



Research Article

Classical Forensic Biomarkers in a Nigerian University
Population: Distribution and Associations Between ABO-Rh Blood
Groups with Primary Fingerprint Patterns

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ABSTRACT

The ABO–Rh blood group system and dermatoglyphic fingerprint patterns represent classical biological markers historically utilized in forensic and medico-legal investigations. Although both traits are genetically determined and stable throughout life, their discriminatory capacities differ substantially, with ABO blood grouping serving primarily an exclusionary role and fingerprint ridge patterns providing morphological classification rather than individual identification when limited to primary categories. This analytical cross-sectional study assessed the distribution of ABO–Rh blood groups and primary fingerprint patterns and examined their associations with sex among undergraduate students of the University of Maiduguri, Nigeria. A total of 1,876 consenting students were enrolled using a convenience sampling approach. Blood groups were determined using the slide agglutination method with Anti-A, Anti-B, and Anti-D antisera, while fingerprint patterns were collected using the inked fingerprint technique and classified into arch, loop, and whorl categories. Statistical analyses were performed using chi-square tests with Cramér's V to evaluate the strength of associations. Blood group O Rh positive was the most prevalent (46.0%), followed by Blood group A Rh positive (22.2%) and Blood group B Rh positive (16.7%), while Rh-negative phenotypes were relatively uncommon. Loop patterns predominated (49.7%), followed by whorls (27.6%) and arches (22.7%). A statistically significant but weak association was observed between ABO Rh blood groups and fingerprint patterns ($p < 0.05$; Cramér's $V \approx 0.14$). A small association was also observed between ABO Rh blood groups and sex ($p < 0.05$; Cramér's $V \approx 0.19$), whereas no statistically significant relationship was found between sex and fingerprint pattern distribution. Overall, the observed associations were modest in magnitude and likely reflect minor distributional variation within the institutional sample rather than strong biological relationships. The forensic relevance of these findings lies primarily in their descriptive contribution to the documentation of classical forensic biomarkers within a defined population, while acknowledging that these markers lack the discriminatory power of DNA profiling or detailed ridge analysis for individual identification.

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INTRODUCTION

Human biological variation forms the foundation of forensic identification and anthropological classification (Nawrocki *et al.*, 2018). Blood group polymorphisms exhibit population variation influenced by historical and demographic factors (Anifowoshe *et al.*, 2017; Doku *et al.*, 2022). Similarly, dermatoglyphic patterns are established during fetal development and remain stable throughout life (Champod *et al.*, 2016). Fingerprint patterns commonly classified into arches, loops, and whorls are established during early fetal development and remain unchanged throughout an individual's lifetime (Chandra, 2025).

Although ABO blood group systems and dermatoglyphic patterns are genetically determined and stable throughout life, their forensic utility differs substantially in scope and discriminatory power. ABO blood grouping is primarily exclusionary and cannot uniquely identify individuals due to limited phenotype variability (Butler, 2015; Saferstein, 2020). Similarly, while complete fingerprint ridge detail permits individualization, classification into primary categories (arch, loop, and whorl) provides only broad morphological grouping and does not confer individual specificity (Champod *et al.*, 2016). Consequently, these classical biomarkers are best regarded as supportive or descriptive markers in forensic and demographic contexts rather than definitive tools for individual identification.

While several Nigerian studies have independently examined ABO blood group distribution or fingerprint patterns, few have explored their combined distribution within a single institutional population. This study was designed as an analytical cross-sectional investigation to describe the distribution of ABO–Rh blood groups and primary fingerprint patterns among undergraduate students of the University of Maiduguri. The study further sought to examine whether ABO–Rh blood group distribution was associated with sex, to evaluate the relationship between ABO–Rh blood groups and primary fingerprint patterns, and to assess whether primary fingerprint pattern distribution differed by sex. These associations were tested using appropriate inferential statistical methods at a 5% level of significance to determine whether statistically

significant associations existed between ABO–Rh blood groups and sex, between primary fingerprint patterns and sex, and between ABO–Rh blood groups and fingerprint patterns

METHODOLOGY

Study Design

This study adopted a cross-sectional descriptive and analytical design to assess the distribution and associations of ABO Rh blood groups and primary fingerprint patterns in relation to sex among undergraduate students.

