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Distribution of hemoglobinopathy phenotypes in western Kenya: a retrospective study done at Aga Khan Hospital, Kisumu

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Abstract

Background: Hemoglobinopathies are inheritable disorders of hemoglobin and are the most common genetic defects in humans. This is a neglected public health problem whose undiagnosis remain a major threat to its prevention and control in sub-Saharan Africa countries; thus its exact magnitude on morbidity and mortality remains poorly documented. These hemoglobin disorders have been associated with *Plasmodium falciparum*; therefore, the current study sought to determine its distribution in a malaria-holoendemic region of Western Kenya as part of remedial intervention recommended by World Health Organization (WHO).

Method: This study analyzed data conveniently selected through census from 2015 to 2020 from hematology laboratory database for patients examined in Aga Khan, Hospital, Kisumu, and its satellites in Western Kenya. A total of 247 cases were selected whose sample size was calculated using Cochran's formula. Distribution of hemoglobinopathies based on stations, gender, and age was expressed in frequencies, proportions, bar graphs, and pie charts.

Results: The distribution of hemoglobinopathies had varying proportions in different locations in Western Kenya with regions that were at proximity to Lake Victoria (Kisumu 41.3%, $n=102$; Busia 21.5%, $n=53$; Homabay 15.4%, $n=38$) recording a higher overall hemoglobinopathy proportions than those that were far from the lake that include Bungoma 5.7%, $n=14$; Kakamega 4.0%, $n=10$; Kitale 4.0%, $n=10$; Kisii 4.0%, $n=10$, and Migori 4.0% $n=10$.

Conclusion: The study represents the burden of hemoglobinopathies in a malaria-holoendemic region of Western Kenya, and even though the present study did not include ethnicity in data collection, stations from where the data was collected are predominated by different communities; therefore, there may be an ethnic correlation in the variation of hemoglobinopathies in Western Kenya. The communities juxtaposed to the lake seems to be the most affected ethnic group along the Lake Victoria economic block region; thus, it may be erroneous to assume that the entire malaria-holoendemic region of Western Kenya has high prevalence of hemoglobin disorders without factoring ethnicity and geographical location in a properly conducted population-based prevalence study in the wider Western Kenya.

Keywords: Hemoglobinopathies, Western Kenya, Aga Khan Hospital, Kisumu, Distribution

Introduction

Hemoglobinopathies are hereditary genetic disorders of hemoglobin that are acquired as recessive and pose a major public health risk in the future if proper programs for prevention and management are not established [1]. Studies have shown that these disorders are common in many parts of the world seen in infancy and childhood

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where children with sickle cell disease (SCD) who live in sub-Saharan Africa have a high mortality rate estimated at 50–80% by 5 years old [2]. A recent study done in Kilifi area of Kenya documented 50–90% mortality of sickle cell disease children who had not enrolled in clinic for management [3, 4]. It confers significant morbidity and mortality among the victims, and its epidemiological profile demonstrates an ethnic and regional diversity of genetic polymorphism among the hemoglobin variants, suggesting the need to consider ethnicity and geographical location of populations in related research and interventions [1]. Due to the recessive nature of hemoglobinopathy inheritance, researchers have recommended screening of carriers in potentially susceptible populations since have a probability of 1 in 4 chance of transmitting a severe form of gene to the offspring [1, 5, 6]. These carriers progress asymptomatically with mixed clinical presentations and normal full hemogram results, e.g., sickle cell trait (SCT) which is clinically asymptomatic reportedly display a normal peripheral blood smear (PBS) and complete blood count (CBC, 6). Although the condition poses no immediate medical threat, identification of these disorders is immensely important during armed force recruitment and screening of families with history of hemoglobinopathies for genetic counseling and for patient management [7].

Phenotypically, hemoglobinopathies fall into two main groups: the thalassemia (α- and β-thalassemia) characterized by production of inadequate quantities of hemoglobin (Hb) protein molecules, accompanied with microcytic erythrocytes that are hemolyzed causing anemia [2]. The other group is the non-thalassaemia hemoglobinopathies, characterized by the production of structurally and functionally abnormal hemoglobin protein molecules that is incompetent to transport oxygen effectively, thus resulting into erythrocyte destruction by reticuloendothelial system leading into anemia and hypoxia [8]. Studies show that hemoglobinopathies are slowly, consistently, and unnoticeably creeping in the society; thus, the World Health Organization (WHO) recommended to governments and international agencies to develop strategies for accurate morbidity and mortality documentation to be able to combat these disorders before overwhelming the healthcare systems [9].

