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Research Article

Evaluation of hemorheological Parameters Among Sickle Cell Anaemic Patients In Obafemi Awolowo University Teaching Hospital Complex Ile-Ife, Nigeria

Awe Adeniyi[2], Arayombo Babatunde Elijah[1], Rose A. Amechi[4], Olusegun T. Oke[5], Pele J.K[6], Omolajaiye Sunday Abraham[3], Judith. N. Adeyombo[2], Folashade. M. Oladipo[2].

[1]Department of Anatomy and Cell Biology, Obafemi Awolowo University Ile-Ife, Nigeria
[2]Department of Haematology Obafemi Awolowo University Teaching Hospital Complex Ile-Ife, Nigeria
[3]National Renal Centre, 1 McNab Drive, Alice Nkonkobe District Municipality, Eastern Cape, South Africa
[4]Department of Haematology and blood transfusion Ambrose Alli University Ekpoma, Edo State, Nigeria
[5]Department of hematology and blood transfusion, Achievers University, Owo Ondo State, Nigeria
[6]Department of Library and information Science, Federal University, Oye-Ekiti, Nigeria

***Corresponding author**
Arayombo Babatunde Elijah. Department of Anatomy and Cell Biology, Obafemi Awolowo University Ile-Ife, Nigeria

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Abstract

INTRODUCTION: Sickle cell disease (SCD) is a genetic disorder of public health concern in many parts of the world, characterised by; Vaso-occlusive crisis.

AIM: To investigate the effects of hemorheological parameters as the probable cause of the recurrent Vaso-occlusive crisis (VOC) among sickle cell anaemic patients.

MATERIALS AND METHODS: A cross sectional laboratory-based study was adopted, a total of 120 samples were used, 60 of which were apparently healthy individual with genotype AA, remaining 60 were sickle cell anaemic subjects (SS), these were grouped into less frequent VOC and frequent VOC according to the number of hospital admission as a result of their VOC occurrence in a year. The history of VOC was taken from the case notes at Haematology Clinic of Obafemi Awolowo University Teaching Hospitals Complex, Ile-Ife Osun State, Nigeria. The samples were analysed for Packed Cell Volume (PCV), Erythrocyte Sedimentation Rate (ESR), Platelet count (C), Whole Blood Viscosity (WBV), Plasma Viscosity (PV), Fibrinogen Concentration (FC). PCV and PC were determined using Sysmex XP 300 haematology auto analyser, WBV and PV by Reid and Ugwu method, plasma Fibrinogen by Clot and Weight method, ESR by modified Westergren method, at OAUTHC haematology laboratory, Ile-Ife.

RESULTS: The results of this study revealed hemorheological Parameters to be statistically significant ($P<0.05$) in sickle cell patients when compared with the control group HbAA. The PCV was significantly reduced (22.57 ± 4.91) when compared with the values obtained in the control group (41.40 ± 4.33). Similar patterns of significance were observed when each sickle cell groups were compared with the control group. There was a marked reduction in the values of Platelets among frequent Vaso occlusive crisis group (268500.00 ± 161157.42) when compared with less frequent Vaso-occlusive group (399634.62 ± 1922418.21).

DISCUSSION: The study revealed some possible prognostic indices and preventive care plan against Vaso-occlusive crisis when significant parameters were properly and clinically applied. Haematocrit values (22.57 ± 4.91) for sickle cell patients were significantly decreased and statistically significant ($P<0.05$) when compared with control group (41.40 ± 4.33). There is observable statistically significant difference ($P<0.05$) in the ESR among the sickle cell patients when compared with the control group. There was high WBC values among the sickle cell groups when compared with the control group with confirmed modest leucocytosis among the sickle cell patients, even at steady state, high platelets count is the usual findings among SCD was also observed in this study when compared with control group. Steady statistically significant differences ($P<0.05$) were observed in whole blood viscosity, plasma viscosity and plasma fibrinogen concentration among the sickle cell patients in Sickle cell groups when compared with the control groups The high values in WBV, PV, Platelets and Fibrinogen concentration with concurrently low values in PCV may be the cause of recurrent VOC.

CONCLUSION: It can be concluded from this study that, high values of Hemorheological parameters (WBC, PV, PC and FC) are partly responsible for sickle cell crisis.

Keywords: Sickle cell disease, Hemorheology, Plasma viscosity, Whole blood viscosity Hemoglobin AA

Introduction

Sickle cell disease is a chronic hemolytic disorder characterized by the tendency of hemoglobin molecules within red blood cells to polymerize, causing the cells to deform into a sickle or crescent shape. This deformation leads to distinct Vaso-occlusive events and accelerated hemolysis [1]. It is characterized by the presence of sickle hemoglobin (HbS), resulting from the substitution of glutamic acid with valine at the sixth position of the β-globin chain. In sub-Saharan Africa, the three most common forms of sickle cell disease are sickle cell anemia (HbSS), sickle hemoglobin C disease (HbSC), and hemoglobin S beta thalassemia disease (HbSBetaThal). These conditions manifest when the mutated hemoglobin gene is inherited from both parents who possess sickle cell traits [2]. The Vaso-occlusive crisis, also known as sickle cell crisis, is a common painful complication experienced by adolescents and adults with sickle cell disease. Severe episodes of acute pain (crises) are the primary drivers for seeking medical attention in hospital emergency departments However, the management of this pain often remains inadequate. Consequently, it is crucial to promptly identify a pain crisis, address underlying causes, manage pain, maintain proper fluid balance, and when required, administer adequate hemoglobin to reduce hemoglobin S levels [3].