Study Area

The study area was Maiduguri, the capital city of Borno State, located in North-Eastern Nigeria. Maiduguri is a major urban center that serves as a convergence point for diverse ethnic and cultural groups drawn from across Nigeria's geopolitical zones (Jimme *et al.*, 2019).

Study Site

The study was conducted at the University of Maiduguri, a federal tertiary institution with a large and heterogeneous student population. The university draws students from all six geopolitical zones of Nigeria (Federal Ministry of Education, 2021).

Study Population and Sample Size

The study population comprised registered undergraduate students of the University of Maiduguri who were present during the 2023/2024 academic session and consented to participate. Recruitment was conducted across multiple faculties within the university. At the conclusion of data collection, a total of 1,876 participants were successfully enrolled and analyzed.

Ethical Considerations

Ethical approval for the study was obtained from the institutional ethics committee of the University of Maiduguri. Informed consent was obtained from all participants prior to enrollment. Confidentiality and anonymity were strictly maintained, and all procedures were conducted in accordance with ethical principles governing research involving human participants (WMA, 2013).

Inclusion Criteria

Participants were included in the study if they were registered students of the University of Maiduguri, aged 16 years and above, and willing to provide informed consent. Only participants with clearly identifiable fingerprint impressions suitable for

classification and able to undergo blood group testing were retained for analysis.

Exclusion Criteria

Students who declined consent or withdrew participation at any stage were excluded from the study. Individuals presenting with finger deformities, extensive hand injuries, active dermatological conditions, or scars that interfered with accurate fingerprint recording were excluded. Participants with known hematological disorders or conditions that could compromise reliable blood group determination were also excluded. In addition, incomplete questionnaires, poorly recorded fingerprints, or indeterminate blood grouping results led to exclusion from the final analysis.

Sampling Technique

A non-probability convenience sampling approach was employed, relying on voluntary participation among eligible students. As such, the sample may not represent the underlying population distribution of Nigeria for inferential analysis. Findings should therefore be interpreted as reflective of the institutional study population rather than the broader regional or national population.

Data Collection

Structured Questionnaire

Data were collected using a structured, interviewer-assisted questionnaire designed to capture key sociodemographic variables. Information obtained included age and sex.

Blood Sample Collection and Preparation

Blood samples were obtained using standard procedures to ensure participant safety and preserve sample quality (Šimundić *et al.*, 2018). Venous blood was collected through routine phlebotomy, beginning with careful vein identification by palpation and the use of a tourniquet to make the vein more visible (Buowari, 2013). The selected puncture site was cleaned with 70% isopropyl alcohol and allowed to dry naturally before sample collection.

A sterile needle attached to a vacuum collection system was inserted gently into the vein until proper blood flow was achieved. Blood was then drawn into EDTA vacutainer tubes, after which the tourniquet was released and the participant was asked to relax their hand. The tubes were slowly inverted several times to ensure proper mixing of blood with the anticoagulant and to prevent clot formation (Grant, 2003).

After collection, the needle was removed and firm pressure was applied to the puncture site to stop bleeding. Each sample was immediately labeled to ensure correct identification and maintain proper documentation and traceability (Godwin *et al.*, 1992).

ABO Group Typing

Before the analysis commences, the blood samples contained in anticoagulated tubes were gently inverted several times to ensure thorough mixing of the blood with the anticoagulant and even distribution of red blood cells within the plasma. Before proceeding, each sample was carefully examined to exclude hemolyzed or clotted specimens, as such samples could compromise the accuracy of the results.

The determination of blood groups was performed using the standard slide agglutination method. A clean white tile was prepared and divided into three clearly labeled sections for Anti-A, Anti-B, and Anti-D monoclonal antisera. One drop of each antisera was dispensed onto its respective area on the tile (Hong-yang & Guo, 2022). Using a sterile plastic Pasteur pipette, a small amount of whole blood was taken from the EDTA tube and added as one drop to each antisera spot.

Separate applicator sticks were used to gently mix the blood with each antisera to obtain a smooth and uniform mixture, ensuring optimal contact between red cell antigens and antibodies. The tile was then gently rocked in a horizontal position for about one minute to enhance antigen-antibody interaction and allow visible agglutination to occur. The reactions were read within one minute under good lighting conditions.