Kenya has a significant burden of hemoglobin disorders that has been reported in malaria-holoendemic regions that includes Western Kenya and coastal regions indicating urgent need for a cost-effective method to enable proper and early diagnosis [10]. Previous studies indicate that the Aga Khan Hospital, Kisumu, and its Western Kenya satellite centers, is located within the Lake Victoria economic block region which is known to have high burden of *Plasmodium falciparum* which has been linked to hemoglobinopathies, especially sickle cell hemoglobinopathy [8, 11, 12]. Sickle cell trait (Hb AS) is more protective to all forms of malaria and is the most prevalent hemoglobinopathy in sub-Saharan African countries [13]. On inheriting two mutated genes of S/S, S/C or S/E results into sickle cell disease whose hemoglobin polymerizes in low oxygen, making cells become deformed and attain sickle form shapes thus lacking integrity in oxygen delivery [2, 14]. Suchdev et al. determined the burden and the consequences of inherited blood disorders among young children selected randomly from 60 villages in Western Kenya [11]. The study revealed that more than 2 out of 3 children had at least one blood disorder where sickle cell trait (Hb AS) and sickle cell disease (Hb SS) were found in 17.1% and 1.6% of children respectively; 38.5% were heterozygotes and 9.6% were homozygotes for alpha thalassemia. Despite these reported high prevalence of hemoglobinopathies, premarital screening of hemoglobin disorders legislation has never been developed in Kenya, which has been described by researchers as a potential threat of passing major hemoglobinopathy genes to offsprings, thus making prevention and control difficult [15]. Taken together, these findings presuppose that there could be many other hemoglobin disorders of which existence in the population remains undocumented. There is need, therefore, to evaluate the current distribution of hemoglobinopathies in Western Kenya, and consequently, a simple model to unmask cases needs to be established. To this end, the WHO has recommended population and newborn screening for hemoglobin disorders as a key part of countries' health services. However, many sub-Saharan Africa countries including Kenya have not implemented these screening due to high financial cost of existing high-quality laboratory methods for hemoglobinopathy detection [4, 8]. It is therefore predicted that by the year 2050, over 14 million children will be born with major hemoglobin disorders in these resource-poor settings if proper measures are not developed to combat these diseases [16]. Therefore, the present study was done to bring the current distribution of hemoglobinopathies into light in malaria-holoendemic region of Western Kenya as part of regional remedial intervention recommended by researchers and the WHO.

Methods

The study comprised of 247 cases who were selected conveniently through census from high-performance liquid chromatography (HPLC)-confirmed hemoglobinopathy cases obtained in the past 5 years from January 2015 to December 2020 in Aga Khan Hospital, Kisumu, and its Western Kenya satellite centers' hematology laboratory database.

Ethical consideration

The study approvals were obtained from the Masinde Muliro University Ethical Review Committee (registration number: MMU/COR:403012 vol 3(03)), National Commission of Science and Technology (NACOSTI) (applicant identification number: 407653), and Aga Khan Hospital, Kisumu Research Review Board (registration number ADM/007/089), who permitted the data collection. To maintain patient anonymity, data was stored in stringently restricted rooms, and soft copies were coded in password-protected computers.

Sample size determination

Sample size was calculated using Cochran's formula, assuming proportions of 19% for α-thalassemia, and the sickle cell study was done among children enrolled in a malaria vaccine clinical trial at Kombewa in Lake Victoria basin, Western Kenya, which was our (p). Thus, at 95% confidence level and a precision level of 5%, a minimum sample size of 237 was therefore obtained.

Data collection

Data were obtained from the laboratory database on patients examined at the hospital's hematology laboratory for the past 5 years from January 2015 to December 2020. The cases were individuals who were confirmed for various hemoglobinopathies using HPLC (Bio-Rad D10), machine manufactured by Bio-Rad Laboratories, Hercules, CA, USA. Therefore, 247 cases were obtained as our study subjects.

