FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 10 No. 23, December, 2026, pp 277 – 283
DOI: https://doi.org/10.33003/fjs-2026-1023-6209

Fetal Haemoglobin Variation Across Reported Crisis-Frequency Categories Among Sickle Cell Disease Patients in ILORIN, Nigeria: A Cross-Sectional Study

[1,3,4]Abdulwaheed Adewale Ademosun, [1]Abdulmalik Halima Abubakar, *[2]Abdullahi Olaleye Olawuyi, [5]Busira Adesina Tijani, [1,6]Luqman Olayinka Olatunbosun, [7]Mutiat Aina Kareem, [6]Fatai Dayo Olalere, [3]Ibrahim Oluwaseun Ahmed, [3]Adeniyi Awe, [4]Nuryn Abdulganiy and [2]Musa Abidemi Muhibi

[1]Department of Medical Laboratory Science, Faculty of Health Sciences, Al-Hikmah University, Ilorin, Kwara State, Nigeria.
[2]Department of Medical Laboratory Science, Federal University of Health Sciences, Ila-Orangun, Osun State, Nigeria.
[3]Department of Haematology and Blood Transfusion Science, Obafemi Awolowo University Teaching Hospital, Ile-Ife, Osun State, Nigeria.
[4]Department of Haematology and Blood Transfusion Science, Mercy Medical University, Iwo, Osun State, Nigeria
[5]Department of Medical Laboratory Science, Fountain University, Osogbo, Osun State, Nigeria.
[6]Department of Haematology and Blood Transfusion, University of Ilorin Teaching Hospital, Ilorin, Kwara State, Nigeria.
[7]Department of Medical Laboratory Science, University of Ilorin, Ilorin, Kwara State, Nigeria.

*Corresponding authors' email: olawuyiabdul@gmail.com
ORCID ID: https://orcid.org/0000-0003-0248-7548

Received: 10 Sept. 2026
Accepted: 12 Nov. 2026
Published: 17 Nov. 2026

ABSTRACT

Background: Sickle cell disease (SCD) is clinically heterogeneous, and fetal haemoglobin (HbF) is an important modifier of disease expression. This study examined whether HbF varied across reported crisis-frequency categories among patients attending the University of Ilorin Teaching Hospital, Nigeria. Methods: This cross-sectional study planned to enrol 45 participants; one withdrew after laboratory analysis and was excluded, leaving 44 participants (36 with HbSS and 8 with HbSC) recruited from July to September 2023. Venous blood collected into EDTA tubes was analysed using a Bio-Rad D-10 haemoglobin analyser. Data were analysed using IBM SPSS Statistics version 25.0, with one-way analysis of variance and Pearson chi-square tests. Results: Overall mean HbF was 6.33 ± 3.24%. Mean HbF was 10.70 ± 3.22% in the annual group, 8.20 ± 2.40% in the biannual group, 5.47 ± 3.24% in the monthly group, 5.86 ± 3.01% in the quarterly group and 5.13 ± 3.00% in the weekly group. The overall difference was statistically significant ($p = 0.047$), although no post-hoc pairwise comparisons were reported. HbA1c, HbA2, HbA and HbS did not differ significantly across categories. Conclusion: Higher HbF was observed among participants reporting less frequent crises, but the cross-sectional design precludes causal inference. Larger multicentre longitudinal studies using clinically verified crisis records and adjustment for treatment and genetic modifiers are recommended.

Keywords: Fetal Haemoglobin, Sickle Cell Disease, Crisis Frequency, High-performance Liquid Chromatography, Nigeria

INTRODUCTION

Sickle cell disease (SCD) is an inherited haemoglobin disorder characterized by substantial clinical heterogeneity. Although sickle haemoglobin polymerization is central to disease pathophysiology, the frequency and severity of vaso-occlusive events and other complications vary substantially between patients with the same major genotype. This variation reflects interacting genetic, haematological, treatment-related and environmental factors (Ware *et al*., 2017; Isa *et al*., 2020; Serjeant, 2022). The burden is particularly important in Africa, where SCD prevalence and childhood mortality remain high (Wastnedge *et al*., 2018; Morrice *et al*., 2025).

Fetal haemoglobin (HbF), which contains gamma rather than beta globin chains, is one of the most consistently recognised modifiers of SCD expression. HbF reduces the proportion of HbS available for polymerisation and, when distributed sufficiently among circulating erythrocytes, can attenuate cellular sickling and vaso-occlusion (Steinberg, 2020; Adekile, 2021). The magnitude of HbF differs considerably among individuals because of genetic and non-genetic influences. Nigerian studies have identified important contributions from BCL11A and HBS1L-MYB variation, while broader evidence confirms that fetal haemoglobin regulation involves a wider network of transcriptional and genomic factors (Adeyemo *et al*., 2018; Sales *et al*., 2022; Santos *et al*., 2024).

