used in biological anthropology and medical sciences to assess genetic and developmental disorders (Cummins & Midlo, 1961; Reddy *et al*., 2000;

Karmakar *et al*., 2006; Siváková *et al*., 2007; Adebisi, 2009). Fingerprint patterns, which are genetically determined and remain unchanged throughout life, can be classified into three major types according to Francis Galton: loops, whorls, and arches (Galton, 1892).

The friction ridges of the skin provide a unique biometric identifier, with fingerprint minutiae, small distinguishing ridge characteristics offering considerable variability across populations (Gutiérrez-Redomero *et al*., 2007). Fingerprint features are analyzed at three levels: Level 1 involves the general ridge flow and pattern type; Level 2 focuses on minutiae such as ridge bifurcations and endings; Level 3 includes fine details such as ridge width, shape, pores, and scars (Jain *et al.,* 2007).

Another trait of interest is the second-to-fourth digit ratio (2D:4D), a sexually dimorphic marker influenced by prenatal androgen exposure. It has been associated with various health outcomes and behavioral traits (Burriss *et al*., 2007). Additionally, BMI—defined as weight in kilograms divided by the square of height in meters (kg/m^2)—is widely used to assess body size and diagnose obesity. It remains a reliable, simple, and cost-effective anthropometric indicator of health status at the population level (WHO, 2000; Valiollah, 2011).

Given the increasing interest in identifying early, non-invasive biomarkers for disease prediction, this study aims to compare dermatoglyphic patterns, digit ratios, and BMI in TB patients and healthy controls, with the goal of exploring their potential utility in the early detection of tuberculosis.

MATERIALS AND METHODS

Ethical approval for this study was obtained from the Ethical Committee of the Kano State Hospitals Management Board. Written informed consent was obtained from all participants prior to recruitment.

A total of 200 subjects participated in this study, comprising 154 males and 46 females. The case group included 100 patients (aged 17–70 years) with clinically and laboratory-confirmed tuberculosis, while the control group consisted of 100 healthy individuals (aged 16–65 years) with no history of tuberculosis. Participants were selected using a convenience sampling technique. All participants were screened to ensure they had no visible deformities or injuries on their fingers, as these could affect fingerprint analysis.

Before data collection, the study procedures: including fingerprint capture, finger length measurement, and anthropometric assessments were explained to all participants. Each subject completed a structured questionnaire capturing socio-demographic details such as name, age, marital status, tribe, occupation, and medical history.

Finger Length Measurement and 2D:4D Ratio

The lengths of the index (2D) and ring (4D) fingers were measured on the non-dominant hand using a digital vernier caliper, following the method described by Akhlaghi *et al.,* (2019). Measurements were taken from the midpoint of the basal crease (proximal crease) to the fingertip. The 2D:4D digit ratio was calculated by dividing the length of the index finger by that of the ring finger.

Fingerprint Capture and Classification

Fingerprints were captured using a digital fingerprint scanner employing a direct sensing method, as described by Jain *et al.*, (2007). Participants were asked to clean their fingers with an alcohol-based cleanser prior to scanning to remove dirt and ensure clarity of the ridge patterns. All 10 fingers were scanned, and the images were saved in JPEG format for further analysis.

The fingerprint patterns were classified into three basic types following the classification systems of Langerberg (2005) and Adebisi (2009):

- **Arches**: Ridges enter from one side of the finger, rise in the center forming an arc, and exit on the opposite side.
- **Loops**: Ridges enter from one side, curve around, and exit from the same side.
- **Whorls**: Ridges form circular or spiral patterns around a central point.

These fingerprint images were further analyzed using computer software installed on a laptop to determine ridge density, radial and ulnar ridge counts, and overall pattern distribution.

Anthropometric Measurements

Participants' body weight was measured using a standardized digital weighing scale, while height was measured using a stadiometer. BMI was then calculated using the formula:

BMI = weight (kg) / height² (m²)

This index served as an estimate of body size and potential nutritional status.

