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Assessment of Visual and Blood-Related Parameters Among Children with Sickle Cell Anemia at Murtala Muhammad Specialist Hospital in Kano, Nigeria.

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Abstract

Sickle cell disease (SCD) is a prevalent genetic disease worldwide and particularly in Nigeria. Retinopathy is a known complication of SCD, underscoring the need to assess visual parameters in children. This study aimed to evaluate the visual acuity (VA), color vision (CV), packed cell volume (PCV), and erythrocyte sedimentation rate (ESR) of Sickle cell anemic (SCA) patients attending the Sickle cell counseling unit of Murtala Muhammad Specialist Hospital (MMSH) in Kano. It was a descriptive cross-sectional study consisting of 60 participants, including 30 SCA patients and 30 healthy controls without systemic or ocular diseases, aged between 8 and 14 years. Visual acuity, CV, PCV, and ESR were assessed using Snellen Chart, Ishihara chart, Hematocrit test, and Westergren Method respectively. Data were analyzed using SPSS version 22.0. Statistical significance was set at $P < 0.05$. Both SCA patients and controls demonstrated limited knowledge about VA, CV, and ESR tests, and a significant percentage had never undergone these tests. SCA patients exhibited mild to moderate visual impairment (VI) in both eyes, while controls had no VI. Abnormally low PCV and ESR values were observed in all SCA patients, whereas controls had normal values. Gender differences were observed in ESR levels, with females showing higher levels. Significant differences were found between controls and SCA patients in terms of VA, ESR, and PCV values. There was a general lack of awareness regarding the importance of VA and CV tests in the community. Visual impairment and abnormal PCV and ESR values were exclusive to the SCA patients, indicating their association with the disease.

Keywords: Packed cell volume, Erythrocyte sedimentation rate, Visual acuity, Color blindness, Sickle cell anemia.

INTRODUCTION

Normally, red blood cells (RBCs) are round and flexible, allowing them to easily move through blood vessels to deliver oxygen to various tissues and organs (Schmid-Schönbein, 1981). In individuals with SCD, the presence of hemoglobin S causes the RBCs to become rigid and take on a characteristic crescent or "sickle" shape (Sahu *et al.*, 2015). These abnormally shaped RBCs can get stuck in small blood vessels, leading to blockages that can cause pain, organ damage, and a variety of complications (Buchanan *et al.*, 2010). Common clinical presentations include painful crisis and organ damage due to vaso-occlusion, Anemia,

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susceptibility to infections, etc. (Costa and Fertrin, 2016). Complications may include stroke, delayed growth, visual problems, and pulmonary hypertension (Sundd *et al.,* 2019).

Sickle cell retinopathy is an eye condition that can occur as a complication of SCD. It primarily affects the retinal blood vessels. The trapping of sickle-shaped RBCs in small blood vessels throughout various structures of the eye, both in the anterior and posterior segments, leads to characteristic damage (AlRyalat *et al.,* 2020). Patients with sickle cell anemia may experience varying degrees of retinal complications, ranging from mild signs of peripheral retinal vascular occlusion to proliferative sickle cell retinopathy. Not all patients with sickle cell anemia (SCA) are equally affected by these diseases (Abdalla-Elsayed *et al.,* 2019).

People with SCD often experience vision problems exacerbated by ocular manifestations of the disease. Clear vision is vital for daily activities, and research shows that SCD patients encounter visual issues more frequently than those without the condition (Fadugbagbe *et al.,* 2010). Early detection and intervention can prevent vision loss, emphasizing the need for regular eye examinations by an ophthalmologist. Unfortunately, only a few SCD patients routinely access eye care in Nigeria (Oluleye *et al.,* 2021). The existing lack of studies on VA, CV and hematological parameters in Kano led to this research aiming to fill the gap. It highlights the importance of regular visual assessments often overlooked by physicians.