Clinical studies generally support an inverse relationship between HbF and important manifestations of SCD, but the relationship is not uniform across populations or phenotypes. In Nigerian children, lower HbF was associated with indicators of greater disease severity (Adeodu *et al*., 2017). More recent African data involving patients from Ghana, Nigeria and Tanzania found associations between HbF parameters and transfusion, painful crises and febrile illness (Amuzu *et al*., 2025). In contrast, a Tanzanian study reported higher HbF among patients classified with a severe phenotype, illustrating that HbF should not be interpreted as the sole determinant of clinical severity (Kahema *et al*., 2024). Genotype, alpha-thalassaemia, beta-globin haplotype, treatment exposure and the cellular distribution of HbF may contribute to these differences (Steinberg, 2020; Adekile, 2021; Serjeant, 2022).

Quantitative haemoglobin profiling is therefore relevant when characterizing SCD populations. High-performance liquid chromatography (HPLC) permits simultaneous identification and quantification of several haemoglobin fractions and has been applied in Nigerian SCD studies, including analyses using the Bio-Rad D-10 platform (Adeodu *et al*., 2017; Fasola *et al*., 2022; Eneh *et al*., 2023). The ability to quantify HbF alongside HbS and other reported haemoglobin fractions provides a laboratory measure that can be considered alongside clinical history. However, the clinical meaning of a cross-sectional HbF measurement depends on how the clinical phenotype is defined and measured.

In Ilorin, local data linking quantitatively measured HbF with reported crisis frequency among patients receiving routine care are limited. The present study therefore investigated whether HbF levels varied across reported crisis-frequency categories among patients with SCD attending the University of Ilorin Teaching Hospital (UITH), while describing the associated HbA, HbA2, HbA1c and HbS profiles.

MATERIALS AND METHODS

Study Area

The study was conducted at the Haematology Department of the University of Ilorin Teaching Hospital (UITH), a federal tertiary healthcare institution at Old Jebba Road, Oke-Ose, Ilorin, Kwara State, Nigeria. The hospital is located at 8°32′15″N, 4°38′48″E. Ilorin has a tropical wet-and-dry climate, with distinct rainy and dry seasons. The 2006 census population reported for Ilorin was 777,667 (National Population Commission, 2006. A map showing the study area and the location of UITH is provided as Figure 1.

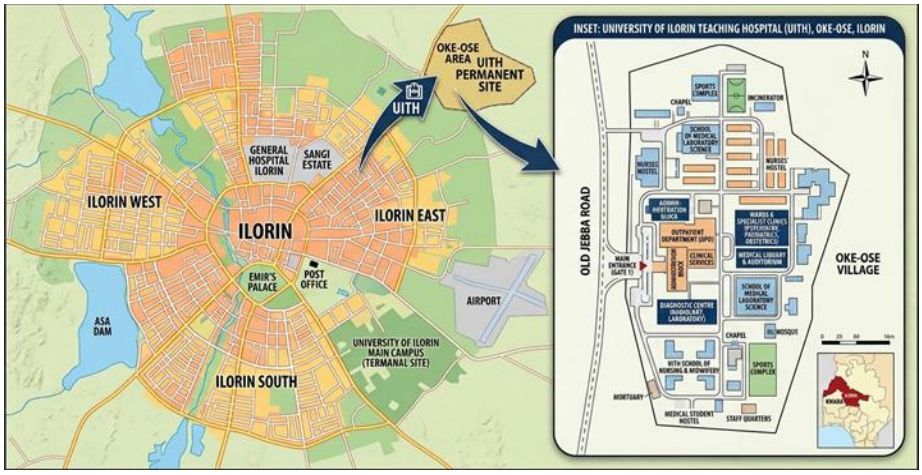


Figure 1: Map of Ilorin, Kwara State, Nigeria, showing the location of the University of Ilorin Teaching Hospital (UITH), Oke-Ose.

Adapted from (OpenStreetMap contributors. (2026). Node: University of Ilorin Teaching Hospital (Coordinates: 8°32′15″N 4°38′48″E). OpenStreetMap. https://www.openstreetmap.org) and (https://www.scholaro.com/u/University-of-Ilorin-Teaching-Hospital-29800/map)

Study Design and Period

This analytical cross-sectional study was conducted from July to September 2023. Reporting was guided by the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement and its molecular epidemiology extension (von Elm *et al*., 2007; Gallo *et al*., 2011).

Study Population

The study population comprised patients with established HbSS or HbSC attending the UITH Haematology Clinic. Previous genotype classification had been established by cellulose acetate haemoglobin electrophoresis at pH 8.6.

Eligibility Criteria

Participants were eligible when they were in steady state and provided informed consent. Steady state was defined as absence of signs or symptoms suggestive of crisis for the preceding three months, stable haemoglobin and haematocrit values over two to three clinic visits at four- to six-week intervals, and no blood transfusion during the preceding three months. Patients who did not consent, had received a blood transfusion within the preceding three months or had a crisis at enrolment were excluded.