Sickle cell disease (SCD) represents a complex disorder and is recognized as the most prevalent genetic ailment within the United States. The impact of SCD encompasses a population of approximately 100,000 individuals in the United States, while the sickle cell trait (SCT) is possessed by around 3 million Americans. Notably, this condition affects 1 in 500 African Americans. An examination of the incidence of SCT per 1000 births during 2010 in the United States reveals rates of 73.1 in black newborns, 3 in white newborns, 6.9 in Hispanic newborns, and 2.2 in Asian or Pacific Islander newborns. Analyzing a study conducted in Michigan from 1997 to 2014, it was identified that about 86% of SCD patients within the study were of black ethnicity, while 2.5% were white [4].

Projections indicate that annually, approximately 300,000 infants are born with sickle cell anemia, a condition defined by homozygosity for the hemoglobin gene (HbS), with expectations suggesting a rise to 400,000 by the year 2050. This disease is prevalent across various regions including sub-Saharan Africa, the Mediterranean, the Middle East, and India, with a substantial concentration of occurrences in Nigeria, the Democratic Republic of the Congo, and India [5].

On a global scale, approximately 5-7% of the population carries an abnormal hemoglobin gene defect, with sickle cell disease representing the most widespread form of hemoglobinopathy. The prevalence of sickle cell disease varies between 10 and 45% across diverse regions of sub-Saharan Africa, notably reaching about 20-30% in Nigeria. Within Nigeria's population of over 160 million, sickle cell disease affects roughly 2%-3% [1].

Concurrent research conducted by [6], similarly highlighted the presence of sickle cell traits among adult Nigerians at a rate of around 25%, while sickle cell disease manifested in 1-3% of cases. Findings from a study by [7], in Lagos, Nigeria, revealed a population distribution of 2.4% among Yoruba indigenes residing in the city.

Blood consists of two distinct phases: a cellular phase composed of suspended erythrocytes, leukocytes, and platelets, and a plasma phase comprising an aqueous solution containing organic molecules, proteins, and salts [8].

Hemorheology, or blood rheology, is the scientific exploration of blood and its formed elements' deformation and flow. This field encompasses macroscopic blood property investigations through rheometric experiments, as well as microscopic properties studied in vitro and in vivo. Hemorheology delves into the interactions among blood constituents and between these elements and the endothelial cells lining blood vessels [8]. The occurrence of complications in sickle cell anemia (SCA) has been linked to alterations in blood rheology, chronic vascular inflammation, abnormal adhesion processes, and vascular dysfunction [9]. The severity of the disease is influenced by a multifaceted interplay of genetic, rheological, hematological, microvascular, and endothelial factors [10]. Blood viscosity, a direct measure of blood's ability to traverse vessels, is primarily determined by five factors: hematocrit (Hct), red blood cell (RBC) deformability, RBC aggregation, plasma viscosity, and temperature [11].

Blood viscosity is often overlooked in the context of Sickle Cell Anemia (SCA), and the impact of abnormal hemorheology on this condition remains underestimated (Yann et al., 2014). The prevailing understanding points to five key factors - hematocrit (Hct), deformability of red blood cells (RBCs), aggregation of RBCs, plasma viscosity, and temperature - as the primary determinants of the hemodynamic and rheological behavior of blood [11]. SCA, as an inherited blood disorder, displays anomalous rheology and hemodynamics particularly in hypoxic conditions. When blood flow slows down, a series of cellular reactions occur, leading to the adhesion of sickle RBCs to the vascular endothelium. This cascade results in vaso-occlusion and subsequent clinical manifestations like organ damage, pain, and even mortality [11].