Data analysis

M-S Excel was used to prepare a database from where the data were exported to the Statistical Package for Social Sciences (SPSS version 23) for analysis. Data was then analyzed and summarized as percentages and proportions within groups. The hemoglobinopathy profiles were also described by use of proportions and frequencies as the summary statistics for prevalence or distribution of cases in the various population groups based on demographic characteristics, where the Aga Khan Hospital, Kisumu, and its satellite centers were in Western Kenya. The distribution of hemoglobinopathies based on stations, gender, and age was also expressed in frequencies, proportions, bar graphs, and pie charts.

Results

Proportion of hemoglobinopathy profiles among the studied sample from Aga Khan Hospital, Kisumu

Among the total sample of 247 hemoglobinopathy cases, 7 hemoglobinopathy phenotypes were detected. Detailed profile of these hemoglobinopathy phenotypes included the following: homozygous sickle cell disease (SCD) 18.2%, $n = 45$; sickle cell disease Hb with fetal Hb (SCD+HbF), 8.1%, $n = 20$; and sickle cell disease Hb with β-thalassemia (SCD+β-Thal), 25.1%, $n = 62$. On the other hand, 41.7% ($n = 103$) of the individuals had sickle cell trait (SCT) hemoglobin (HbAS) and in combination with β-thalassemia (SCT+β thalassemia) had proportions of 2.4% ($n = 6$), while sickle cell trait (Hb AS) with fetal Hb (SCT+HbF) had the lowest proportions of 0.8% ($n = 2$). The homozygous β-thalassemia was similarly low with proportions of 3.6% ($n = 9$). These results are summarized in Table 1 and as shown on the bar graph in Fig. 1.

Proportions of hemoglobinopathy phenotypes in selected stations in Western Kenya

The regions that were juxtaposed at the lake including Kisumu, Busia, and Homabay regions had the highest proportions of hemoglobinopathies of 41.3% ($n = 102$), 21.5% ($n = 53$), and 15.4% ($n = 38$) respectively. Western Kenya regions at a far proximity to the lake are usually dominated by Bantu-speaking communities which includes Bungoma that had low proportions of 5.7% ($n = 14$), while Kitale, Kakamega, Kisii, and Migori regions recorded similar low proportions of 4% ($n = 10$) each as shown in Table 1 and on the bar graph in Fig. 2.

Busia station that represents Busia region in western Kenya had SCT proportions of 10.9% ($n = 27$), homozygous SCD 2.8% ($n = 7$), and heterozygote of SCD which includes SCD+β-thalassemia 4.5% ($n = 11$) and SCD+HbF was 1.6% ($n = 4$), while heterozygotes of SCT (SCT+HbF, SCT+β-thalassemia) had low proportions of less than 1% each. Beta thalassemia similarly recorded low proportions of 0.4% ($n = 1$). In Bungoma, the heterozygotes of SCD+β-thalassemia had the highest proportions of 2.8% ($n = 7$), followed by SCT of 2.0% ($n = 5$), while homozygous SCD and SCD+HbF had proportions of 0.4% ($n = 1$) each. There were no heterozygotes of SCT and beta thalassemia in Bungoma. All the hemoglobinopathies profiles in Kitale had proportions of less than 2% with SCD+β-thalassemia having the highest proportions of 1.2% ($n = 3$), SCD+HbF 1.2% ($n = 3$), while SCD and SCT had proportions of 0.8% ($n = 2$) each. Three hemoglobinopathy profiles were recorded in Kakamega that includes SCD, SCD+HbF, and SCD which had proportions of 1.6% ($n = 4$), 1.2% ($n = 3$), and 1.2% ($n = 3$) respectively.

Kisumu station had the largest share of hemoglobinopathies led by SCD + β-thalassemia with proportions of 12.6% ($n = 31$), followed by SCT with proportions of 12.1% ($n = 30$). Sickle cell disease (SCD) had 10.1% ($n = 25$), and SCD + HbF had 2.8% ($n = 7$) with the

Table 1 Distribution of hemoglobinopathies among patients investigated at Aga Khan Hospital, Kisumu, in Kenya