Sampling and Sample-Size Calculation

The planned sample size was calculated using Fisher's single-proportion formula, with a 95% confidence level (Z = 1.96), a working prevalence estimate of 3% (p = 0.03), and a 5% margin of error (d = 0.05). The 3% value is within the upper end of the 1–3% range cited in Nigerian literature (Nwabuko *et al*., 2022), but it is not a UITH-specific prevalence estimate. National survey-based modelling has produced a lower estimated birth prevalence for HbSS and HbSC combined, underscoring that the 3% value should be treated as a pragmatic planning assumption rather than a definitive contemporary national estimate (Nnodu *et al*., 2021).

$n = Z^2p(1 - p) / d^2 = (1.96^2 \times 0.03 \times 0.97) / 0.05^2 = 44.70 \approx 45$

The calculation was $n = Z^2p(1 - p) / d^2 = (1.96^2 \times 0.03 \times 0.97) / 0.05^2 = 44.70$, rounded up to 45. Forty-five participants were planned. One participant withdrew after laboratory analysis, and that participant was excluded from the final analysis; 44 participants were analysed, comprising 36 with HbSS and 8 with HbSC. The final sample-size shortfall and absence of an outcome-specific power calculation are acknowledged as limitations.

Clinical and Sociodemographic Data

A structured questionnaire captured age, sex, ethnicity, religion, employment, marital status, education, residence, reported crisis frequency and reported use of folic acid, multivitamins, antimalarial drugs, non-steroidal anti-

inflammatory drugs, calcium, antibiotics, hydroxyurea and other supplements. Participants classified their usual crisis frequency as annual, biannual, monthly, quarterly or weekly. Crisis frequency was treated as a retrospectively reported clinical history rather than an independently verified event rate.

Specimen Collection and Laboratory Analysis

Four millilitres of venous blood were collected aseptically from the antecubital fossa into an ethylenediaminetetraacetic acid (EDTA)-containing evacuated blood collection tube. Samples were stored at 2–8 °C for up to four days before analysis. Haemoglobin measurements were obtained using a Bio-Rad D-10 haemoglobin analyser (Bio-Rad Laboratories, Hercules, California, USA). Samples were brought to room temperature and homogenised before analysis. Whole-blood samples were introduced into the analyser for the manufacturer's automated sample handling and dilution, followed by chromatographic separation and photometric detection. No separate pre-injection filtration step is reported. Nigerian studies have previously used the Bio-Rad D-10 for haemoglobin profiling (Adeodu *et al*., 2017; Eneh *et al*., 2023). HbA1c denotes glycated haemoglobin A and is treated as a glycation measurement, not as an additional structural haemoglobin fraction.

Statistical Analysis

Data were analysed using IBM SPSS Statistics version 25.0. Continuous variables were summarised as mean and standard deviation, and categorical variables as frequencies and percentages. One-way analysis of variance (ANOVA) compared continuous haemoglobin measurements across the five crisis-frequency categories. Pearson chi-square tests examined associations between HbSS/HbSC phenotype and the study-specified categorical haemoglobin thresholds. ANOVA assumptions were reported as assessed and satisfied. Statistical significance was set at $p < 0.05$. No post-hoc pairwise comparisons were reported.

Ethical Considerations

Ethical approval was obtained from the Ethics Committee of the University of Ilorin Teaching Hospital, Ilorin, Nigeria (UITH/CAT/189/21B/457). Confidentiality, privacy and voluntary participation were maintained throughout the study.

Informed Consent

Written informed consent was obtained from participants before data collection.

RESULTS AND DISCUSSION

Participant Characteristics and Reported Crisis Frequency

Forty-four participants were included in the analysis, comprising 36 with HbSS (81.8%) and 8 with HbSC (18.2%). The largest age group was 21-30 years (21/44, 47.7%), followed by 11-20 years (18/44, 40.9%). Females constituted 59.1% of the sample. Yoruba participants accounted for 75.0%, while Islam was the predominant reported religion (77.3%). Students represented 56.8% of participants, and 93.2% were single. Most participants resided in Ilorin (68.2%). The preponderance of young adults is compatible with the demographic profile commonly encountered in Nigerian SCD clinic populations, although the present single-centre sample is not intended to represent the national distribution (Isa *et al*., 2020; Morrice *et al*., 2025).