METHODOLOGY

Study Setting and Design: It was a descriptive cross-sectional study conducted between March and April, 2023 at the Sickle cell clinic of Murtala Muhammad Specialist Hospital (MMSH) in Kano, Nigeria. The study involved 30 SCA patients and 30 age and sex-matched controls between the age of 8-14 years.

Inclusion/ Exclusion Criteria: The study included all children without any systemic or ocular diseases whose parents provided an informed consent to participate in the study and excludes those children with other systemic or ocular diseases or those whose parents denied consent.
Ethical Consideration: ethical clearance was obtained from the ministry of health Kano state, with the reference (SHREC/2022/3725) and approval number NHREC/17/03/2018.

Data Collection: A questionnaire was used to capture biodata, vision-related data, and physical examination of the participants. Color vision, VA, and hematological parameters were assessed below.

Visual Acuity Test: The Snellen chart is a widely used visual acuity test involving rows of letters or symbols of varying sizes. During the test, the individual stands or sits at a standardized distance (6 meters) from the chart and reads or identifies the characters from the largest to the smallest row. The VA score is based on the smallest line accurately read. This test aids in diagnosing conditions like nearsightedness, farsightedness, and astigmatism, as well as monitoring changes in vision related to diseases (Snellen, 1862).

Color Vision Test: The test involved viewing plates held at arm's length, and set at eye level. Participants were asked to report the numbers seen on plates 1-15, with a quick response time. If 13 or more plates were read correctly, color vision was considered normal; if only 9 plates were read correctly, it indicated red-green deficiency.

Ishihara's chart, featuring symbols with subtle color differences, was used to assess CV. The symbols could be distinguished by individuals with normal vision but posed a challenge for

those with color defects. The test was designed to detect even mild color deficiencies, with significant differences between symbols and background for individuals with normal color vision to pass (Ishihara, 1990).

Assessment of the Packed Cell Volume: Assessment of PCV involves taking a blood sample from a patient. The blood is placed in a heparinized capillary tube, and then subjected to centrifugation. The PCV was determined by measuring the volume occupied by settled RBCs in relation to the total blood volume in the tube, expressed as a percentage (Bull and Hay, 2001).

Assessment of the Erythrocyte Sedimentation Rate: The ESR was evaluated using the Westergren method, which involves drawing a blood sample and placing it in a vertical tube (Jou, 2012). Over one hour, RBCs settle at the bottom due to gravity, leaving clear plasma at the top. The test result, measured in millimeters per hour (mm/hour), indicates the rate at which sedimentation occurs and provides insights into inflammatory conditions.

Data Analysis: Descriptive data were presented as frequency tables. Chi-Square Test and Mann-Whitney U Test were used to show comparison. Statistical significance was set at $P<0.05$. The data analysis was conducted using SPSS version 25.0.

RESULTS AND DISCUSSION

The study involved a total of sixty participants, comprising thirty SCA patients (15 males and 15 females) and thirty controls who were matched in terms of age and sex (17 males and 13 females) (Table 1). The age range is between 8-14 years, majority of whom were 12 years of age in both groups. But the SCA group had equally higher number of 9 years old (Table 1). Majority of the participants in both groups were Hausas, followed by Fulanis and then Yoruba tribes (Table 1). Majority of the participants in both groups were primary school pupils, with few at junior secondary school level (Table 1).

Table 1: Socio-demographic Characteristics of the Participants

Biodata	Categories	Control	Sickle cell patient
		Frequency (%)	Frequency (%)
Gender	Male	17 (57%)	15 (50%)
	Female	13 (43%)	15 (50%)
Age	8	0 (0%)	2 (6.7%)
	9	5 (17%)	7 (23.3%)
	10	4 (13%)	6 (20%)
	11	7 (23%)	5 (16.7%)
	12	9 (30%)	7 (23.3%)
	13	4 (13%)	2 (6.7%)
	14	1 (3%)	1 (3.3%)
Ethnicity	Hausa	20 (66.7%)	25 (83.3%)
	Fulani	5 (16.7%)	4 (13.3%)
	Yoruba	5 (16.7%)	1 (3.3%)
Educational Level	Primary School	21 (70%)	23 (76.7%)
	Junior Secondary School	9 (30%)	7 (23.3%)
	Blue-Green Defect (BGD)	0 (0%)	29 (96.7%)