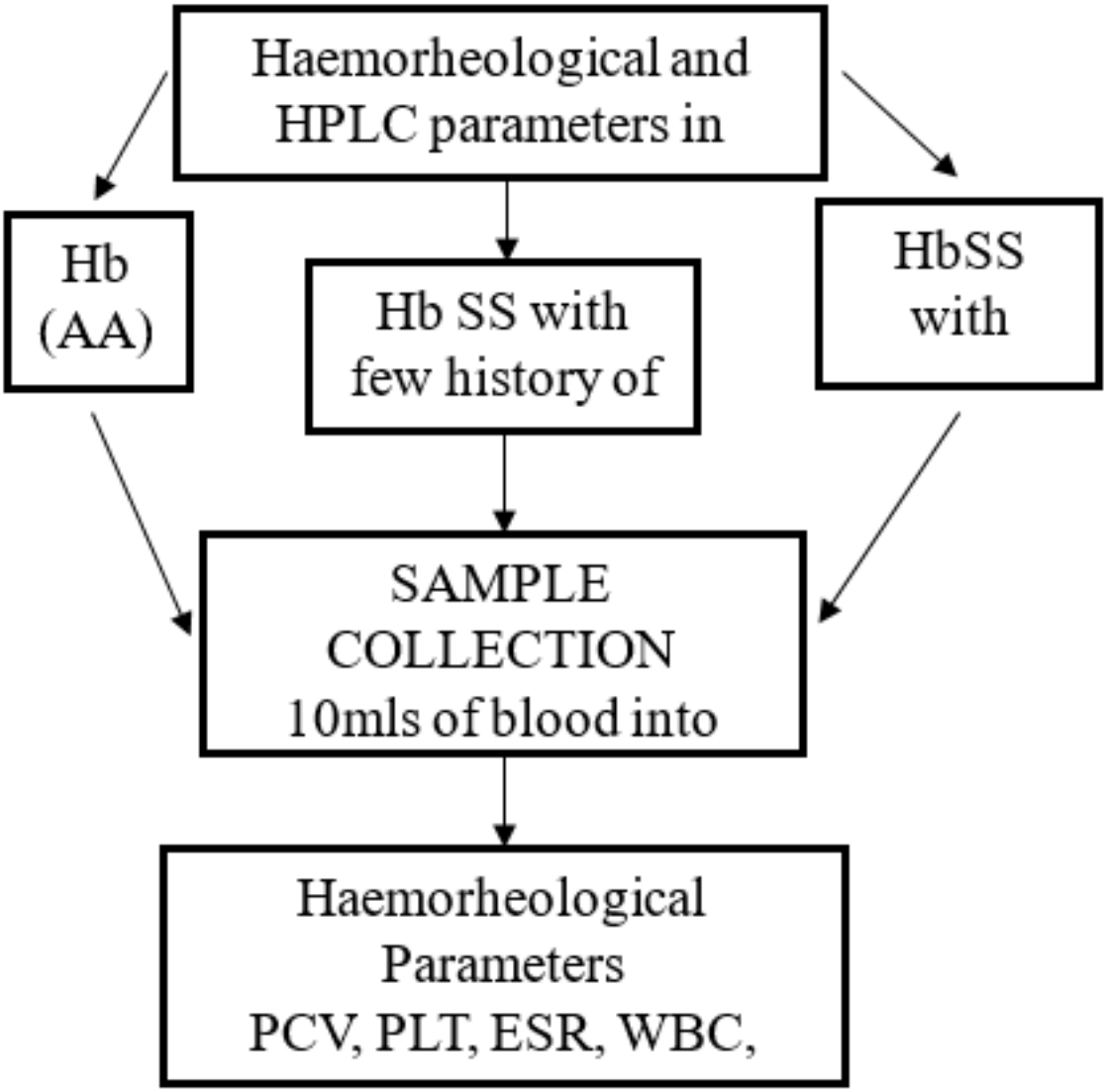
Sickle cell disease is an inherited hemoglobinopathy stemming from a mutant variant of the β-globin gene (βA) on chromosome 11. This gene is responsible for the assembly of β-globin chains within the hemoglobin A protein. The mutated β-allele (βS) leads to the production of the variant hemoglobin, hemoglobin S. The most prevalent and severe form of SCD, known as HbSS disease, arises from homozygosity for the sickle mutation. The polymerization of deoxygenated hemoglobin S is a fundamental event in the molecular pathogenesis of this disease. This process exists in a dynamic equilibrium with soluble hemoglobin tetramer, causing a distortion in the shape of the red cell, a substantial reduction in deformability, and ultimately the sickle morphology that lends its name to the disease [12]. Consequently, the rigidity of these cells is the root cause of the vaso-occlusive phenomena that hallmark the disease [12].

Though the measurement of blood viscosity is seldom undertaken in Sickle Cell Anemia (SCA), its link to abnormal hemorheological parameters is frequently disregarded [13]. The consensus suggests that five pivotal factors, namely, hematocrit (Hct), deformability of red blood cells (RBCs), RBC aggregation, plasma viscosity, and temperature, collectively dictate the hemodynamic and rheological attributes of blood [11]. In the context of hypoxic conditions, where blood flow is sluggish, SCA demonstrates aberrant rheological and hemodynamic behaviors, culminating in adhesion of sickle RBCs to the vascular endothelium, vaso-occlusion, and subsequent clinical ramifications such as pain, organ damage, and even fatality [11].

From a biological standpoint, key hemorheological properties of blood include plasma viscosity and whole blood viscosity attributed to hematocrit, mechanical deformability of red blood cells, and their propensity for reversible aggregation.

The study area, ILE-IFE, is geographically positioned between latitudes 7°28'N and 7°46'N, as well as longitudes 4°36'E and 4°56'E. Nestled within the heart of south-western Nigeria, Ile-Ife holds the distinction of being an ancient Yoruba town. Its strategic location places it at the epicenter of the Yoruba-speaking states in Nigeria. Bordered to the west by Ibadan and to the east by Akure, the town serves as a pivotal gateway to the prominent Yoruba settlements in the eastern direction. Notably, Ile-Ife stands approximately 200 kilometers north-east of Lagos, which served as Nigeria's coastal capital city for more than a century [14].

Research Design



Study Design

This study is a cross sectional study and is designed with the study subjects grouped as follows:

The parameters that were carried out were PCV, PLT, ESR, WBC, whole blood viscousity, plasma viscousity and plasma fibrinogen concentration for both study subjects and control.

Sample Size Calculations.

Prevalence 2.4 % [15].

Case control study

$N = Z^2 \times P(1-P)/d^2$ [16].

In the context of statistical analysis, the variables are defined as follows:

N represents the desired sample size, reflecting the number of observations or data points needed to achieve a reliable and representative outcome.