Table 1: Sociodemographic Characteristics of Study Participants (N = 44)

Variable	Category	n	%
Age group	11-20 years	18	40.9
	21-30 years	21	47.7
	31-40 years	5	11.4
Sex	Female	26	59.1
	Male	18	40.9
Ethnicity	Hausa	2	4.5
	Ibira	1	2.3
	Igbo	5	11.4
	Nupe	3	6.8
	Yoruba	33	75.0
Religion	Christianity	10	22.7
	Islam	34	77.3
Employment	Private practice	3	6.8
	Public practice	6	13.6
	Self-employed	3	6.8
	Student	25	56.8
	Unemployed	7	15.9
Marital status	Married	2	4.5
	Single	41	93.2
	Widower	1	2.3
Residence	Ibadan	3	6.8
	Ilorin	30	68.2
	Kishi	5	11.4
	Offa	6	13.6
Education*	No formal education	6	13.6
	Primary	2	4.5
	Secondary	5	11.4
	Tertiary	31	70.5

Note. Percentages are Based on N = 44. Education Categories Sum to 100% and are Presented to one Decimal Place

The most frequently reported therapies or supplements were antimalarial drugs (65.9%) and folic acid (52.3%), whereas hydroxyurea was reported by 38.6%. These data are descriptive and were not incorporated as covariates in the analysis of HbF. Hydroxyurea is clinically relevant because it can increase HbF, yet treatment access and use in Nigeria remain heterogeneous (Quinn *et al*., 2021; Okocha *et al*., 2022). Consequently, treatment exposure represents a potential source of residual confounding in the relationship observed between HbF and reported crisis frequency.

Table 2: Reported Medication and Supplement Use Among Study Participants (N = 44)

Variable	Yes, n (%)	No, n (%)
Folic acid	23 (52.3)	21 (47.7)
Multivitamin	6 (13.6)	38 (86.4)
Antimalarial	29 (65.9)	15 (34.1)
NSAID	15 (34.1)	29 (65.9)
Calcium	16 (36.4)	28 (63.6)
Antibiotics	8 (18.2)	36 (81.8)
Hydroxyurea	17 (38.6)	27 (61.4)
Supplement	6 (13.6)	38 (86.4)

Note. NSAID = Non-Steroidal Anti-inflammatory Drug

Overall Haemoglobin Profile

The overall mean HbF concentration was 6.33 ± 3.24%, ranging from 1.2% to 14.6% (Table 3). The recorded means were 4.03 ± 1.66% for HbA2, 3.97 ± 1.17% for HbA, 6.52 ± 1.87% for HbA1c and 76.02 ± 8.86% for HbS. The observed between-participant variation in HbF is consistent with recognised heterogeneity of HbF expression in SCD (Steinberg, 2020; Adekile, 2021; Adeyemo *et al*., 2018). Nigerian HPLC studies have also reported variation in haemoglobin profiles among SCD populations (Adeodu *et al*., 2017; Fasola *et al*., 2022; Eneh *et al*., 2023).

Table 3: Overall Haemoglobin Profile of Study Participants (N = 44)

Haemoglobin measure	Range (%)	Mean ± SD (%)
HbF	1.2-14.6	6.33 ± 3.24
HbA1c	0.3-10.6	6.52 ± 1.87
HbA2	1.3-8.6	4.03 ± 1.66
HbA	2.2-7.6	3.97 ± 1.17
HbS	49.2-85.6	76.02 ± 8.86

Note. Values are Percentages. HbA1c Represents Glycated Haemoglobin A.

HbF Across Reported Crisis-Frequency Categories

Mean HbF varied across the five reported crisis-frequency categories (Table 4). The highest mean was observed in the annual group (10.70 ± 3.22%), followed by the biannual group (8.20 ± 2.40%). Mean HbF was 5.47 ± 3.24% in the monthly group, 5.86 ± 3.01% in the quarterly group and 5.13 ± 3.00% in the weekly group. The omnibus ANOVA was statistically significant ($p = 0.047$). The pattern is broadly compatible with lower HbF among groups reporting more frequent crises, but it is not monotonic because the quarterly mean exceeded the monthly mean. No post-hoc pairwise comparisons were reported, so specific category differences cannot be inferred.

This finding is consistent with substantial evidence that HbF attenuates HbS polymerization and is associated with a less severe clinical phenotype. Adeodu *et al.* (2017) reported lower HbF among Nigerian children with clinical indicators of greater disease severity, while Steinberg (2020) and Adekile (2021) reviewed the biological and clinical basis for the protective effect of HbF. In a three-country African cohort, HbF and F-cell parameters were associated with painful crises and other clinical manifestations (Amuzu *et al*., 2025). These results provide a plausible explanation for the higher HbF concentrations observed among participants in the less frequent crisis categories in the present study.

The relationship should nevertheless be interpreted within the context of known phenotypic complexity. Serjeant (2022) emphasised that clinical variation in HbSS reflects interacting effects of HbF, alpha-thalassaemia and beta-globin haplotypes. Nigerian genetic studies have demonstrated substantial inherited variation in HbF levels related to BCL11A and HBS1L-MYB, indicating that an observed HbF concentration is partly determined by underlying genetic architecture (Adeyemo *et al*., 2018). A recent Nigerian genome-wide analysis further demonstrated that variation at recognised HbF regulatory loci contributes to inter-individual differences in HbF expression (Ojewunmi *et al*., 2024). Treatment exposure is another relevant source of variation because hydroxyurea can increase HbF, although access and uptake in Nigeria remain inconsistent (Okocha *et al*., 2022; Quinn *et al*., 2021).