Most of the control (83%) and SCA (87%) patients did not know the meaning or importance of VA test. Majority of the control (93%) and all the SCA (100%) patients did not know the meaning or importance of CV test. Ninety percent of the controls and 87% of the SCA patients had never undergone any VA test. Equally all the SCA patients and 93% of the controls did

not undergo any CV test. Majority of the controls (60%) and the SCA patients (57%) never had any ESR test done. Olatunya *et al.,* (2020) documented that the perceptions and practice of early prenatal SCD diagnosis was found to be suboptimal in Ekiti state of Nigeria and the commonest reason given by both the physicians and mothers was the high cost of the procedure. However, all the participants in both groups had at least a PCV test done earlier in their lifetime. Sixty-three percent of the participants in both groups had difficulty reading in dim light. Majority of the participants in both groups sits at the front rows of the class followed by the middle and then the back rows (Table 2).

All the controls had no pain while watching television compared to 80% of the SCA patients. Only one (3.3%) SCA patient complained of difficulty in reading an ordinary printing in both groups. All the controls had no difficulty searching or finding something while 87% of the SCA patients complained of difficulty in finding somethings. None of the controls complained of any eye problem; however, 7% of the SCA patients noticed some sight problems in their eyes. Majority of the controls (67%) and the SCA patients (87%) did not discuss their eye problems with any health practitioner. About 83% of the SCA patients had difficulty watching movies compared to none of the control. None of the participants in both groups ever used an ordinary glass. All the participants in both groups used either television or mobile phones (Table 2).

It is important to understand that both the physicians and the care-givers did not seem to care much about ocular health in general talk less of the SCA patients. According to Afolabi *et al.,* (2020), many care-givers have poor knowledge of SCD, although nearly all of them were aware of the disease. In another study, fewer than 50% of the mothers had moderate knowledge of SCD and its genetic inheritance (Babalola *et al.,* 2019). This portrays the poor general knowledge concerning SCD. In line with this, Uche *et al.,* (2017) revealed that although general awareness of SCD among undergraduate students at Lagos State University was high. However, this awareness did not translate to good overall knowledge about the disease.

Table 2: Descriptive Statistics of Vision-Related Data

Biodata	Category	Control Frequency (%)	Sickle cell patient Frequency (%)
Meaning/ Importance of Visual Acuity Test	Yes	5 (16.7%)	4 (13.3%)
	No	25 (83.3%)	26 (86.7%)
Meaning/ Importance of Color Vision Test	Yes	2 (6.7%)	0 (0%)
	No	28 (93.3%)	30 (100%)
Ever undergone VA Test Before	Yes	3 (10%)	4 (13.3%)
	No	27 (90%)	26 (86.7%)
Ever Undergone CV Test Before	Yes	2 (6.7%)	0 (0%)
	No	28 (93.3%)	30 (100%)
Ever Undergone ESR Test Before	Yes	12 (40%)	13 (43.3%)
	No	18 (60%)	17 (56.7%)
Ever Undergone PCV Test Before	Yes	30 (100%)	30 (100%)
	No	0 (0%)	0 (0%)
Having difficulty in reading under dim light	Yes	11 (36.7%)	11 (36.7%)
	No	19 (63.3%)	19 (63.3%)
Sitting position in class	Front	11 (36.7%)	13 (43.3%)
	Middle	11 (36.7%)	9 (30%)
	Back	8 (26.7%)	8 (26.7%)
Do you experience pain while watching TV	Yes	0 (0%)	24 (80%)
	No	30 (100%)	6 (20%)
Have you undergone all the tests above	Yes	11 (36.7%)	0 (0%)
	No	19 (63.3%)	30 (100%)
Any difficulty reading ordinary printing	Yes	0 (0%)	1 (3.3%)
	No	30 (100%)	29 (96.7%)
Do you have difficulty searching/ finding something	Yes	0 (0%)	4 (13.3%)
	No	30 (100%)	26 (86.7%)
Did you observe any Eye problem	Yes	0 (0%)	2 (6.7%)
	No	30 (100%)	28 (93.3%)
Did you discuss your Eye problem with any health practitioner	Yes	10 (33.3%)	4 (13.3%)
	No	20 (66.7%)	26 (86.7%)
Difficulty in watching film	Yes	0 (0%)	25 (83.3%)
	No	30 (100%)	5 (16.7%)
Are you using ordinary glass	Yes	0 (0%)	0 (0%)
	No	30 (100%)	30 (100%)
which device are you using between TV, phone?	TV	19 (63.3%)	15 (50%)
	Phone	11 (36.7%)	15 (50%)
	None	0 (0%)	0 (0%)