➢Location		Hemoglobinopathies							Total
		SCD	SCD-HHBF	SCD-beta thalassemia	SCT	SCT-HBF	SCT-beta thalassemia	Beta thalassemia	
	Busia	7 (2.8%)	4(1.6%)	11 (4.5%)	27 (10.9%)	2 (0.8%)	1(0.4%)	1 (0.4%)	53 (21.5%
	Bungoma	1 (0.4%)	1 (0.4%)	7 (2.8%)	5 (2.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	14 (5.7%)
	Kitale	2 (0.8%)	3 (1.2%)	3 (1.2%)	2 (0.8%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	10 (4.0%)
	Kakamega	4 (1.6%)	3 (1.2%)	0 (0.0%)	3 (1.2%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	10 (4%)
	Kisumu	25 (10.1%)	7 (2.8%)	31 (12.6%)	30 (12.1%)	0 (0.0%)	3 (1.2%)	6 (2.4%)	102 (41.3%)
	Kisii	0 (0.0%)	1 (0.4%)	4 (1.6%)	5 (2.0%)	0 (0.0%)	0(0.0%)	0(0.0%)	10 (4.0%0
	Homabay	4 (1.6%)	1 (0.4%)	6 (2.4%)	24 (9.7%)	0 (0.0%)	2 (0.8%)	1 (0.4%)	38 (15.4%)
	Migori	2(0.8%)	0 (0.00%)	0 (0.0%)	7 (2.8%)	0 (0.0%)	0(0.0%)	1 (0.4%)	10 (4.0%)
Gender	Male	20 (8.1%)	5 (2.0%)	28 (11.3%)	48 (19.4%)	1 (0.4%)	5 (2.0%)	5 (2.0%)	112 (45.3%)
	Female	25 (10.1%)	15 (6.1%)	34 (13.8%)	55 (22.3%)	1 (0.4%)	1 (0.4%)	4 (1.6%)	135 (54.7%)
Age (years)	0–5 years	17 (6.9%)	12 (4.9%)	33 (13.4%)	53 (21.5%)	2 (0.8%)	4 (1.6%)	4 (1.6%)	125 (50.6%)
	6–12 years	16 (6.5%)	5 (2.0%)	19 (7.7%)	18 (7.3%)	0 (0.0%)	0 (0.0%)	2 (0.8%)	60 (24.3%)
	> 13 years	12 (4.9%)	3 (1.2%)	10 (4.0%)	32 (13.0%)	0 (0.0%)	2 (0.8%)	3 (1.2%)	62 (25.1%)
Overall hemoglobinopathies		45 (18.2%)	20 (8.1%)	62 (25.1%)	103 (41.7%)	2 (0.8%)	6 (2.4%)	9 (3.6%)	247 (100%)

heterozygote of SCT + β-thalassemia having proportions of 1.2% ($n = 3$). Beta thalassemia had proportions of 2.4% ($n = 6$) which was the highest among the same disorders across the rest of the stations. Kisii region captured only 3 hemoglobinopathies with low proportions of SCT 2% ($n = 5$), SCD + β-thalassemia 1.6% ($n = 4$), and SCD + HbF having proportions of 0.4% ($n = 1$). Homabay showed higher proportions of hemoglobinopathies with SCT having 9.7% ($n = 24$), SCD + β-thalassemia 2.4% ($n = 6$), pure SCD had 1.6% ($n = 4$), and SCD + HbF had proportions of 0.4% ($n = 1$). SCT + β-thalassemia and beta thalassemia had proportions of 0.8% ($n = 2$) and 0.4% ($n = 1$) respectively. Migori reported only 3 hemoglobinopathies that included SCT of 2.8% ($n = 7$), pure SCD of 0.8% ($n = 2$), and β-thalassemia of 0.4% ($n = 1$). These results are summarized in Table 1.

Distribution of hemoglobinopathies proportions based on gender and age

It was important to note that, generally, SCT had the highest proportions of 41.7% ($n = 103$), followed by SCD+β thalassemia with 25.1% ($n = 62$), 18.2% ($n = 45$) SCD, 8.1% ($n = 20$) SCD+HbF, and then the rest were distributed in small fractions of less than 4%. A similar trend was observed in gender and across the age groups and in the three regions that include Kisumu, Busia, and Homabay regions. Females recorded higher proportion of 54.7% ($n = 135$ with SCT having the highest proportion of 22.3% ($n = 55$), followed by SCD+β thalassemia 13.8% ($n = 34$), SCD 10.1% ($n = 25$), SCT+HbF 6.1% ($n = 15$), and the remaining had an overall fraction of about 2% Males showed similar trend of flow with SCT having proportions of 19.4% ($n = 48$), SCD+β thalassemia 11.3% ($n = 28$), SCD 8.1%($n = 20$), SCD+HbF 2% ($n = 5$), and the rest recorded about 5% of the 247 cases listed by the study. These results are summarized in Table 1 and Fig. 3.