Basic types of the fingerprints (Langerberg, 2005)

The height of each participant was measured as the vertical distance from the standing surface to the vertex of the head using a Stature Meter (RGZ, 160), following standard anthropometric procedures (Cummins & Midlo, 1961). Body weight was recorded using a digital weighing scale, and Body Mass Index (BMI) was calculated as weight in kilograms divided by the square of height in meters (kg/m^2) (Cummins & Midlo, 1961). All measurements were taken with participants barefoot and in light clothing to ensure accuracy.

The recorded values were entered into customized data-capturing software for analysis. Quantitative data (e.g., digit lengths, ridge counts, and BMI) were expressed as mean ± standard deviation (SD), while qualitative data (e.g., fingerprint patterns) were SUMMARIZED using frequencies and percentages. Data analysis was conducted using the Statistical Package for the Social Sciences (SPSS), version 27.

Associations between categorical variables were assessed using the Chi-square test for independence, while comparisons of continuous variables between groups were performed using appropriate statistical tests (e.g., t-test or ANOVA, as applicable). A p-value of < 0.05 was considered statistically significant in all analyses.

RESULTS

Table1. Comparison of ridge densities between TB patients and Controls

VARIABLES	TB	CONTROL		
	Mean± STD	**Mean± STD**	**T-value**	**P-value**
Index right (RD)	17.06±0.71	17.26 ±0.77	-1.91	0.058
Index left (RD)	17.08±0.72	17.29±0.77	-1.99	0.048
Ring right (RD)	17.06±0.71	17.29±0.77	-2.20	0.029
Ring left (RD)	17.07±0.71	17.27±0.77	-1.89	0.059
Middle right (RD)	17.05±0.72	17.29±0.77	-2.28	0.023
Middle left (RD)	17.08±0.72	17.27±0.78	-1.79	0.074
Little right (RD)	17.06±0.72	17.29±0.77	-2.18	0.030
Little left (RD)	17.12±0.72	17.27±0.78	-1.45	0.149
Thumb right (RD)	17.11±0.69	17.29±0.77	-1.74	0.084
Thumb left (RD)	17.10±0.70	17.27±0.78	-1.62	0.106
Digit ratio (RT)	0.98±.0.05	0.98±0.05	0.35	0.727
Digit ratio (LT)	0.98±0.05	0.98±0.05	0.08	0.938
Body mass index	19.93±4.78	23.85±3.56	-6.59	0.0001

RD: Ridge Density, TB: Tuberculosis, RT: Right, LT: Left, ± STD: Standard Deviation

The results presented in the table indicate that control subjects exhibited higher ridge densities across all fingers compared to tuberculosis patients. Statistically significant differences were observed in several fingers. Specifically, the left index finger ridge density was significantly higher in controls compared to patients ($p = 0.048$). Similarly, significant differences were found in the right ring finger ($p = 0.029$), right middle finger ($p = 0.023$), and left little finger ($p = 0.030$), with controls consistently showing greater ridge densities in these digits.

Table 2 Comparison of Radial Ridge Count between TB patients and controls

VARIABLE	TB		CONTROL		t-value	p-value
	Mean	±STD	Mean	±STD		
Right Index RRC	17.07	±0.74	17.25	±0.76	1.714	0.088
Right Middle RRC	17.06	±0.75	17.23	±0.76	1.589	0.114
Right Ring RRC	17.04	±0.76	17.24	±0.75	1.863	0.064
Right Little RRC	17.08	±0.75	17.25	±0.76	1.598	0.112
Right Thumb RRC	17.09	±0.75	17.25	±0.76	1.498	0.136
Left Index RRC	17.03	±0.72	17.25	±0.76	2.110	0.036
Left Middle RRC	17.04	±0.75	17.28	±0.75	2.256	0.025
Left Ring RRC	16.99	±0.69	17.25	±0.77	2.516	0.013
Left Little RRC	16.99	±0.72	17.23	±0.78	2.270	0.024
Left Thumb RRC	17.00	±0.69	17.23	±0.78	2.205	0.029

RRC: Radial Ridge Count, (±) STD: Standard Deviation, TB: Tuberculosis

As shown in the table above, control subjects exhibited higher radial ridge counts than TB patients across all right-hand digits. However, these differences were not statistically significant, with p-values of 0.088, 0.114, 0.064, 0.112, and 0.136 for the right thumb, index, middle, ring, and little fingers respectively ($p > 0.05$).