The presence of visible clumping indicated a positive reaction and confirmed the presence of the corresponding A, B, or Rh(D) antigen on the red blood cells, while the absence of clumping signified a negative reaction and lack of the antigen. This enabled accurate determination of the ABO and Rh blood groups (Odeh *et al.*, 2021).

Fingerprint Collection

Fingerprint data were obtained using the inked fingerprint method, a simple, reliable, and widely used technique in forensic and anthropological investigations (Bose and Kabir, 2017). Participants were first instructed to wash their hands thoroughly with water and

to dry them completely to remove dirt that could affect print quality.

Fingerprint impressions were produced by applying gentle, uniform pressure to the distal phalanges on a fingerprint ink pad, ensuring a thin and even coating of ink. Each finger was then carefully transferred onto a clean sheet of paper by rolling it from one side to the other while maintaining gentle pressure, allowing clear ridge patterns to be captured (Gupta and Gupta, 2013).

The fingerprint sheets were clearly labeled with the participant identification number to ensure accurate record and traceability.

Fingerprint Pattern Classification

The collected fingerprint impressions were carefully examined and categorized into the three fundamental dermatoglyphic pattern types namely arch, loop, and whorl, in accordance with established classification standards (Raja *et al.*, 2020). Each fingerprint was independently assessed by trained examiners to reduce observer bias and enhance classification reliability and prints that showed unclear or borderline features were removed from the study.

RESULTS

A total of 1,876 students from the University of Maiduguri were included in the analysis. Of these, 1,231 (65.6%) were male and 645 (34.4%) were female (Figure 1).

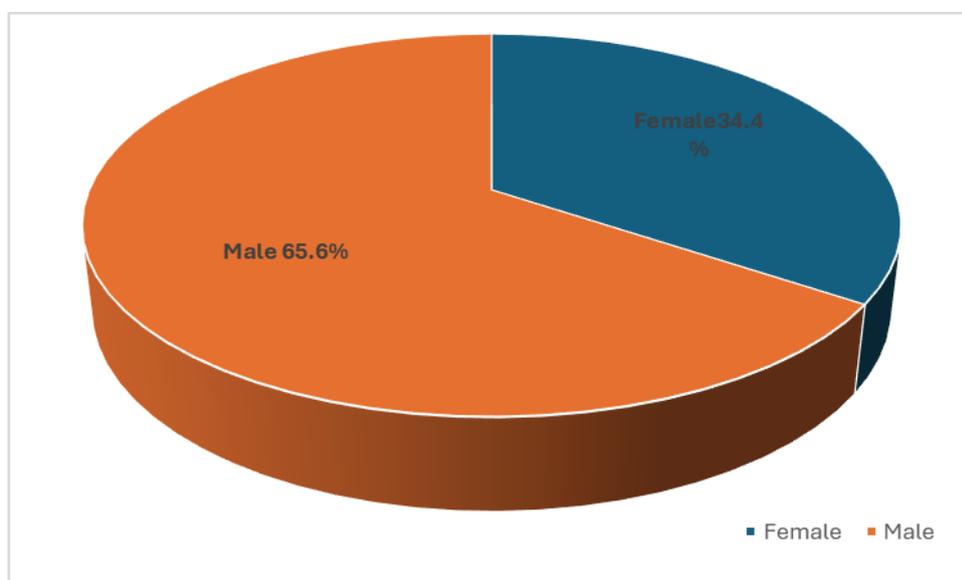


Figure 1: Gender Distribution of Study Participants

The distribution of ABO–Rh blood groups (Figure 2) showed that blood group O Rhesus positive phenotype was the most prevalent blood group (46.0%), followed by blood group A Rh positive phenotype (22.2%) and blood group B Rh positive phenotype (16.7%). Negative Rh phenotypes were relatively

uncommon, with blood group O Rh negative phenotype, blood group B Rh negative phenotype (3.5%), and blood group A Rh negative phenotype (2.4%). Blood group AB Rh positive phenotype constituted 4.6% of the population.