Children under the age of 5 years had the highest proportions of 50.6% ($n = 125$), 6–12 years had 24.3% ($n = 60$), and those above 13 years had proportions of 25.1% ($n = 62$). Under the age of 5 years, SCT recorded the highest proportions of 21.5% ($n = 53$), and then 13.4% ($n = 33$) SCD+β thalassemia, 6.9% ($n = 17$) SCD, and 4.9% ($n = 12$) SCD+HbF, with the rest having an overall proportion of 4%. The age set of 6–12 years had 7.7% ($n = 19$) proportions of SCD+β-thalassemia, followed by SCT with 7.3% ($n = 18$), SCD with 6.5% ($n = 16$), SCD+HbF 2.0% ($n = 5$), and then beta thalassemia of 0.8% ($n = 2$). Study subjects > 13 years had 13.0% ($n = 32$) SCT as the highest proportion, followed by SCD 4.9% ($n = 12$), SCD+β-thalassemia 4.0% ($n = 10$), SCD+HbF 1.2% ($n = 3$), and finally beta thalassemia of 1.2% ($n = 3$). These results are summarized on Table 1 and Fig. 4.

Discussion

Several previous studies have been conducted in different regions of Western Kenya; however, this is the first ever study to determine the difference on proportions of hemoglobinopathies in the wider Western Kenya and thus may serve as a potential pilot study on the distribution of hemoglobinopathies based on geographical location, thus featuring the role ethnicity in