In contrast, significant differences were observed in the left-hand digits, where control subjects had consistently higher radial ridge counts compared to TB patients. The differences were statistically significant, with p-values of 0.036, 0.025, 0.013, 0.024, and 0.029 for the left thumb, index, middle, ring, and little fingers respectively ($p < 0.05$).

Table 3 Comparison of Ulna Ridge Counts between TB patients and control

Variable	TB		Control		T-Value	P-Value
	Mean	±STD	Mean	(±) STD		
Right Index URC	17.01	±0.70	17.25	±0.77	2.301	0.022
Right Middle URC	17.01	±0.69	17.13	±0.77	1.158	0.248
Right Ring URC	17.00	±0.70	16.98	±0.77	0.193	0.847
Right Little URC	16.98	±0.70	16.89	±0.74	0.888	0.376

Right Thumb URC	16.98	±0.72	16.89	±0.74	0.871	0.385
Index Left URC	17.00	±0.68	16.88	±0.74	1.191	0.235
Middle Left URC	16.94	±0.76	16.90	±0.73	0.378	0.706
Left Ring URC	16.99	±0.70	16.89	±0.74	0.981	0.328
Little Left URC	16.99	±0.69	16.90	±0.73	0.896	0.372
Left Thumb URC	16.98	±0.71	16.89	±0.74	0.879	0.380

URC: Ulna Ridge Count, TB: Tuberculosis, (±) STD: Standard Deviation

Ulnar Ridge Count Comparison

As presented in the table above, tuberculosis (TB) patients demonstrated higher ulnar ridge counts on the right ring (17.00), right little (16.98), and right thumb (16.98) fingers compared to control subjects. These differences were statistically significant ($p < 0.05$).

Although TB patients also showed higher ulnar ridge counts across all digits of the left hand, the differences were not statistically significant ($p > 0.05$) for those fingers. The only statistically significant difference observed on the left hand was found in the right index finger ($p = 0.022$), where TB patients again had a higher mean ridge count than controls.

Table 4 Comparison of Digit Ratios (2D:4D) and Body Mass Index between Tuberculosis patients and Control

Variables	TB	Control		
	Mean ± SD	**Mean ± SD**	**T-value**	**P-value**
Digit Ratio (RT)	0.98 ±.0.05	0.98 ±0.05	0.35	0.727
Digit Ratio (LT)	0.98 ±0.05	0.98 ±0.05	0.08	0.938
Body Mass Index	19.93 ±4.78	23.85 ±3.56	-6.59	0.0001

±SD: Standard_Deviation, TB: Tuberculosis patients, RT: Right, LT: Left

Digit Ratio (2D:4D) and Body Mass Index (BMI) Comparison

Table 4 shows that the mean right-hand digit ratio (R2D:4D) for both TB patients and controls was 0.98 ± 0.05, while the mean left-hand digit ratio (L2D:4D) was also 0.98 ± 0.05 for both groups. An independent samples t-test revealed no statistically significant difference between the digit ratios of TB patients and control subjects, with p-values of 0.727 for R2D:4D and 0.938 for L2D:4D.

In contrast, a significant difference was observed in Body Mass Index (BMI) between the two groups. The mean BMI for TB patients was 19.93 ± 4.78, whereas the mean BMI for controls was 23.85 ± 3.56. This difference was statistically significant ($p = 0.0001$), indicating that TB patients had significantly lower BMI compared to healthy controls.