Only one SCA patient had conjunctivitis and Blepharitis among all the participants in both groups. None of the participants had Dacryocystitis. Only one (3.3%) control had a stye (Table 3). All the controls had normal VA; however, 20% and 10% of the SCA patients had mild and moderate visual impairment (VI) of the right eye and 23% and 10% mild and moderate VI of the left eyes respectively. All the participants in both groups had normal near vision. Only one (3.3%) SCA patient in all the participants had normal CV. All the controls had normal PCV and ESR, and all the SCA patients had abnormal PCV and ESR (Table 4).

Table 3: Descriptive Statistics of the Past Medical History

Biodata	Categories	Control	Sickle cell patient
Conjunctivitis	Yes	0 (0%)	1 (3.3%)
	No	30 (100%)	29 (96.7%)
Blepharitis	Yes	0 (0%)	1 (3.3%)
	No	30 (100%)	29 (96.7%)
Dacryocystitis	Yes	0 (0%)	0 (0%)
	No	30 (100%)	30 (100%)
Stye	Yes	1 (3.3%)	0 (0%)
	No	29 (96.7%)	30 (100%)

Table 4: Descriptive Statistics of the Visual Acuity, Near Vision, Color Vision, Erythrocyte Sedimentation Rate, and Packed Cell Volume of the Participants.

Biodata	Categories	Control Frequency (%)	Sickle cell patient Frequency (%)
Visual acuity of right eye	Normal VA	30 (100%)	21 (70%)
	Mild visual impairment	0 (0%)	6 (20%)
	Moderate visual impairment	0 (0%)	3 (10%)
Visual acuity left eye	Normal	30 (100%)	20 (66.7%)
	Mild visual impairment	0 (0%)	7 (23.3%)
	Moderate visual impairment	0 (0%)	3 (10%)
Near vision	Normal Near Vision	30 (100%)	30 (100%)
	Abnormal Near Vision	0 (0%)	0 (0%)
Color vision	Normal Color Vision	30 (100%)	1 (3.3%)
	Blue-Green Defect (BGD)	0 (0%)	29 (96.7%)
PCV	Normal	30 (100%)	0 (0%)
	Abnormal	0 (0%)	30 (100%)
ESR	Normal	30 (100%)	0 (0%)
	Abnormal	0 (0%)	30 (100%)

At ophthalmologic examination, Manara *et al.,* (2021) found that 12% of SCD children had mild VA deficits and 8% had mild tortuosity of the retinal vessels. Sickle cell disease also causes anatomical and functional changes in children with SCD, even though there was absence of retinopathy. Additionally, all participants in both groups had normal near vision. Al-Naim *et al.,* (2017) also concluded that there was no significant relationship between SCD and vision disabilities based on the visual quality assessment questionnaire response of the participants in their study. However, all SCA patients had CV defects, except one male patient. It's noteworthy that gender was not associated with CV impairment. Previous study also documented abnormal CV test in SCA patients (Roy *et al.,* 1987).