Z denotes the statistical value associated with a chosen level of confidence.

For instance, at a confidence level of 95%, Z is set at 1.96, signifying the standard deviation from the mean within which the data points are likely to fall.

P signifies the expected prevalence or proportion within the population being studied. In this instance, the anticipated prevalence is estimated to be 2.4%.

D stands for the level of significance, often denoted as α, which indicates the probability of making a Type I error. In this case, a significance level of

0.05 is employed, suggesting a 5% likelihood of incorrectly rejecting the null hypothesis.

$[(1.96)^2 x 2.4/100(1-(2.4/100)]/(0.05)^2 = 3.84$ X0.024 (1-0.024) / (0.0025) = 3.84 X 0.024(0.976) /0.0025 = 3.84 X 0.0234/0.0025 = 0.089856/0.0025 = 36.

Therefore, sample size shall be adjusted to 120

MATERIALS AND METHODS

A 120 individuals age 18-48, male and female were investigated, 60 of which are apparently healthy individual with genotype AA, 60 sickle cell patients which were sub-grouped into: sickle cell anaemic individuals with less frequent Vaso-Occlusive crisis and sickle cell anaemic patients with recurrent Vaso-occlusive crisis that are attending Haematology department of OAUTHC, Ile-Ife. The VOC occurrence was confirmed from their medical records history. The vaso occlusive was classified based on classification of frequency of vaso occlusion [17].

Inclusion/Exclusion Criteria

Inclusion Criteria: Individual with Blood genotype AA and Genotype SS were included into this study.

Exclusion Criteria: All individual with Hb genotype other than the above mentioned and with history of hypertension, diabetes, Hepatitis and HIV were excluded from this study.

Informed Consent

This was obtained from participant based on a well-structured profoma.

Ethical Clearance

Ethical approval for this study was sought and obtained from Ethical Committee of Obafemi Awolowo University Teaching Hospitals Complex, Ile-Ife, Osun State. This crucial step ensures that the research adheres to the highest ethical standards, safeguarding the rights, well-being, and confidentiality of all individuals involved in the study. The oversight and endorsement from the ethical committee provide assurance to both participants and stakeholders that the research is conducted responsibly and in accordance with established ethical guidelines.

Laboratory Analysis
Sample collection

A total of 10mls of blood sample was collected from each participant, 2.7mls of blood were added to 0.3mls of (3.8%) sodium citrate for the fibrinogen assay, and 4.0mls was used for packed cell volume, Erythrocyte sedimentation rate, platelets, plasma viscosity and whole blood viscosity test. The 4.0mls of EDTA blood was spun at 500g for 10minutes for plasma viscosity test, while the citrated samples were spun at 1500g for 15minutes for fibrinogen assay.

Heamorheology Parameters

Whole blood and plasma viscousity shall be estimated using the method described by Reid and Ugwu and Fibrinogen Concentration by clot weight method as adapted by Ajayi and Uche, (2015). This method is used for its simplicity, rapid, cheapness and accuracy. PCV, White Blood Cell count (WBC), Platelets count shall be estimated using a 3-part automated haematology analyser (Sysmex XP-300) and ESR, by Modified Westergre method as adapted by [19].

Fibrinogen Assay Clot weight method as adapted by [18].

Principle

When calcium chloride is added to plasma, a clot is formed whose weight is directly proportion to the amount of fibrinogen present.

Plasma fibrinogen concentration =Dry weight *10ul/Volume of plasma

Whole Blood and Plasma Viscosity Measurements. Reid and Ugwu method as adapted by Ajayi [18].

Principle

This experimental procedure involves a comparative analysis of whole blood, plasma, and distilled water. The study investigates their behavior under controlled conditions of pressure and consistent temperature, utilizing capillary tubes of identical dimensions in terms of bore and length. Subsequently, the results obtained are used to quantify the viscosity of both whole blood and plasma, relative to the viscosity of distilled water. This approach provides valuable insights into the fluid dynamics and viscosity properties of these substances, contributing to a deeper understanding of their characteristics and interactions. By examining how these components react within a confined capillary environment, the research sheds light on their relative viscosities and enables the establishment of meaningful comparisons.

The relative viscosity of whole blood or plasma can be determined by calculating the ratio of the test flow rate to the flow rate of distilled water. This comparison offers valuable insights into the fluid dynamics and viscosity of these substances, shedding light on their unique characteristics in various conditions and contexts. By employing this formula, we can quantitatively assess how the viscosity of whole blood or plasma compares to that of distilled water, providing a deeper understanding of their behavior under specific pressures and temperatures.

Erythrocyte Sedimentation Rate. Modified westergen method as adapted by [19].

Principle of ESR

When blood that has been treated with an anticoagulant is left undisturbed in a vertically oriented narrow glass tube, a natural process occurs where the red blood cells (RBCs) gradually separate from the plasma due to the gravitational force acting on them. This separation process can be observed over a certain duration of time. To quantify this phenomenon, the measurement involves determining the height of the clear plasma that remains at the upper portion of the column after a specific time interval, usually one hour. This measurement, expressed in millimeters per hour (mm/hr), provides valuable information about the settling rate of red blood cells in the anticoagulated blood sample and offers insights into the sedimentation characteristics of the blood components.

Normal Value:

For males: 0-10mm/hr For females: 0-15 mm/hr

Packed Cell Volume (PCV), White Blood Cell (WBC) Count, and Platelet Count.