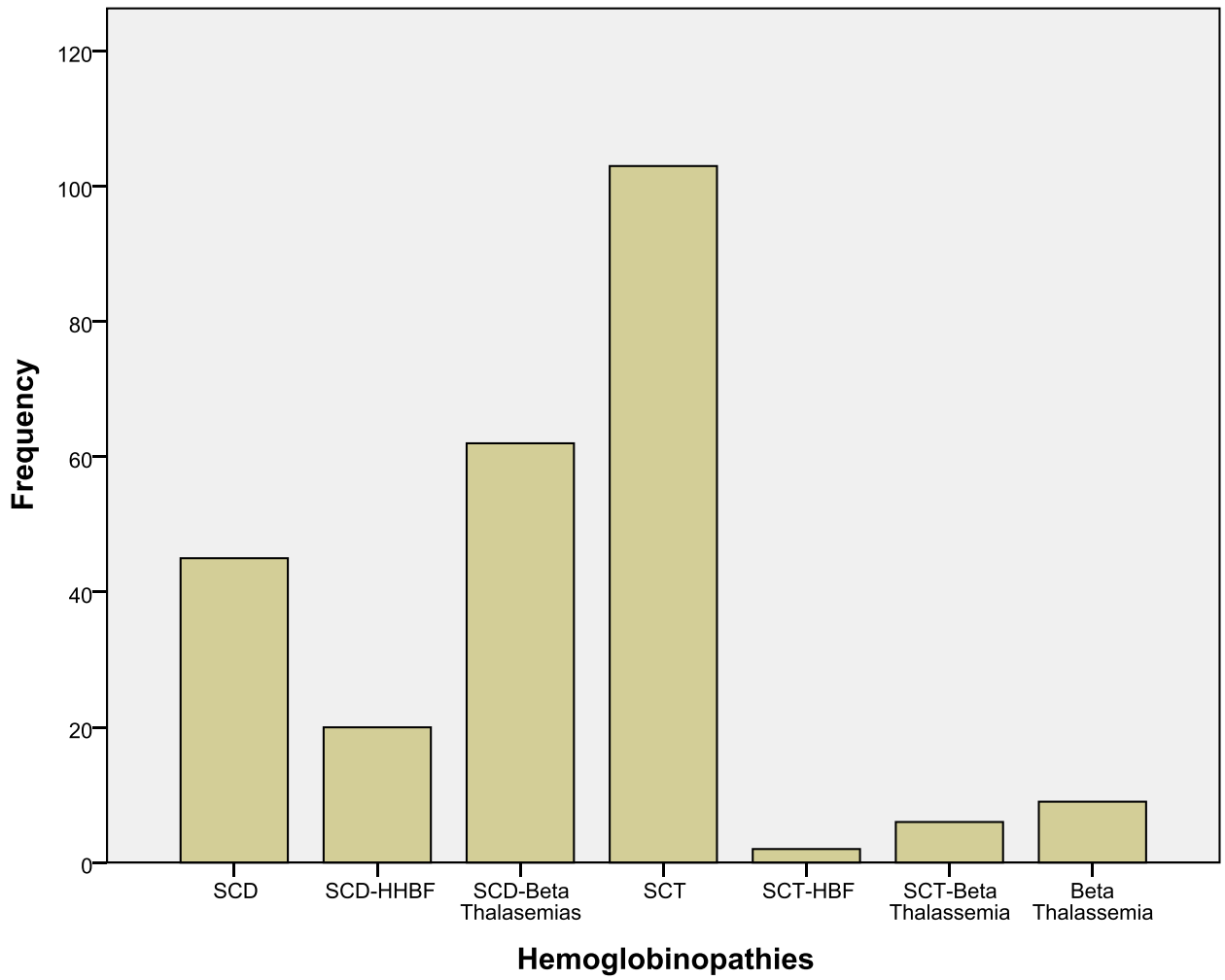

Fig. 1 Distribution of hemoglobinopathies among patients investigated at Aga Khan Hospital, Kisumu, and its satellite centers in Western Kenya

hemoglobinopathy distribution in Western Kenya as reported by previous findings [1]. Even though the present study did not include ethnicity in data collection, stations from where the data was collected are predominated by different communities which may imply a significant role of ethnicity in the variation of hemoglobinopathies in western Kenya.

Kisumu station had the largest share of hemoglobinopathies led by SCD + β-thalassemia with a high proportion of 12.6% ($n = 31$), followed by SCT with 12.1% ($n = 30$). Sickle cell disease (SCD) had 10.1% ($n = 25$), and SCD + HbF had 2.8% ($n = 7$) with the heterozygote of SCT + β-thalassemia having proportion of 1.2% ($n = 3$). Beta thalassemia had a proportion of 2.4% ($n = 6$) which was the highest among the same disorders across the rest of the stations. These results were similar to a study done in Jaramogi Odinga referral hospital in Kisumu recording a high prevalence of sickle cell hemoglobinopathy in Kisumu, with SCT having 23.5%, ($n = 31$), while SCD had 8.3% ($n = 11$) among subjects who had tested negative for malaria. Among those who tested positive for malaria, 16.5% % ($n = 14$) were SCT and 15.3% ($n = 13$) [10]. These findings validate the high proportions of hemoglobinopathies in Kisumu town more than any other Western Kenya region that were selected in the present study.

Busia region is predominated by three major tribes that include Luyha, Luo, and Teso communities [17], but the increasing proportions of hemoglobin disorders could not be attributed to any specific ethnic group. The literature reviewed shows that no similar prevalence study on hemoglobinopathies has ever been conducted in Busia despite the present study demonstrating an increasing public health burden. This is in tandem with previous findings that undiagnosed hemoglobinopathies especially HbS remains a major threat to healthcare system since