Thus, African evidence is not entirely uniform. Kahema *et al*. (2024) found higher HbF among participants classified as having severe disease at a Tanzanian tertiary centre. Differences in phenotype definition, disease stage, genotype composition, treatment exposure, sample structure and residual confounding may account for discordant findings. The present study therefore supports an association within this UITH cohort but does not establish that HbF independently determines crisis frequency.

Table 4: Haemoglobin Measurements According to Reported Crisis Frequency

Measure	Annual	Biannual	Monthly	Quarterly	Weekly	p
HbF (%)	10.70 ± 3.22	8.20 ± 2.40	5.47 ± 3.24	5.86 ± 3.01	5.13 ± 3.00	0.047
HbA1c (%)	7.15 ± 0.07	5.97 ± 1.83	6.57 ± 0.99	6.57 ± 1.88	6.00 ± 1.04	0.948
HbA2 (%)	2.95 ± 0.21	2.77 ± 0.57	5.43 ± 2.31	4.03 ± 1.67	5.10 ± 1.04	0.162
HbA (%)	4.53 ± 0.81	4.43 ± 0.42	3.60 ± 0.54	4.00 ± 1.28	2.70 ± 0.56	0.429
HbS (%)	79.70 ± 5.54	79.00 ± 1.69	78.35 ± 4.36	76.23 ± 10.07	75.27 ± 2.71	0.895

Note. Values are Mean ± SD. HbA1c Represents Glycated Haemoglobin A. One-way ANOVA was used. The HbF Comparison was Statistically Significant by One-way ANOVA (p = 0.047); However, no Post-hoc Pairwise Comparisons were Reported

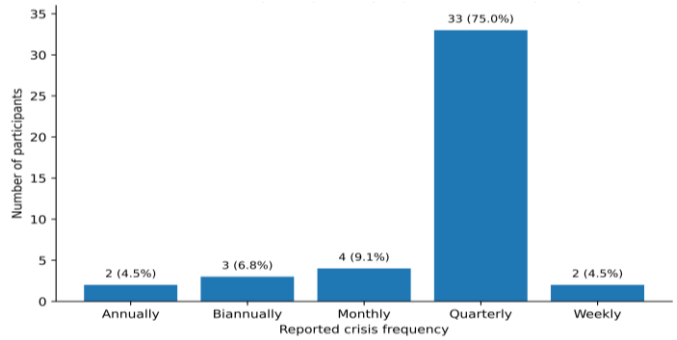


Figure 2: Distribution of Participants by Reported Crisis Frequency

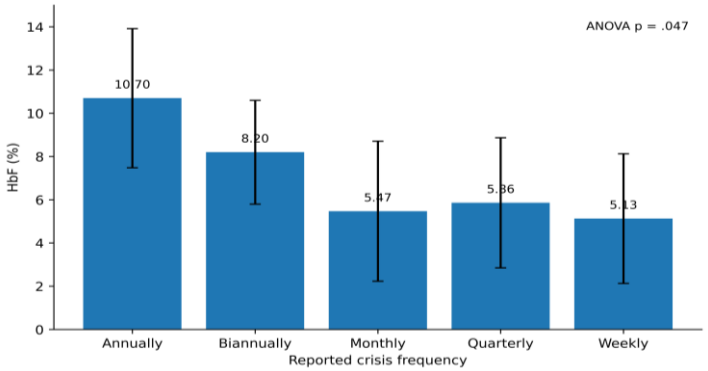


Figure 3: Mean HbF According to Reported Crisis Frequency. Error Bars Represent Standard Deviation

Other Haemoglobin Measures Across Crisis-frequency Categories

HbA1c, HbA2, HbA and HbS did not differ significantly across the five reported crisis-frequency groups. The largest numerical differences were observed for HbA2, which ranged from 2.77 ± 0.57% in the biannual group to 5.43 ± 2.31% in the monthly group, but the omnibus comparison was not statistically significant (p = 0.162). HbA and HbS similarly showed non-significant comparisons (p = 0.429 and 0.895, respectively). The absence of statistical significance should not be interpreted as proof of identical distributions, particularly given the very small annual, biannual and weekly groups.

HbA2 is useful when characterising haemoglobinopathy patterns, but its interpretation in SCD requires caution and should not be used alone to diagnose a co-inherited beta-thalassaemia syndrome. The present dataset did not include molecular confirmation of beta-thalassaemia, and the available study record does not provide sufficient information to support a specific diagnostic attribution. HPLC remains useful for characterizing haemoglobin fractions, as demonstrated in Nigerian studies (Fasola *et al*., 2022; Eneh *et al*., 2023).