In a study to assess the ocular manifestations of children with SCD in Ibadan, Nigeria, Oluleye *et al.,* (2017) found that retinal vascular tortuosity is the commonest ocular manifestation of the children 15 years and below. Also, George and Cookey, (2012) reported ocular abnormalities in 34% SCA children; However, no evidence of proliferative retinopathy was found in the SCA patients. Several ocular abnormalities were also reported in previous studies (Osafo-Kwaako *et al.,* 2011; Oladimeji *et al.,* 2021). However, other researchers (Eruchalu *et al.,* 2006; El-Ghamrawy *et al.,* 2014) did not find any ocular abnormalities in the participants studied in their respective study.

Our results also indicated a significant and strong association between SCA patients and the control group concerning VI in both the right eye ($p = 0.002$) and the left eye ($p = 0.002$). Most SCA patients had normal vision, and none of the control children exhibited mild or moderate

VI in their eyes (Fisher's Exact Test, p=0.002 for the right eye and 0.001 for the left eye) (Table 5).

Table 5: Relationship between Sickle Cell Anemic Patients, Controls and Visual Impairment of the Right and Left Eyes

			Visual Impairment (VI)			
			Normal VA	Mild VI	Moderate VI	P value
Groups	**Sickle cell patients**	**Right eye**	21 (41.2%)	6 (100%)	3 (100%)	0.002**
	Control		30 (58.8%)	0 (0%)	0 (0%)	
Groups	**Sickle cell patients**	**Left eye**	20 (40%)	7 (100%)	3 (100%)	0.001**
	Control		30 (60%)	0 (0%)	0 (0%)	

Right Eye: Chi-Square Test (Fisher's Exact Test (10.250). Left Eye: Chi-Square Test (Fisher's Exact Test (11.890). Control n= 30, Sickle Cell Patients n=30. *Indicates statistical significance and its absence indicates insignificance. P < 0.05.

There was a significant and strong association between SCA patients and the controls in terms of their PCV and ESR. Specifically, all SCA patients had abnormal PCV and ESR values, while all controls had normal PCV and ESR values (X^2 test, p-values of 0.001 for both PCV and ESR) (Table 6). This is inline with what was observed by Mohammed *et al.,* (2006) and Akinbami *et al.,* (2012).

Table 6: Relationship between The Groups and Packed Cell Volume or Erythrocyte Sedimentation Rate

		Packed Cell Volume (PCV)		
		Normal	Abnormal VI	P value
Groups	**Sickle Cell Patient**	0 (0%)	30 (100%)	0.001**
	Control	30 (100%)	0 (0%)	

		Erythrocyte Sedimentation Rate (ESR)		
		Normal	Abnormal VI	P value
Groups	**Sickle Cell Patient**	0 (0%)	30 (100%)	0.001**
	Control	30 (100%)	0 (0%)	

Chi-Square Test (Fisher's Exact Test). Control n= 30; Sickle Cell Anemia Patients n=30. *Indicates statistical significance and its absence indicates insignificance. P < 0.05.

Within the SCA patients, no significant association was found between gender and VI in the right eye (p=1.00). Most SCA patients, both males and females, had normal VA, with 50% experiencing mild VI. However, a higher percentage of males (67%) had moderate VI compared to females (33%) (Fisher's Exact Test, p=0.547) (Table 7). Similarly, for VI in the left eye among SCA patients, there was also no significant association between gender and VI (p=0.067). Although most SCA patients had normal VA, a higher percentage of males had mild (86%) and moderate (67%) VI compared to females (14% and 33%) respectively (Fisher's Exact Test =5.572). The results indicated that males exhibit a higher susceptibility to VI in both eyes compared to females (Table 7). There was also insignificant association (p=1.00) between males and females in terms of color vision in the SCA patients. Only one (100%) male sickle cell patient was normal; all the rest (males and females) had blue-green defect (Table 8).