Table 5. Comparison of left and right fingerprint patterns between TB patients and controls

PATTERN	LEFT		RIGHT	
	TB	Control	TB	Control
LOOP	40 (40%)	42 (42%)	37 (37%)	41 (41%)
WHORL	38 (38%)	54 (54%)	42 (42%)	52 (52%)
ARCH	22 (22%)	4 (4%)	21 (21%)	7 (7%)
X^2= 15.293, d.f = 2, p= 0.000478		X^2 = 8.269, d.f = 2, p = 0.016011		

Fingerprint Pattern Distribution

As shown in Table 5, the arch fingerprint pattern was more prevalent among TB patients, occurring in 22% of left-hand prints and 21% of right-hand prints. In contrast, the loop and whorl patterns were more common among the control group, with 42% (loop) and 54% (whorl) observed on the left hand, and 41% (loop) and 52% (whorl) on the right hand.

Chi-square analysis revealed a statistically significant difference in fingerprint pattern distribution between TB patients and controls for both hands. The left-hand pattern difference had a p-value of 0.000478, while the right-hand difference had a p-value of 0.016011, indicating a significant association between fingerprint pattern type and TB status ($p < 0.05$).

These findings suggest a potential link between dermatoglyphic pattern variation and susceptibility to tuberculosis.

DISCUSSION

Dermatoglyphics refers to the scientific study of epidermal ridge patterns on the palmar surface of the hands and fingers, and the plantar surface of the feet and toes (Cummins & Midlo, 1926). These ridge configurations are determined by the interaction between the cornified layer of the epidermis and the dermal papillae during fetal development. Once formed in utero, dermatoglyphic patterns remain unchanged throughout life, except in their dimensions, which may change proportionally with physical growth (Cummins & Midlo, 1943). Although not a diagnostic tool, dermatoglyphics has been widely used as a screening method in detecting congenital and genetically influenced disorders (Holt, 1961).

In this study, the ridge densities of the left index, right ring, right middle, and left little fingers were significantly lower among TB patients compared to controls. Statistically significant differences were observed in these digits (p-values: 0.048, 0.029, 0.023, and 0.030, respectively). Similarly, radial ridge counts were lower among TB patients, with significant differences recorded on the left-hand digits thumb, index, middle, ring, and little fingers (p-values: 0.036, 0.025, 0.013, 0.024, and 0.029).

TB patients also showed higher ulnar ridge counts on the right-hand ring, little, and thumb fingers (values: 17.00, 16.98, 16.98), with significant differences ($p < 0.05$). Although TB patients had higher ulnar ridge counts on all left-hand digits, these differences were not statistically significant, except for the right index finger ($p = 0.022$). These findings are consistent with previous studies (Patloo *et al.*, 2017; Jelia *et al.*, 2016).

The differences in ridge counts may be influenced by body mass index (BMI). Prior studies have reported that BMI and body size are correlated with fingerprint ridge breadth and density (Mundorff *et al.*, 2014). Furthermore, studies among the Hausa ethnic group of Nigeria have shown that BMI can be predicted from thumbprint ridge minutiae count and thickness (Adamu *et al.*, 2017). While dermatoglyphic traits are predominantly determined by genetic factors (Oladipo *et al.*, 2010), studies have suggested that environmental and biometric variables such as sex, nutrition, and hormonal exposure may modulate ridge patterns. Genes involved in limb development are also known to influence fingerprint variation (Li *et al.*, 2022).

Sexual dimorphism may also play a role in the dermatoglyphic differences observed in this study. It has been reported that females tend to have higher ridge counts than males in various populations, including Mataco-Mataguayo (Gutiérrez-Rodemero *et al.*, 2011), Sudanese (Kapoor & Badiye, 2015), Gujarati (Sharma et al., 2018), and Indian populations (Kaur *et al.*, 2020). Additionally, males are known to have coarser ridges approximately 10% thicker than those of females (Králík & Novotný, 2003).

The current study also revealed that the arch fingerprint pattern was more prevalent among TB patients for both the left (22%) and right (21%) hands, whereas the loop and whorl patterns were more frequent among the controls (42% and 54% on the left; 41% and 52% on the right, respectively). Chi-square analysis confirmed a significant association between fingerprint patterns and TB status ($p = 0.000478$ for the left hand, and $p = 0.016011$ for the right). These findings agree with previous studies (Jain *et al.*, 2016; Patloo *et al.*, 2017; Jelia *et al.*, 2016), which reported an increased frequency of arch patterns among TB patients.