The HbS values were also broadly similar across crisis categories, with means ranging from 75.27 ± 2.71% in the weekly group to 79.70 ± 5.54% in the annual group (p = 0.895). Because HbS concentration is influenced by the full haemoglobin profile and other biological and treatment factors, its stable group means do not exclude clinically meaningful heterogeneity in sickling behaviour or disease severity (Steinberg, 2020; Serjeant, 2022).

Haemoglobin Fraction Categories by HbSS and HbSC Phenotype

The phenotype comparison using the study-specified thresholds is shown in Table 5. Among participants with HbSS, 52.8% had HbF ≥6.2%, compared with 62.5% of participants with HbSC; the difference was not statistically significant ($\chi^2 = 0.250$, p = 0.617). No statistically significant phenotype differences were observed for the recorded HbA1c, HbA2 or HbA thresholds. These comparisons are descriptive because the thresholds were not validated as clinical cut-points in this study and the HbSC subgroup contained only eight participants.

Table 5: Distribution of Participants Above and Below Source-Specified Haemoglobin Thresholds by Phenotype

Phenotype	HbF <6.2	HbF ≥6.2	HbA1c <4.1	HbA1c ≥4.1	HbA2 <4.1	HbA2 ≥4.1	HbA <4.0	HbA ≥4.0
HbSS, n=36	17 (47.2)	19 (52.8)	3 (8.3)	33 (91.7)	24 (66.7)	12 (33.3)	21 (58.3)	15 (41.7)
HbSC, n=8	3 (37.5)	5 (62.5)	1 (12.5)	7 (87.5)	6 (75.0)	2 (25.0)	5 (62.5)	3 (37.5)
Chi-square	0.250		0.138		0.210		0.047	
p value	0.617		0.711		0.647		0.828	

Note. Percentages are within Phenotype Groups. The Thresholds shown are those Used in the Analysis and Should not be Interpreted as Validated Diagnostic Cut-offs

Limitations

Limitations include the cross-sectional design, retrospective self-reporting of crisis frequency, markedly unequal category sizes, the small sample, lack of adjustment for clinical and genetic modifiers, and single-centre convenience sampling. One participant withdrew after laboratory analysis and was excluded, leaving 44 of the 45 planned participants. HbA1c is glycated haemoglobin A rather than a separate structural haemoglobin fraction; its clinical interpretation in participants with HbSS/HbSC should be cautious because haemoglobin variants and the limited or absent HbA fraction may affect the validity of HbA1c measurement.

CONCLUSION

HbF levels differed significantly across the reported crisis-frequency categories among patients with SCD attending UITH, with higher mean HbF observed among participants reporting annual and biannual crises than among those reporting more frequent crises. HbA1c, HbA2, HbA and HbS did not show significant differences across the crisis-frequency categories. The findings are compatible with the established role of HbF as a modifier of SCD phenotype, but the association observed here should be interpreted cautiously because of the cross-sectional design, and self-reported clinical classification. Larger longitudinal studies with objectively documented vaso-occlusive events and adjustment for genotype, treatment exposure and other clinical modifiers are warranted.

Declarations

Conflict of interest

The authors declare that they have no competing interests.

Funding

The authors declare that they received no funding for this work.

AUTHOR CONTRIBUTIONS

AAA and AHA conceived and designed the study and developed the research framework. OAO, AAA and AHA conducted the literature search and collated the retrieved evidence. AAA, AHA, OAO, BAT, NA and MAM contributed to evidence examination, critical appraisal, synthesis and interpretation. MAK, FDO, LOO, IOA and AA contributed to manuscript writing and editing. The authors contributed to drafting and critical revision of the manuscript. All authors reviewed and approved the final manuscript and agreed to be accountable for all aspects of the work.

Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Consent for publication: All authors consent to publication of this article.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the support of SCD Clinic and SCD patients attending UITH during the course of the study.

REFERENCES

Adekile, A. (2021). The genetic and clinical significance of fetal hemoglobin expression in sickle cell disease. *Medical Principles and Practice*, 30(3), 201-211. https://doi.org/10.1159/000511342

Adeodu, O. O., Akinlosotu, M. A., Adegoke, S. A., & Oseni, S. B. A. (2017). Foetal haemoglobin and disease severity in Nigerian children with sickle cell anaemia. *Mediterranean Journal of Hematology and Infectious Diseases*, 9(1), e2017063. https://doi.org/10.4084/MJHID.2017.063

Adeyemo, T. A., Ojewunmi, O. O., Oyetunji, I. A., Rooks, H., Rees, D. C., Akinsulie, A. O., Akanmu, A. S., Thein, S. L., & Menzel, S. (2018). A survey of genetic fetal-haemoglobin modifiers in Nigerian patients with sickle cell anaemia. *PLOS ONE*, 13(6), e0197927. https://doi.org/10.1371/journal.pone.0197927