Table 7: Relationship between Gender and Visual Impairment in Sickle Cell Anemic Patients

			Visual Impairment (VI)			
			Normal VA	Mild VI	Moderate VI	P value
Right Eye	**Gender**	**Male**	10 (47.6%)	3 (50%)	2 (66.7%)	1.00
		Female	11 (52.4%)	3 (50%)	1 (33.3%)	
Left Eye	**Gender**	**Male**	7 (35%)	6 (85.7%)	2 (66.7%)	0.067
		Female	13 (65%)	1 (14.3%)	1 (33.3%)	

Right Eye: Chi-Square Test (Fisher's Exact Test (0.547). Left Eye: Chi-Square Test (Fisher's Exact Test (5.572). Male n= 15; Female n=15. *Indicates statistical significance and its absence indicates insignificance. P < 0.05.

Table 8: Relationship between Gender and Color Vision in Sickle Cell Anemic Patients

		Color Vision		
		Normal Color Vision	Blue-Green Defect	P value
Gender	**Male**	1 (100%)	14 (48.3%)	1.00
	Female	0 (0%)	15 (51.7%)	

Chi-Square Test (Fisher's Exact Test. Male n= 15; Female n=15. *Indicates statistical significance and its absence indicates insignificance. P < 0.05.

Only ESR was significantly (p=0.001) different between males and females in the control group when their VA, ESR, and PCV were compared. Females had significantly higher ESR (8.29 mm/Hr) compared to males (4.88 mm/Hr) (Table 9). In the SCA patients also, a similar analysis of VA, ESR, and PCV between males and females showed significant differences. Specifically, in the left eye, VA (p=0.03) and ESR (p=0.001) differed significantly between the sexes. Females had significantly higher ESR (4.60 mm/Hr) compared to males (2.85 mm/Hr) (Table 9).

Table 9: Comparing the Visual Acuity, Erythrocyte sedimentation rate, and Packed cell volume between Males and Females in the Control and Sickle cell Anemic Groups.

Variable	Male (Mean ± SEM)	Female (Mean ± SEM)	Z-value	P-Value
Control				
Visual acuity of right eye	6.00±0.001	6.00±0.001	0.001	1.00
Visual acuity of left eye	6.00±0.001	6.00±0.001	0.001	1.00
Erythrocyte sedimentation rate	4.88±0.077	8.29±0.112	-4.639	0.001**
Packed cell volume	38.65±0.242	38.62±0.331	-0.131	0.896
Sickle Cell Anemic Patient				
Visual acuity of right eye	7.40±0.576	7.00±0.478	-0.46	0.64
Visual acuity of left eye	8.00±0.561	6.60±0.434	-2.15	0.03*
Erythrocyte sedimentation rate	2.853±0.031	4.60±0.093	-4.71	0.001**
Packed cell volume	24.00±0.293	24.27±0.284	-0.64	0.52

Mann-Whitney U Test. **Control**: Male n=17, Female n=13. **Sickle Cell Anemic patients**: Male n=15, Female n=15. * Indicates statistical significance and its absence indicates insignificance. SEM= standard error of the mean. P < 0.05.

When comparing the VA, ESR, and PCV of the control group with those of the SCA patients, significant differences were observed in all variables. Specifically, both the ESR and PCV values of SCA patients were significantly lower (ESR=3.73 mm/Hr, PCV=24.13%) compared to those of the control group (ESR=6.36 mm/Hr, PCV=38.63%) (Table 10).

Table 10: Comparing the Visual Acuity, ESR, and PCV Between Controls and Sickle Cell Anemic Patients.

Variable	Control (Mean ± SEM)	SCA Patient (Mean ± SEM)	Z-value	P-Value
Visual acuity of right eye	6.00±0.001	7.20±0.370	-3.217	0.001**
Visual acuity of left eye	6.00±0.001	7.30±0.372	-3.423	0.001**
Erythrocyte sedimentation rate	6.36±0.321	3.73±0.169	-5.506	0.001**
Packed cell volume	38.63±0.195	24.13±0.202	-6.714	0.001**

Mann-Whitney U Test. Controls n=30, SCA Patients n=30. * Indicates statistical significance and its absence indicates insignificance. SEM= standard error of the mean. $P < 0.05$.