Method: using automated haematology analyser (Sysmex XP-300)

A fully automated machine, Sysmex XP 300, was used for the analysis of these parameters in both control and subjects.

Procedure: After collection, the samples were arranged serially on sample rocker for proper mixing. The sysmex machine is put on and one has to wait for about 5 minutes for priming, until the machine status display READY. Sample ID were then entered into the machine and the well mixed EDTA anticoagulated blood samples were introduced to the probe of the machine, then the start button was pressed, The automated system performs an automatic analysis of the samples, and the results are promptly presented on the LCD screen. Additionally, a hard copy of the results is generated through the connected printer. Following the completion of sample analyses, the unit transitions into a ready state, ready to process the

next set of samples. Prior to powering off, a shutdown process is initiated, which includes the thorough cleaning of the TD chamber and the diluted sample line. It is essential to ensure that the shutdown process is executed after all sample analyses are complete before turning off the power.

Normal range for PCV; Male; 40-54%, Female; 38-47%
Normal range for Platelet count; 150,000- 400,000($x10^3$/μl)
Normal range for WBC count: 4,000-11,000($x10^3$/μl
Determination of Haemoglobin Genotype
Westergren Method as Adapted by [20].

Principle

In the context of electrophoresis, haemoglobin exhibits a negatively charged characteristic at alkaline pH. Consequently, during the electrophoretic process, haemoglobin migrates towards the anode (+). Distinct structural variants of haemoglobin that exhibit altered surface charge properties at alkaline pH undergo separation from haemoglobin A. It is worth noting that internally located haemoglobin variants may not experience separation, while those with amino acid substitutions that do not impact the overall charge will not be distinguishable through electrophoresis. This phenomenon allows for the differentiation and analysis of various haemoglobin variants based on their charge characteristics under alkaline conditions.

Method

1. Begin by ensuring the homogenous lysis of the haemolysate and blood sample through centrifugation.
2. Before connecting the power supply, introduce Tris-buffer into the buffer compartment within the tank. Immerse two chamber wicks in the buffer solution and position them along each divider or bridge support, ensuring proper contact with the buffer.
3. Submerge the cellulose acetate paper into the buffer reservoir, allowing it to soak for approximately 5 minutes prior to use.
4. Load the sample well plate with 5ul of each diluted sample or control.
5. Gently position the pre-soaked cellulose acetate paper across the bridge, ensuring optimal contact. Initiate electrophoresis at 220v for a duration of 15 minutes.
6. Upon completion of the electrophoresis, promptly transfer the cellulose acetate paper to a solution of Ponceau S, allowing it to fix and stain for a period of 5 minutes.
7. Following staining, eliminate excess stain by immersing the paper in the first acetic acid solution for a 5-minute wash.

This process involves a series of sequential steps aimed at achieving efficient electrophoresis and staining of diluted samples or controls on cellulose acetate paper. Properly executed, these steps facilitate the separation and visualization of distinct components, aiding in the identification and analysis of various substances within the sample.

Principle

In this experimental setup, phosphate buffers with varying concentrations are employed as the mobile phase. These buffers are propelled under controlled pressure through an ionic exchange column, serving as the stationary phase. The column is integrated within a temperature-controlled analytical cartridge, housing a specialized resin composed of finely tuned anionic or cationic particles with diameters ranging from 3 to 5 micrometers.

The primary objective of this setup is to facilitate the separation of haemoglobin molecules based on their distinctive interactions with the stationary phase. As the phosphate buffers flow through the column, the haemoglobin molecules undergo specific interactions with the anionic or cationic particles present in the resin.

The separation process relies on the principle of ionic exchange, where haemoglobin molecules with differing charges interact differentially with the charged resin particles. This interaction leads to the distinct migration of haemoglobin species within the column. As a result, haemoglobin components are eluted from the column at varying rates, based on their affinity for the anionic or cationic sites on the resin.

The temperature control within the analytical cartridge ensures optimal separation conditions, minimizing the influence of temperature fluctuations on the separation process. Consequently, the separation of haemoglobin species remains consistent and reproducible, enabling accurate analysis and identification.

Method

The blood sample from all participants were collected in labelled 5ml EDTA anticoagulant tube using - Bio Rad (USA) for the determination of the Hb variants.

Statistical Analysis

The data obtained from the experiment underwent a comprehensive analysis encompassing both descriptive and inferential statistical methods. The socio-demographic information gathered from the participants was evaluated utilizing descriptive statistics to provide a detailed summary of the essential characteristics.

Descriptive statistics enabled the organization and presentation of socio-demographic data in a clear and concise manner. Parameters such as mean, median, mode, standard deviation, and range were computed to offer insights into the central tendency, dispersion, and distribution of the socio-demographic variables.

Through this approach, key demographic details such as age, gender, educational background, and occupation were summarized, offering a comprehensive overview of the study participants. Descriptive statistics allowed for a precise portrayal of the socio-demographic landscape, facilitating a better understanding of the sample characteristics, while the haemorheological parametres were determined using student t-test. The haemorheological parameters in both groups (HbSS and HbAA) were determined using Analysis of Variance (ANOVA).