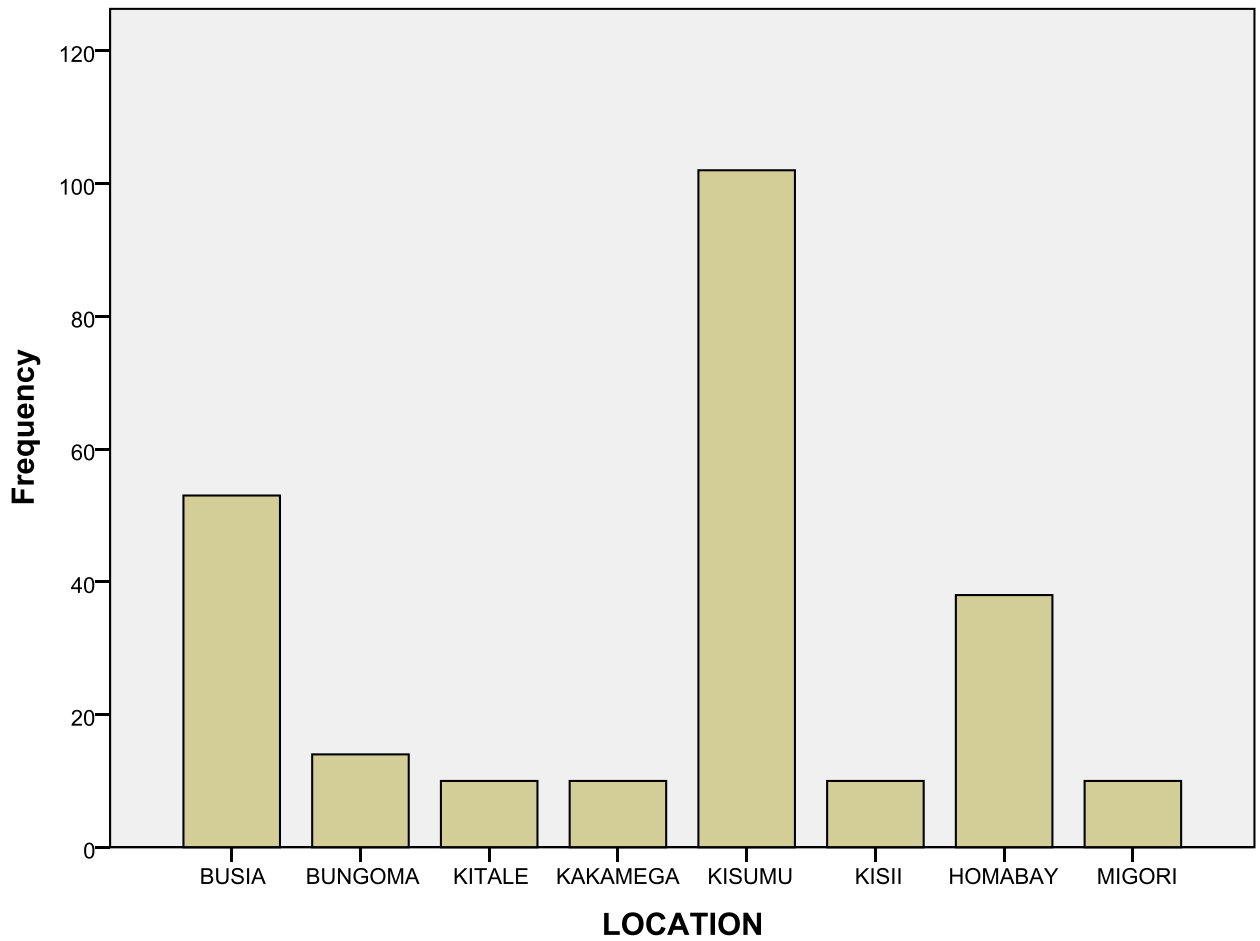

Fig. 2 Distribution of hemoglobinopathies among patients investigated at Aga Khan Hospital, Kisumu, and its satellite centers in Western Kenya

its unnoticeably creeping in societies when governments and international agencies focus more on other diseases [18]. This calls for a population-based study that would provide an exact magnitude of this problem in Busia region. Another study done to determine the trends of sickle cell trait in the neighboring country Uganda, which share ethnicity and geographical location with Busia, documented similar findings with an overall prevalence of sickle cell trait and disease identified in the 5-year screening period of 14.7% and 2.8%, respectively, which confirms the widespread sickle cell hemoglobinopathy in African regions [19]. This serves as a wake-up call for governments to initiate collaborative measures to combat these disorders before they reach the estimated proportion of over 14 million newborns each year by the year 2050, where 82% is expected to come from sub-Saharan African countries [8].

Homabay showed a higher proportion of hemoglobinopathies with SCT having 9.7% ($n=24$), SCD + β-thalassemia 2.4% ($n=6$), pure SCD had 1.6% ($n=4$), and SCD + HbF had proportions of 0.4% ($n=1$). SCT + β-thalassemia and beta thalassemia had proportions of 0.8% ($n=2$) and 0.4% ($n=1$) respectively. No studies have ever been done on prevalence of hemoglobinopathies in Homabay; however, a cross-sectional study was done on hydroxyurea use and *Plasmodium falciparum* prevalence among children with sickle cell anemia. This indicates a significant burden of hemoglobinopathies, thus attracting scientists to perform related studied in the same region; however, a population-based study would yield an accurate morbidity in the same region [20].