Amuzu, E. X., Urio, F., Dogbe, E. E., Ponsian, P., Abubakar, S. Y., Okeke, C., Balogun, O. O., Ozumba, P. J., Osei-Akoto, A., Paintsil, V., Nnodu, O., Balandya, E., Makani, J., Anazoeze, M., Ansong, D., & Nkya, S. (2025). Clinical manifestations of sickle cell disease in Africa and its association with foetal haemoglobin parameters. *Communications Medicine*, 5, 238. https://doi.org/10.1038/s43856-025-00954-z

Eneh, C. I., Nwankwo, C. A., & Nwaezike-Okafor, C. J. (2023). High performance liquid chromatographic pattern of children with sickle cell anaemia in Enugu Nigeria. *International Journal of Tropical Disease & Health*, 44(7), 23-30. https://doi.org/10.9734/IJTDH/2023/v44i71419

Fasola, F. A., Babalola, O. A., Brown, B. J., Odetunde, A., Falusi, A. G., & Olopade, O. (2022). The effect of alpha thalassemia, HbF and HbC on haematological parameters of sickle cell disease patients in Ibadan, Nigeria. *Mediterranean Journal of Hematology and Infectious Diseases*, 14(1), e2022001. https://doi.org/10.4084/MJHID.2022.001

Gallo, V., Egger, M., McCormack, V., Farmer, P. B., Ioannidis, J. P. A., Kirsch-Volders, M., Matullo, G., Phillips, D. H., Schoket, B., Stromberg, U., Vermeulen, R., Wild, C., Porta, M., & Vineis, P. (2011). STrengthening the Reporting of OBservational studies in Epidemiology-Molecular Epidemiology (STROBE-ME): An extension of the STROBE statement. *PLoS Medicine*, 8(10), e1001117. https://doi.org/10.1371/journal.pmed.1001117

Isa, H., Adegoke, S., Madu, A., Hassan, A.-A., Ohiaeri, C., Chianumba, R., Brown, B., Okocha, E., Ugwu, N., Diaku-

Akinwumi, I., Adeyemo, T., Kuliya-Gwarzo, A., Dogara, L., Lawal, H., Tanko, Y., Ladu, A., Kangiwa, U., Ekwem, L., Oniyangi, S., Wakama, T., Umoru, D., Olanrewaju, O., Akinola, N., Nnebe-Agumadu, U., Asala, S., Adekile, A., Olaniyi, J., Sangeda, R., Sickle Africa Data Coordinating Center, & Nnodu, O. (2020). Sickle cell disease clinical phenotypes in Nigeria: A preliminary analysis of the Sickle Pan Africa Research Consortium Nigeria database. *Blood Cells, Molecules, and Diseases*, 84, 102438. https://doi.org/10.1016/j.bcmd.2020.102438

Kahema, S. E., Mbulwa, C. H., Bagenda, C. N., Niyonzima, N., & Muwanguzi, E. (2024). Association between fetal hemoglobin, lactate dehydrogenase, and disease severity in patients with sickle cell disease at Bugando Medical Centre, Mwanza, Tanzania. *PLOS ONE*, 19(7), e0286891. https://doi.org/10.1371/journal.pone.0286891

Morrice, J., Mupfururirwa, W., Chianumba, R. I., Amuzu, E. X., Kandonga, D., Nembaware, V., Jonas, M., Hotchkiss, J., Masamu, U., Nguweneza, A., Mmbando, B. P., Minja, I., Jonathan, A., Mulder, N., Balandya, E., Osei-Akoto, A., Paintsil, V., Makani, J., Nnodu, O., Members of SPARCO Nigeria, Sangeda, R. Z., Kengne, A. P., Kuzamunu, G., & Wonkam, A. (2025). Sickle cell disease in Africa: SickleInAfrica Registry in Ghana, Nigeria and Tanzania. *eJHaem*, 6(3), e70044. https://doi.org/10.1002/jha2.70044

Ojewunmi, O. O., Adeyemo, T. A., Oyetunji, A. I., Inyang, B., Akinrindoye, A. A., Mkumbe, B. S., Gardner, K., Rooks, H., Brewin, J., Patel, H., Lee, S. H., Chung, R., Rashkin, S., Kang, G., Chianumba, R., Sangeda, R., Mwita, L., Isa, H., Agumadu, U.-N., Ekong, R., Faruk, J. A., Jamoh, B. Y., Adebiyi, N. M., Umar, I. A., Hassan, A., Grace, C., Goel, A., Inusa, B. P. D., Falchi, M., Nkya, S., Makani, J., Ahmad, H. R., Nnodu, O., Strouboulis, J., & Menzel, S. (2024). The genetic dissection of fetal haemoglobin persistence in sickle cell disease in Nigeria. *Human Molecular Genetics*, 33(10), 919–929. https://doi.org/10.1093/hmg/ddae014