RESULTS

Table 4.1 shows the socio-demographic characteristics of the general population of the Sickle Cell Anaemic Patients and the control group. There is no significant difference in age, sex, ethnicity, marital status, religion, and occupation. The mean value of age for sickle cell patients is 30.03±5.73, while apparently healthy HbAA individual is 28.16±4.37 and P>0.05. Hence there is no statistical significant difference

TABLE 4.1 showing anthropological parameters of the sickle cell and the control. There were no significant differences between these parameters.

PARAMETERS	SS Mean ± SD	AA Mean ± SD	T-TEST	P Val	Remark
Age	30.03±5.73	28.16±4.37	2.007	>0.05	Not sig.
Height	1.49±0.12	1.50±0.12	-.684	>0.05	Not sig.
Weight	63.30±11.73	65.95±9.67	-1.350	>0.05	Not sig.

BMI	29.02±7.21	29.7±6.65	-.534	>0.05	Not sig.
	SS	**AA**	**Total**	**X²**	**P val**
Gender	Male	28(23.3)	29(24.2)	57(47.5)	
	Female	32(26.7)	31(25.8)	63(52.5)	0.033
Ethnicity	Yoruba	43(35.8)	51(42.5)	94(78.3)	
	Ibo	10(8.3)	3(2.5)	13(10.3)	
	Hausa	7(5.8)	4(3.3)	11(9.2)	
	Others	-	2(1.7)	2(1.7)	7.269 .64
Religion	Christian	4(3.3)	7(5.8)	11(9.2)	
	Islam	50(41.7)	49(40.8)	99(82.5)	
	Traditional	6(5)	2(1.7)	8(6.7)	
	Others	-	2(1.7)	2(1.7)	
Marital Status	Single	24(20)	22(18.3)	46(38.3)	4.828 .19
	Married	36(30)	38(31.7)	74(61.7)	0.141 .71
Occupation	Civil Servant	3(2.5)	8(5.8)	10(8.3)	
	Trading	21(17.5)	15(12.5)	36(30)	
	Schooling	15(12.5)	14(11.7)	29(24.2)	
	Artisan	7(5.8)	15(12.5)	22(18.3)	
	others	14(11.7)	8(6.7)	22(18.3)	8.180 0.15

KEY
P<0.05=Significant
SS= Haemoglobin SS
AA= Haemoglobin AA

Table 4.2 shows the mean values of haemorheological parameters across all sickle cell patients and control group HbAA in which there are statistical significant difference in all the parameters (P<0.05). The mean values for PCV were 22.57 ± 4.91 and the control group were 41.40 ±4.33 showing marked reduction in the values of Packed Cell Volume compared with the Control group. The remaining parameters exhibited elevated values in sickle cell patients compared to the control group.

TABLE 4.2 showing haemorheological parameters of sickle cell group (HbSS) and control group (HbAA)

PARAMETERS	SG(N=60)	CONTROL AA(N=60)	T-VALUE	P-VALUE
PCV (%)	22.57±4.91	41.40 ± 4.33	- 22.28	<0.05
ESR (mm/hr)	25.20±31.91	9.02 ± 8.35	3.80	<0.05
PLT(x10³/µl)	384816.67±190999.29	186733.33 ±57145.92	7.70	<0.05
WBV (cp)	154.27± 3699	4.68 ± 0.96	31.32	<0.05
PV (cp)	66.93±11.70	1.44 ± 0.12	43.34	<0.05
FIB (g/l)	0.43±0.02	0.02 ± 0.0	6.82	<0.05
WBC (x10³/µl	13033.33±4561.77	5568.331699.99	11.88	<0.05

KEY;
P<0.05- Significant
PCV= Packed Cell Volume, ESR= Erythrocyte Sedimentation Rate, PLT= Platelets, WBV= Whole Blood Viscousity, PV= Plasma Viscousity, FIB= Fibrinogen, WBC=White Blood Cell, SSG=Sickle Cell General.

Table 4.3 shows the mean values of haemorheological parameters of sickle cell patients with less frequent vaso occlusive crisis and control group. The mean values of all the haemorheological parameters were higher among the sickle cell patients when compared with the control group, exception is that of packed cell volume which has a lower value when compared to the mean cell value of the control group. There were however statistical significantly difference in all the haemorheological parameters from the control groups (P<0.05).

TABLE 4.3 showing haemorheological parameters of sickle cell patients with less frequent VOC and control group (HbAA)

PARAMETERS	SS WITH LESS FREQ. VOC	CONTROL AA(N=60)	T-value	P-value
PCV (%)	22.77 ±4.91	41.40 ± 4.33	21.12	<0.05
ESR(mm/hr)	24.58 ± 31.52	9.02 ± 8.35	-3.46	<0.05

PLT(x10³/µl)	399634.62 ± 1922418.21	186733.33 ± 57145.92	-7.70	<0.05
WBV(cp)	154.00 ± 36.68	4.68 ± 0.96	-31.96	<0.05
PV(cp)	65.13 ± 9.51	1.44 ± 0.12	-48.31	<0.05
FIB(g/l)	0.04 ± 0.02	0.02 ± 0.01	-6.04	<0.05
WBC(x10³/µl)	13365.38 ± 4678.31	5568.33 ± 1699.99	-11.39	<0.05

KEY;

P<0.05-Significant

PCV= Packed Cell Volume, ESR= Erythrocyte Sedimentation Rate, PLT= Platelets, WBV= Whole Blood Viscousity, PV= Plasma Viscousity, FIB= Fibrinogen, WBC=White Blood Cell, VOC=Vaso Occlusive Crisis

Table 4.4 shows the mean values for haemorheological parameters of sickle cell patients with frequent vaso occlusive crisis and control group. There were statistical differences in all the haemorheological parameters when compared with controls (P<0.05) except platelets in which there is no significant difference (P>0.05). The platelets mean value of the subjects is 268500.00 ± 161157.42 while the control group has mean value of 186733.33 ± 57145.92.