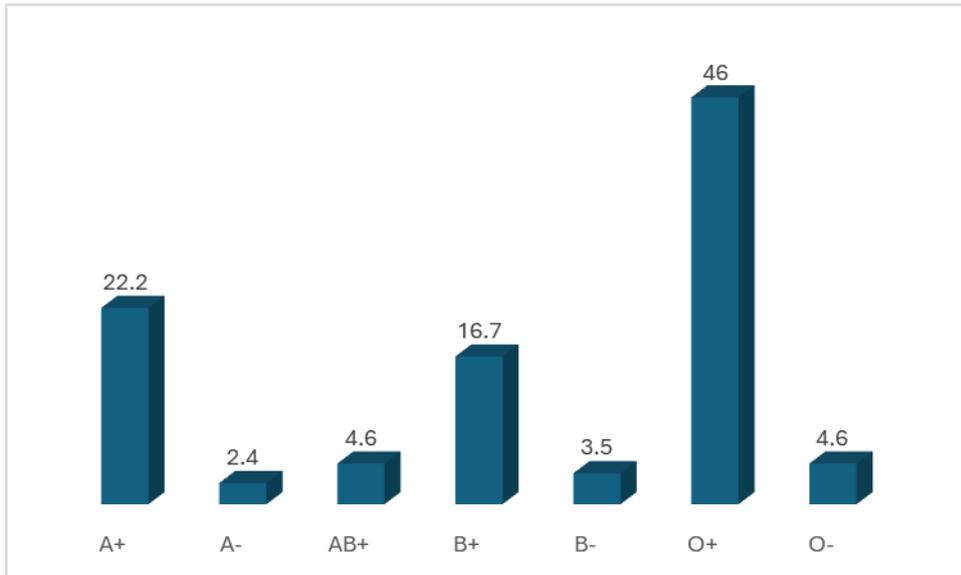


Figure 2: ABO Blood Group and Rhesus Phenotype Distribution Among Study Participants

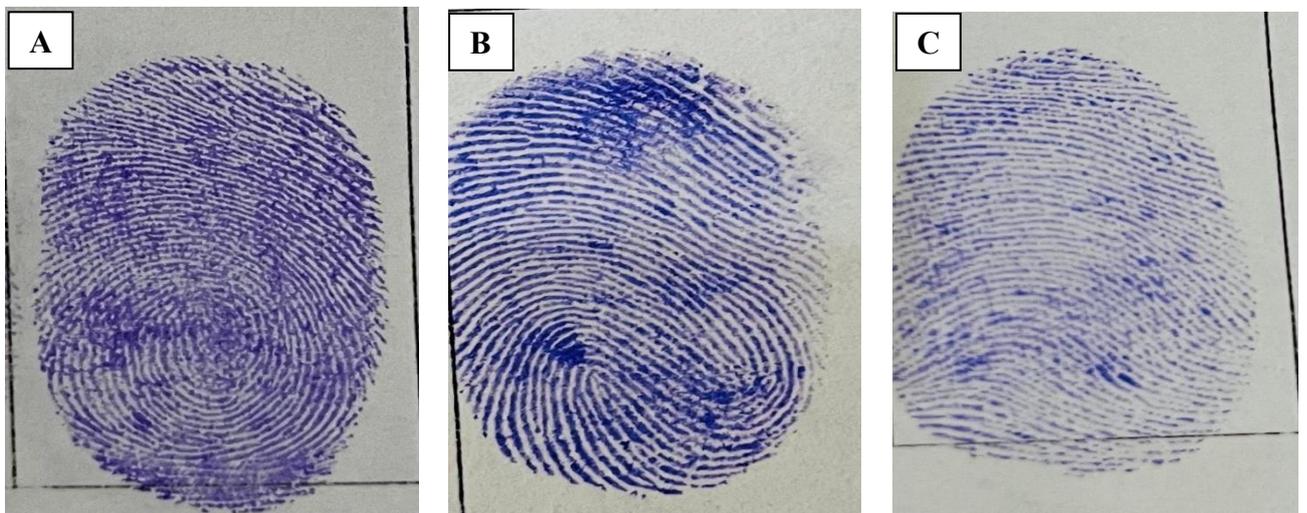


Plate 1: Representative images of the three primary fingerprint pattern types: (A) Arch, (B) Loop, and (C) Whorl

Analysis of fingerprint patterns demonstrated that loops were the dominant pattern (49.7%), followed by whorls (27.6%) and arches (22.7%), consistent with global dermatoglyphic trends (Figure 3).