National Population Commission. (2006). *Population and housing census of the Federal Republic of Nigeria, 2006: Priority tables (Volume I).*

Nnodu, O. E., Oron, A. P., Sopekan, A., Akaba, G. O., Piel, F. B., & Chao, D. L. (2021). Child mortality from sickle cell disease in Nigeria: A model-estimated, population-level analysis of data from the 2018 Demographic and Health Survey. *Lancet Haematology*, 8(10), e723–e731. https://doi.org/10.1016/S2352-3026(21)00216-7

Nwabuko, O. C., Onwuchekwa, U., & Iheji, O. (2022). An overview of sickle cell disease from the socio-demographic triangle: A Nigerian single-institution retrospective study. *Pan African Medical Journal*, 41, Article 161. https://doi.org/10.11604/pamj.2022.41.161.27117

Okocha, E. C., Gyamfi, J., Ryan, N., Babalola, O., Etuk, E.-A., Chianumba, R., Nwegbu, M., Isa, H., Madu, A. J., Adegoke, S., Nnebe-Agumandu, U., Brown, B., Peprah, E., & Nnodu, O. E. (2022). Barriers to therapeutic use of hydroxyurea for sickle cell disease in Nigeria: A cross-sectional survey. *Frontiers in Genetics*, 12, 765958. https://doi.org/10.3389/fgene.2021.765958

OpenStreetMap contributors. (n.d.). OpenStreetMap [Map]. Retrieved October 14, 2026, from https://www.openstreetmap.org/?mlat=8.5375&mlon=4.6468#map=15/8.5375/4.6468

Quinn, C. T., Niss, O., Dong, M., Pfeiffer, A., Korpik, J., Reynaud, M., Bonar, H., Kalfa, T. A., Smart, L. R., Malik, P., Ware, R. E., Vinks, A. A., & McGann, P. T. (2021). Early initiation of hydroxyurea (hydroxycarbamide) using individualised, pharmacokinetics-guided dosing can produce sustained and nearly pancellular expression of fetal haemoglobin in children with sickle cell anaemia. *British Journal of Haematology*, 194(3), 617-625. https://doi.org/10.1111/bjh.17663

Sales, R. R., Nogueira, B. L., Tosatti, J. A. G., Gomes, K. B., & Luizon, M. R. (2022). Do genetic polymorphisms affect fetal hemoglobin (HbF) levels in patients with sickle cell anemia treated with hydroxyurea? A systematic review and pathway analysis. *Frontiers in Pharmacology*, 12, 779497. https://doi.org/10.3389/fphar.2021.779497

Santos, G. P. dos, Rabi, L. T., Bezerra, A. A., Cunha, M. R. da, Iatecola, A., & Fernandes, V. A. R. (2024). Transcriptional regulators of fetal hemoglobin. *Hematology, Transfusion and Cell Therapy*, 46(Suppl 5), S258-S268. https://doi.org/10.1016/j.htct.2024.06.001

Serjeant, G. (2022). Phenotypic variation in sickle cell disease: The role of beta globin haplotype, alpha thalassemia, and fetal hemoglobin in HbSS. *Expert Review of Hematology*, 15(2), 107-116. https://doi.org/10.1080/17474086.2022.2040984

Steinberg, M. H. (2020). Fetal hemoglobin in sickle cell anemia. *Blood*, 136(21), 2392-2400. https://doi.org/10.1182/blood.2020007645

University of Ilorin Teaching Hospital. (n.d.). *Contact us*. Retrieved October 14, 2026, from https://www.uithilorin.org.ng/cho_schools

Wikidata. (n.d.). *University of Ilorin Teaching Hospital (Q30254143)*. Retrieved October 14, 2026, from https://www.wikidata.org/wiki/Q30254143

von Elm, E., Altman, D. G., Egger, M., Pocock, S. J., Gøtzsche, P. C., & Vandenbroucke, J. P. (2007). The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: Guidelines for reporting observational studies. *PLoS Medicine*, 4(10), e296. https://doi.org/10.1371/journal.pmed.0040296

Ware, R. E., de Montalembert, M., Tshilolo, L., & Abboud, M. R. (2017). Sickle cell disease. *The Lancet*, 390(10091), 311-323. https://doi.org/10.1016/S0140-6736(17)30193-9

Wastnedge, E., Waters, D., Patel, S., Morrison, K., Goh, M. Y., Adeloye, D., & Rudan, I. (2018). The global burden of sickle cell disease in children under five years of age: A systematic review and meta-analysis. *Journal of Global Health*, 8(2), 021103. https://doi.org/10.7189/jogh.08.021103

©2026 This is an Open Access article distributed under the terms of the Creative Commons Attribution 4.0 International license viewed via https://creativecommons.org/licenses/by/4.0/ which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is cited appropriately.