The genetic basis of susceptibility to tuberculosis has been explored in several studies, suggesting that certain genetic markers may predispose individuals to TB infection (Badamsi *et al.*, 2023). Interestingly, similar fingerprint anomalies have been reported in genetic disorders such as Down syndrome, Turner's syndrome, and Klinefelter's syndrome, indicating that dermatoglyphic traits may reflect underlying chromosomal abnormalities (Rajangam *et al.*, 1995; Holt, 1961; Reed *et al.*, 1977; Komotz & Yoshida, 1976; Walker, 1964).

Regarding digit ratio (2D:4D), no significant differences were observed between TB patients and controls for either hand (p-values > 0.05). Although there is limited research on 2D:4D ratios specifically in TB patients, previous studies have shown that alcohol-dependent patients tend to have lower 2D:4D ratios (Kornhuber *et al.*, 2011). The 2D:4D ratio is believed to reflect prenatal androgen exposure and is typically lower in males (Burriss *et al.*, 2007; Kornhuber *et al.*, 2011). Given that TB disproportionately affects males globally (Fernandes et al., 2018), the hormonal influences on immune function may be relevant. For example, testosterone, the primary circulating androgen in males, has immunosuppressive properties and impairs macrophage activation, potentially increasing susceptibility to TB (Bini *et al.*, 2014; Metwally *et al.*, 2019).

This study also found a significantly lower BMI among TB patients (mean = 19.93 ± 4.78) compared to controls (mean = 23.85 ± 3.56) with $p < 0.0001$, supporting previous findings that low BMI is strongly associated with increased TB risk (Casha & Scarci, 2017). The connection between nutritional status and tuberculosis has long been recognized even by Hippocrates (Snide, 1987). Numerous studies have documented a consistent inverse relationship between BMI and TB incidence across different populations and BMI categories (Cegielski & McMurray, 2005; Lönnroth *et al.*, 2010). This pattern contrasts with non-TB respiratory diseases such as chronic obstructive pulmonary disease (COPD) and lung cancer, where higher BMI is linked to increased mortality (Whitlock & Lewington, 2009). The low BMI observed among TB patients in this study may reflect the chronic, debilitating nature of the disease, often accompanied by poor appetite, weight loss, and malabsorption.

CONCLUSION

This study demonstrated that ridge densities of the left index, right ring, right middle, and left little fingers were significantly lower in tuberculosis (TB) patients compared to healthy controls. Similarly, radial ridge counts (RRC) were markedly reduced in TB patients, particularly on the left index, middle, ring, little, and thumb fingers, while ulnar ridge counts (URC) were significantly decreased on the right index finger. The three predominant fingerprint patterns; loop, whorl, and arch were identified in both groups, with the arch pattern occurring more frequently among TB patients, suggesting a potential association with disease susceptibility. No significant differences were observed in digit ratios (2D:4D) between TB patients and controls, indicating its limited utility as a biomarker for TB risk. Consistent with existing literature, TB patients exhibited significantly lower body mass index (BMI), underscoring the link between poor nutritional status and heightened vulnerability to tuberculosis.

Collectively, these findings suggest that dermatoglyphic characteristics and BMI hold promise as complementary, non-invasive screening tools for identifying individuals at elevated risk of developing TB.

Incorporation of these parameters could aid physicians, anatomists, anthropologists, and public health practitioners in early risk stratification and surveillance efforts, particularly within resource-constrained settings. Further large-scale studies are warranted to validate these associations and explore their practical applicability in TB control programs.

Recommendations

Larger-scale studies with more diverse and representative populations are needed to validate the findings of this study and to establish whether dermatoglyphic characteristics particularly fingerprint patterns can serve as reliable screening or investigative tools for identifying individuals at risk of tuberculosis.

A validation study should be conducted among individuals undergoing TB screening to evaluate the predictive value of the identified anthropometric and dermatoglyphic parameters, with a focus on their utility for early detection and risk stratification.

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