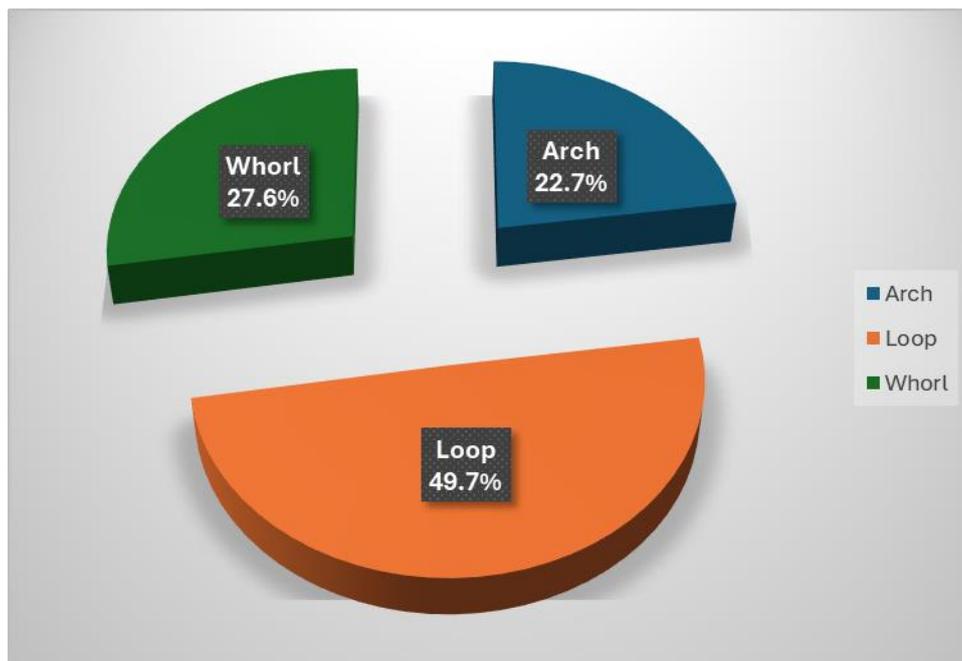


Figure 3: Finger Print Pattern Among Study Participants

A very weak association was observed between blood group and fingerprint pattern (table 1) ($p < 0.005$; Cramér’s $V = 0.14$). Among individuals with arch fingerprint patterns, the population was dominated by blood group ‘O’ Rh positive phenotype (50.94%), followed by blood group ‘B’ Rh positive phenotype (17.84%) and blood group ‘A’ Rh positive phenotype (20.66%), while Rh negative phenotype blood groups (A-, B- AB-

and O-) were relatively uncommon. Participants with whorl patterns exhibited a distinct distribution with a notably higher proportion of blood group ‘AB’ Rh positive phenotype (7.7%) and blood group ‘B’ Rh negative phenotype (6%) compared with the other fingerprint types. Those with loop patterns showed the highest representation of A⁻ (4.3%).

Table 1: Association between ABO–Rh Blood Groups and Primary Fingerprint Patterns

ABO–Rh Blood Group	Arch (%)	Loop (%)	Whorl (%)	Total (%)
A+	20.7	23.1	21.8	22.2
A-	1.2	4.3	0.0	2.4
AB+	0.7	4.6	7.7	4.6
B+	17.8	17.4	14.5	16.7
B-	3.3	2.4	6.0	3.6
O+	50.9	43.6	46.3	46.0
O-	5.4	4.7	3.7	4.6
Total	100	100	100	100

Chi-square Test: $p < 0.005$, Cramér’s $V = 0.141$

According to Table 2, blood group distribution differed slightly between males and females, although the strength of association was small (Cramér’s $V = 0.196$). Blood group A Rh positive was markedly more common in females (31.0%) than males (17.6%), while

blood group AB Rh positive phenotype and blood group O Rh negative phenotype were more frequent in males. Blood group O Rh positive phenotype remained the dominant blood group in both sexes, accounting for approximately 45–47% of individuals.