TABLE 4.4 showing haemorheological parameters of sickle cell patients with frequent VOC and control group HbAA.

PARAMETERS	SICKLE CELL WITH FREQ VOC(N=8)	CONTROL AA(N=60)	T-value	P-value
PCV (%)	21.25 ±5.06	41.40 ± 4.33	10.74	<0.05
ESR(mm/hr)	29.25 ± 36.37	9.02 ± 8.35	-1.57	<0.05
PLT x10³/µl	268500.00 ± 161157.42	186733.33 ± 57145.92	-1.77	>0.05
WBV(cp)	155.98 ± 57.11	4.68 ± 0.96	-7.5	<0.05
PV(cp)	78.56 ± 17.81	1.44 ± 0.12	-12.25	<0.05
FIB(g/l)	0.05 ± 0.02	0.02 ± 0.01	-4.43	<0.05
WBC(x10³/µl)	10875.00 ± 3129.47	5568.33 ± 1699.99	-4.71	<0.05

KEY;

P<0.05-Significant

PCV= Packed Cell Volume, ESR= Erythrocyte Sedimentation Rate, PLT= Platelets, WBV= Whole Blood Viscousity, PV= Plasma Viscousity, FIB= Fibrinogen Concentration, WBC=White Blood Cell, VOC=Vaso Occlusive Crisis.

Table 4.5 shows the mean values of haemorheological parameters between sickle cell patients with frequent vaso occlusive crisis and less frequent vaso occlusive crisis. There were no significant differences in all the parameters estimated (P>0.05). The mean values for ESR for frequent group is 29.25 ± 36.37 while infrequent is 24.58 ± 31.52, for WBV frequent has 155.98 ± 57.11 while infrequent has 154.00 ± 36.68, and for PV, frequent has 78.56 ± 17.81 while infrequent has 65.13 ± 9.51.

TABLE 4.5 showing haemorheological parameters between sickle cell patients with frequent VOC and sickle cell with less frequent VOC.

PARAMETERS	SS WITH FREQ. VOC(N=8)	SS WITH LESS FREQ.VOC (N=52)	T-value	P-value
PCV(mm/hr)	21.25 ±5.06	22.77 ±4.91	0.79	>0.05
ESR(mm/hr)	29.25 ± 36.37	24.58 ± 31.52	-3.44	>0.05
PLT(x10³/µl)	268500.00 ± 161157.42	399634.62 ± 1922418.21	1.77	>0.05
WBV(cp)	155.98 ± 57.11	154.00 ± 36.68	-0.10	>0.05
PV(cp)	78.56 ± 17.81	65.13 ± 9.51	-2.09	>0.05
FIB(g/l)	0.05 ± 0.02	0.04 ± 0.02	-0.67	>0.05
WBC(x10³/µl)	10875.00 ± 3129.47	13365.38 ± 4678.31	-1.94	>0.05

KEY;

P<0.05-Significant

PCV= Packed Cell Volume, ESR= Erythrocyte Sedimentation Rate, PLT= Platelets, WBV= Whole Blood Viscousity, PV= Plasma Viscousity, FIB= Fibrinogen Concentration, WBC=White Blood Cell, VOC=Vaso Occlusive Crisis.

TABLE 4.6 shows Analysis of Variance of Haemorheological Parameters and HPLC parameters of both sickle cell patient groups and control group (HbAA) in the study area.

Parameters	Control HbAA. n=60	SS with Frequent VOC. N=8	SS with Less Frequent n=52	F	Sig.
PCV (%)	41.40 ± 4.33	21.25 ± 5.06	22.77 ± 4.91	248.067	0.000
ESR (mm/hr)	9.02 ± 8.35	29.25 ± 36.37	24.58± 31.52	7.315	0.001

PLT (x10³/µl)	186733.33± 57145.92	268500.00 ± 161157.42	399634.62 ± 1922418.21	32.685	0.000
WBV (cp)	4.68 ± 0.96	155.98 ± 57.11	154.00 ± 36.68	486.379	0.000
PV (cp)	1.44 ± 0.12	78.56 ± 17.81	65.13 ± 9.51	1112.296	0.000
FIB (g/)	0.02 ± 0.01	0.05 ± 0.02	0.04 ±0.02	23.339	0.000
WBC (x10³/µl)	5568.33 ± 1699.99	10875.00 ± 3129.47	13365.38 ± 4678.31	74.018	0.000

KEY;
P<0.05-Significant
Hb A2=Haemoglobin A2, HbF= Fetal haemoglobin, HbS= Sickled haemoglobin, HbA= Adult haemoglobin, HPLC= High performance liquid chromatography VOC=Vaso Occlusive Crisis.

TABLE 4.7 shows Multiple Comparism of Haemorheological Parameters and HPLC parameters of both sickle cell patient groups and control group (HbAA) in the study area.