CONCLUSION

In conclusion, the study discovered that the majority of participants were 12 years old, falling within an age range of 8 to 14 years. The children demonstrated limited awareness of the significance of VA, CV, and ESR tests, with many never having undergone these tests. However, the PCV test was common. Individuals with SCA reported higher levels of visual difficulties, and a significant association was observed between SCA and VI. All control participants exhibited normal VA, near vision, CV, PCV, and ESR. Conversely, one-third of SCA patients had mild to moderate VI in both eyes, but all SCA patients had normal near vision. Almost all SCA patients (except one) had Blue-Green color defects. A significant association was found between SCA and abnormal PCV and ESR, indicating a link with the disease. Abnormally lower PCV and ESR values were observed in all SCA patients compared to the controls. The normal gender differences in ESR were consistent among all participants, with females having higher ESR values than males. While no significant associations were noted between gender and VI in both eyes, males were found to be more susceptible to severe VI in both eyes compared to females. The study underscores the importance of regular eye examinations for SCA patients to prevent vision loss.

REFERENCES

Abdalla-Elsayed, M. E., Mura, M., Al Dhibi, H., Schellini, S., Malik, R., Kozak, I., & Schatz, P. (2019). Sickle cell retinopathy. A focused review. *Graefe's Archive for Clinical and Experimental Ophthalmology*, 257: 1353-1364.

Afolabi OF, Esomonu NE. (2020). Sickle cell disease: an assesment of awareness, knowledge and perception among parents of children attending a suburban health facility in North central Nigeria. *Niger Delta Medical Journal,* 4(4): 27-37.

Akinbami, A., Dosunmu, A., Adediran, A., Oshinaike, O., Phillip, A., Vincent, O., ... & Oluwaseun, A. (2012). Steady state hemoglobin concentration and packed cell volume in homozygous sickle cell disease patients in Lagos, Nigeria. *Caspian journal of internal medicine*, *3*(2): 405.

Al-Naim, A. F., Al-Mulla, A. H., Al-Shikmubarak, I. A., Al-Mulhim, K. S., & Al-Dossary, S. K. (2017). Vision Quality Assessment in Patients with Sickle Cell Disease Versus Normal Population in Al-Ahsa, Saudi Arabia. *International Journal of Scientific Study*, *5*(8): 155-158.

AlRyalat, S. A., Nawaiseh, M., Aladwan, B., Roto, A., Alessa, Z., & Al-Omar, A. (2020). Ocular manifestations of sickle cell disease: signs, symptoms and complications. *Ophthalmic epidemiology*, *27*(4): 259-264.

Buchanan, G., Vichinsky, E., Krishnamurti, L., & Shenoy, S. (2010). Severe sickle cell disease—pathophysiology and therapy. Biology of Blood and Marrow Transplantation, 16(1), S64-S67.

Bull, B. S., & Hay, K. L. (2001). Is the packed cell volume (PCV) reliable?. *Laboratory Hematology*, *7*, 191-196.

Costa, F. F., & Fertrin, K. Y. (2016). Clinical manifestations and treatment of adult sickle cell disease. *Sickle cell anemia: From basic science to clinical practice*, 285-318.

El-Ghamrawy, M. K., El Behairy, H. F., El Menshawy, A., Awad, S. A., Ismail, A., & Gabal, M. S. (2014). Ocular manifestations in Egyptian children and young adults with sickle cell disease. *Indian Journal of Hematology and Blood Transfusion*, 30: 275-280.

Eruchalu, U. V., Pam, V. A., & Akuse, R. M. (2006). Ocular findings in children with severe clinical symptoms of homozygous sickle cell anaemia in Kaduna, Nigeria. *West African Journal of Medicine*, *25*(2): 88-92.

Fadugbagbe, A. O., Gurgel, R. Q., Mendonça, C. Q., Cipolotti, R., Dos Santos, A. M., & Cuevas, L. E. (2010). Ocular manifestations of sickle cell disease. *Annals of tropical paediatrics*, *30*(1), 19-26.