Table 2: Gender-Based Distribution (%) of ABO–Rh Blood Groups

ABO–Rh Blood Group	Female (%)	Male (%)	Total (%)
A+	31.0	17.6	22.2
A-	1.4	2.9	2.4
AB+	1.2	6.3	4.6
B+	15.5	17.3	16.7
B-	2.5	4.1	3.6
O+	44.8	46.6	46.0
O-	3.6	5.1	4.6
Total	100	100	100

Chi-square Test: $p < 0.005$, Cramér's $V = 0.196$

Table 3 showed males predominated across all fingerprint types with no statistical association between gender and fingerprint patterns ($p > 0.005$), reflecting the overall male-biased

sample. Whorl patterns showed a slightly higher female proportion (38.0%) compared with loop patterns (31.2%).

Table 3: Association between Gender and Primary Fingerprint Patterns

Gender	Arch (%)	Loop (%)	Whorl (%)	Total (%)
Female	36.9	31.2	38.0	34.4
Male	63.2	68.8	62.0	65.6
Total	100.0	100.0	100.0	100.0

Chi-square Test: $p > 0.005$

DISCUSSION

This study provided an assessment of ABO–Rh blood groups and fingerprint patterns in relation to gender among students of the University of Maiduguri, North-Eastern Nigeria.

The predominance of blood group O Rh positive phenotype (46.0%) in this institutional sample is consistent with previous Nigerian reports indicating higher frequency of blood group O relative to other ABO blood group phenotypes (Anifowoshe *et al.*, 2017). However, the magnitude observed in this study falls within the mid-range of reported national estimates rather than representing an extreme distribution. Given the small effect sizes observed in the current study, the predominance of blood group O Rh positive phenotype appears to reflect broader population baseline frequencies. The relatively low frequency of Rh negative phenotypes in this study is also consistent with African population genetics, where RhD positivity

exceeds 90% in most demographic studies (Doku *et al.*, 2022).

Fingerprint patterns represent one of the most stable morphological traits established during early fetal development and unaffected by postnatal environment (Karim and Barua, 2025). Loop patterns constituted approximately half of all fingerprint types in this sample (49.7%), aligning with widely reported dermatoglyphic distributions in diverse populations (Champod *et al.*, 2016). However, the small effect sizes in demographic comparisons suggest that loop predominance in this study primarily reflects general human dermatoglyphic distribution rather than distinctive regional variation within the institution.

A very weak but statistically significant association was observed between ABO–Rh blood groups and primary fingerprint patterns in the present study indicating that the observed differences across fingerprint categories were modest in magnitude. Previous investigations have reported mixed

findings, ranging from inconsistent relationships (Manikandan *et al.*, 2019) to weak or negligible associations in some populations, including Nigeria (Eboh, 2013; Siddiqui *et al.*, 2025). In contrast, Al-Habsi *et al.* (2023) reported a statistically significant relationship between these markers. Such variation across studies may partly reflect differences in sample size, sampling design, and population composition. Given the large sample size in the present study, statistical significance may have been influenced by increased analytical power despite the relatively small effect size observed. Although both ABO blood groups and dermatoglyphic patterns are genetically determined traits (Daniels, 2013; Champod *et al.*, 2016), this study did not assess molecular markers, allele frequencies, or developmental mechanisms. Consequently, the observed association should be interpreted as a weak statistical relationship within the study population rather than evidence of shared genetic regulation or developmental linkage.