Parameters	Study Groups	HbSS with less frequent VOC	HbAA Control	HbSS with Frequent VOC
PCV	**HbSS with less frequent VOC**	-	0.000	0.665
	HbAA Control	0.000	-	0.000
	HbSS with Frequent VOC	0.665	0.000	-
ESR	**HbSS with less frequent VOC**	-	0.002	0.859
	HbAA Control	0.002	-	0.060
	HbSS with Frequent VOC	0.859	0.060	-
PLATELETS	**HbSS with less frequent VOC**	-	0.000	0.093
	HbAA Control	0.000	-	0.131
	HbSS with Frequent VOC	0.093	0.131	-
WBV	**HbSS with less frequent VOC**	-	0.000	0.979
	HbAA Control	0.000	-	0.000
	HbSS with Frequent VOC	0.979	0.000	-
PV	**HbSS with less frequent VOC**	-	0.000	0.000
	HbAA Control	0.000	0.000	0.000
FIB	**HbSS with Frequent VOC**	0.000	0.000	0.000
	HbSS with less frequent VOC	-	0.0000	0.790
	HbAA Control	0.000	-	0.001
	HbSS with Frequent VOC	0.790	0.001	-
WBC	**HbSS with less frequent VOC**	-	0.000	0.136
	HbAA Control	0.000	-	0.000
	HbSS with Frequent VOC	0.136	0.000	-

DISCUSSION

This study was aimed at determining the Haemorheological parameters among Sickle Cell Subjects with recurrent Vaso Occlusive crisis in OAUTHC, Ile Ife Osun State, Nigeria. The study recruited 60 participants of Sickle Cell subjects for the study group and 60 Heamoglobin AA as control group, of which 28 (23.7%) and 32 (26.7%) represent male and female in the study group, while 29 (24.2%) and 31(25.8%) represent male and female in the control group respectively. The age range for the subjects were 30.03±5.73 while those of control group were 28.16±4.37. The study showed that there were no statistically significant differences between the Subjects and the control groups observed for clinical parameters such as Age, Height, Weight and BMI. Also, there were no statistically significant differences in all the socio-demographic data between the groups. It was revealed from this research that the haematocrit values (22.57 ± 4.91) for sickle cell patients were significantly decrease and statistically significant (P<0.05) when compared with control group (41.40 ± 4.33). The decrease in Haematocrit may be largely due to ineffective haematopoiesis that is characterised among Sickle Cell Patients. There observed a slight decrease but not statistically significant p>0.05 in the mean haematocrit value among the frequent vaso occlusive crisis (VOC) group (21.25 ±5.06) when compared with the less frequent group (22.77 ±4.91) in this study. there was observable statistically significant difference (P<0.05) in the ESR among the sickle cell patients when compared with the control group. The statistically significant difference in this study may be due to underline infection comorbid with the onset of vaso occlusive crisis at the time of their visit to the hospital. High WBC values among these sickle cell groups when compared with the control group confirmed a modest leucocytosis among the sickle cell patients even at steady state. Leucocytosis has been hypothesised to be a reflection of the constant inapparent inflammation with subsequent release of Cytokines which consequently results in in-

crease production of Leucocytes in the bone Marrow. , there was observable slight reduction of WBC among people with frequent vaso occlusive crisis when compared with the Less Frequent group, there may have arisen the possibility of adherence of leucocytes SS RBCs to the endothelium which plays a major role in the initiation of VOC and consequent slight reduction in their Leucocytes (Deepa and Paul, 2013). This adherence may have caused the reduction in the circulatory leukocytes and might be a significant indication among SS with recurrent Vaso occlusive crisis.

High platelets count which is the usual findings among SCD was also observed in this study when compared with control group. Redistribution of the white blood cells between the marginal and circulating pools that causes leucocytosis in the absence of infection had been attributed to the cause of this thrombocytosis. There was a slight difference in platelets value of sickle cell with frequent group (268500.00 ± 161157.42) when compared with less frequent group (399634.62 ± 1922418.21) vaso occlusive crisis. Production defects associated with frequent vaso occlusive crisis as a result of compromised bone marrow couple with sickle cell-endothelial interaction which result in coagulation factor activation and a state of compensated disseminated intravascular coagulation with platelet consumption may have caused these slight changes in the platelet counts among the recurrent vaso occlusive group according to (Durjoy, Ahmed, Ahmad, & All, 2018). Steady statistically significant differences ($p<0.05$) were observed in whole blood viscousity, plasma viscousity and plasma fibrinogen concentration among the sickle cell patients in both groups when compared with the control groups. The statistically significant increase in the fibrinogen concentration among the sickle cell group and the consequential increase in the blood viscousity in this study is in agreement with many previous works. The slight increase in the values but statistically insignificant fibrinogen concentration and Plasma Viscousity was observed in sickle cell group with recurrent VOC when compared with the less frequent group. An increased Plasma viscousity and Fibrinogen is known to aggravate the VOC, which was the the reason for the recurrent episode of vaso occlusive crisis in this group.

CONCLUSION

It can be concluded from this study that, some Haemorheological Parameters which include Whole Blood Viscousity, Plasma Viscousity, Erythrocyte Sedimentation rate, Platelets Count, Total White Blood Cell count and Fibrinogen Concentration were raised while the values of Packed Cell Volume were low among all the HbSS Patients.

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