George, I. O., & Cookey, S. A. H. (2012). Eye manifestations of children with homozygous sickle cell disease in Nigeria. *J Med Med Sci*, *3*(5): 302-305.

Ishihara, S. (1990). Ishihara's tests for color-blindness, 38 plate ed. *Tokyo/Kyoto, Japan: Kanehara, Shuppan*, *1*.

Jou, J. M. (2012). Erythrocyte sedimentation rate (ESR). *Laboratory Hematology Practice*, 638-646.

Manara, R., Dalla Torre, A., Lucchetta, M., Ermani, M., Favaro, A., Baracchini, C., ... & Colombatti, R. (2021). Visual cortex changes in children with sickle cell disease and normal visual acuity: a multimodal magnetic resonance imaging study. *British Journal of Haematology*, *192*(1): 151-157.

Mohammed, H. I., Agabeldoor, A. A., Khalid, K. E., & Ali, K. E. (2006). Clinical and haematological Findings in Sudanese patients With sickle cell disease Attending the hospitals in Elobeid, Kordofan. *Gezira Journal of Health Sciences*, *2*(1).

Oladimeji, O. I., Adeodu, O. O., Onakpoya, O. H., & Adegoke, S. A. (2021). Prevalence of ocular abnormalities in relation to sickle cell disease severity among children in South-western, Nigeria. *European Journal of Ophthalmology*, *31*(5): 2659-2665.

Olatunya, O. S., Babatola, A. O., Ogundare, E. O., Olofinbiyi, B. A., Lawal, O. A., Awoleke, J. O., ... & Olaleye, A. O. (2020). Perceptions and practice of early diagnosis of sickle cell disease by parents and physicians in a southwestern state of Nigeria. *The Scientific World Journal*, *2020*.

Oluleye, T. S., Brown, B. J., & Olawoye, O. (2017). Ocular manifestations of children with sickle cell disease in Ibadan, Nigeria. *East African Medical Journal*, *94*(10): 812-819.

Oluleye, T. S., Babalola, Y. O., Majekodunmi, O. I., & Ijaduola, M. A. (2021). Sickle cell retinopathy: Patient awareness, mode of presentation, and treatment modalities in Ibadan, South-West Nigeria. *Nigerian Journal of Medicine*, *30*(5), 481-486.

Osafo-Kwaako, A., Kimani, K., llako, D., Akafo, S., Ekem, I., Rodhgues, O., ... & Nentwich, M. M. (2011). Ocular manifestations of sickle cell disease at the Korlebu Hospital, Accra, Ghana. *European Journal Of Ophthalmology*, *21*(4): 484-489.

Roy, M. S., Rodgers, G., Gunkel, R., Noguchi, C., & Schechter, A. (1987). Color vision defects in sickle cell anemia. *Archives of Ophthalmology*, *105*(12): 1676-1678.

Sahu, M., Biswas, A. K., & Uma, K. (2015). Detection of Sickle cell anemia in red blood cell. *International Journal of Engineering and Applied Sciences (IJEAS)*, *2*(3), 45-48.

Schmid-Schönbein, H. (1981). Blood rheology and oxygen transport to tissues. In *Oxygen Transport to Tissue* (pp. 279-289). Pergamon.

Scott, A. W. (2016). Ophthalmic manifestations of sickle cell disease. *South Med J*, 109(9): 542-8.

Snellen, H. (1862). *Letter tests, to determine the tightened sharpness* (Vol. 1). (1). J. J. - Greven.

Sundd, P., Gladwin, M. T., & Novelli, E. M. (2019). Pathophysiology of sickle cell disease. *Annual review of pathology: mechanisms of disease*, 14: 263-292.

Uche, E., Olowoselu, O., Augustine, B., Ismail, A., Akinbami, A., Dosunmu, A., & Balogun, A. (2017). An assessment of knowledge, awareness, and attitude of undergraduates toward sickle cell disease in Lagos, Nigeria. *Nigerian Medical Journal: Journal of the Nigeria Medical Association*, *58*(6): 167.