Observed differences in the distribution of ABO–Rh blood groups across fingerprint categories were modest. For example, blood group ‘O’ Rh positive phenotype appeared more frequently among arch patterns, whereas blood group ‘AB’ Rh positive phenotype and blood group ‘B’ Rh negative phenotype showed slightly higher proportions within whorl patterns, and blood group ‘A’ Rh negative appeared somewhat more common among loop patterns. However, these variations were small and consistent with the overall weak strength of association observed in the statistical analysis (Cramér’s $V = 0.141$). Similar patterns of minor variation have been reported in previous studies from South Asia, where some authors observed uneven distributions of blood groups across dermatoglyphic categories, although the strength and consistency of such relationships remain limited (Joseph *et al.*, 2025; Manikandan *et al.*, 2019). Evidence from African populations on this relationship remains relatively limited. In addition, previous work has shown that primary fingerprint pattern distribution is not significantly associated with biological sex (Rastogi *et al.*, 2023), suggesting that these dermatoglyphic categories primarily reflect general population variation rather than strong biological differentiation. Consequently, the

present findings should be interpreted as minor distributional differences within the study population rather than evidence of specific serogenetic clustering.

A very small association was observed between ABO–Rh blood groups phenotypes and sex in the present study ($p < 0.05$, Cramér’s $V = 0.196$), indicating that the observed differences between males and females were modest. Although certain variations were noted such as a higher proportion of A^+ among females and slightly greater frequencies of blood group ‘AB’ Rh positive AB^+ , blood group ‘O’ Rh negative, and blood group ‘B’ Rh negative among males, the overall distribution of ABO blood group phenotypes remained broadly similar across both sexes, with blood group ‘O’ Rh positive representing the most common phenotype in both groups. Given the autosomal inheritance of the ABO locus on chromosome 9 (Daniels, 2013), population-level blood group distribution is generally expected to be independent of biological sex. Consequently, the significance observed in this study likely reflects sampling variation or demographic composition within the study population rather than a true biological sex-linked difference indicating limited practical significance despite the statistical association observed.

No statistically significant association between sex and primary fingerprint pattern distribution was observed ($p > 0.005$). Although males represented a slightly higher proportion within loop patterns while females showed marginally higher representation within arch and whorl patterns, these variations did not indicate meaningful biological differentiation. The overall distribution of fingerprint categories remained broadly similar between the two sexes. Previous dermatoglyphic studies have also reported that primary fingerprint pattern types are largely independent of sex and show only minor population-level variation (Rastogi *et al.*, 2023). Therefore, the minor variations observed between males and females likely reflect the overall male-biased sample rather than a true biological difference.

The forensic implications of these findings should be interpreted cautiously. ABO blood groups, due to their limited phenotypic variation, are primarily exclusionary markers and do not provide individual identification

capability (Butler, 2015). Likewise, classification into primary fingerprint categories lacks the discriminatory resolution of ridge minutiae analysis required for forensic individualization (Champod *et al.*, 2016). Therefore, while the combined distribution of these markers may contribute to descriptive demographic profiling in low-resource settings, they cannot substitute DNA-based identification or full fingerprint comparison.

CONCLUSION

This study describes the distribution of ABO–Rh blood groups and primary fingerprint patterns within a single tertiary institutional population in North-Eastern Nigeria. These findings therefore reflect minor distributional variation within an institutional sample rather than strong demographic or biological structuring. The forensic relevance of the present findings therefore lies primarily in their descriptive contribution rather than predictive identification capability. While ABO blood groups lack individualizing power and primary fingerprint categories do not substitute detailed ridge comparison, understanding their distribution within defined populations provides contextual information that may be useful in exclusionary analysis or preliminary demographic inference in resource-limited forensic settings.

Limitations

Although this study provides forensic descriptive insights, certain limitations are acknowledged. First, the study was conducted within a single tertiary institution. Second, the use of a convenience sampling approach may introduce selection bias, as participation was voluntary and may not perfectly represent the underlying population structure. Third, fingerprint classification was restricted to the three primary pattern types (arch, loop, and whorl), and more detailed sub-classifications or ridge-count analyses were not included.

Authors Contribution

Chiwar HM conceptualized the study. Chiwar HM and Holma M designed the study. Holma M, Maibulamgi IM and Ishiyaku A and Adebuto HJ participated in fieldwork and data collection. Kolomi ML, AA Kindin and Abbas MM performed the data analysis; Yirima AI, AA Kindin, LB Zarami and Chiwar HM interpreted the data. Chiwar HM prepared the first draft of the manuscript, reviewed by Kolomi ML, LB Zarami and Yirima AI. All authors contributed to the

development of the final manuscript and approved its submission.

Conflict of Interest

The authors declare NO conflict of interest

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