The present study documented a low proportion of hemoglobinopathies in Bungoma, with heterozygote of SCD + β-thalassemia having the highest proportions of 2.8% ($n=7$), followed by SCT of 2.0% ($n=5$), while homozygous SCD and SCD + HbF had a proportion of 0.4% ($n=1$) each. There were no heterozygotes of SCT and beta thalassemia in Bungoma. These results contrasted the findings of a population prevalence study

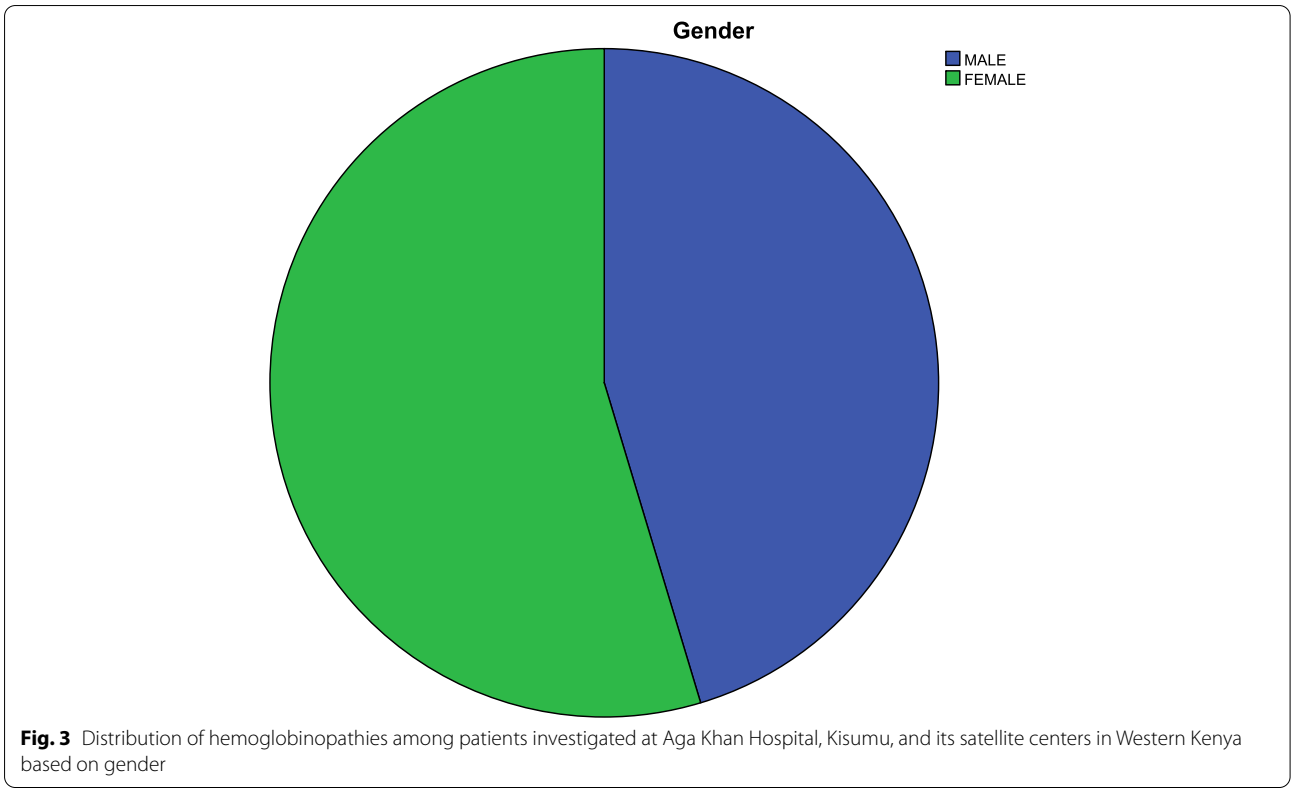

Fig. 3 Distribution of hemoglobinopathies among patients investigated at Aga Khan Hospital, Kisumu, and its satellite centers in Western Kenya based on gender

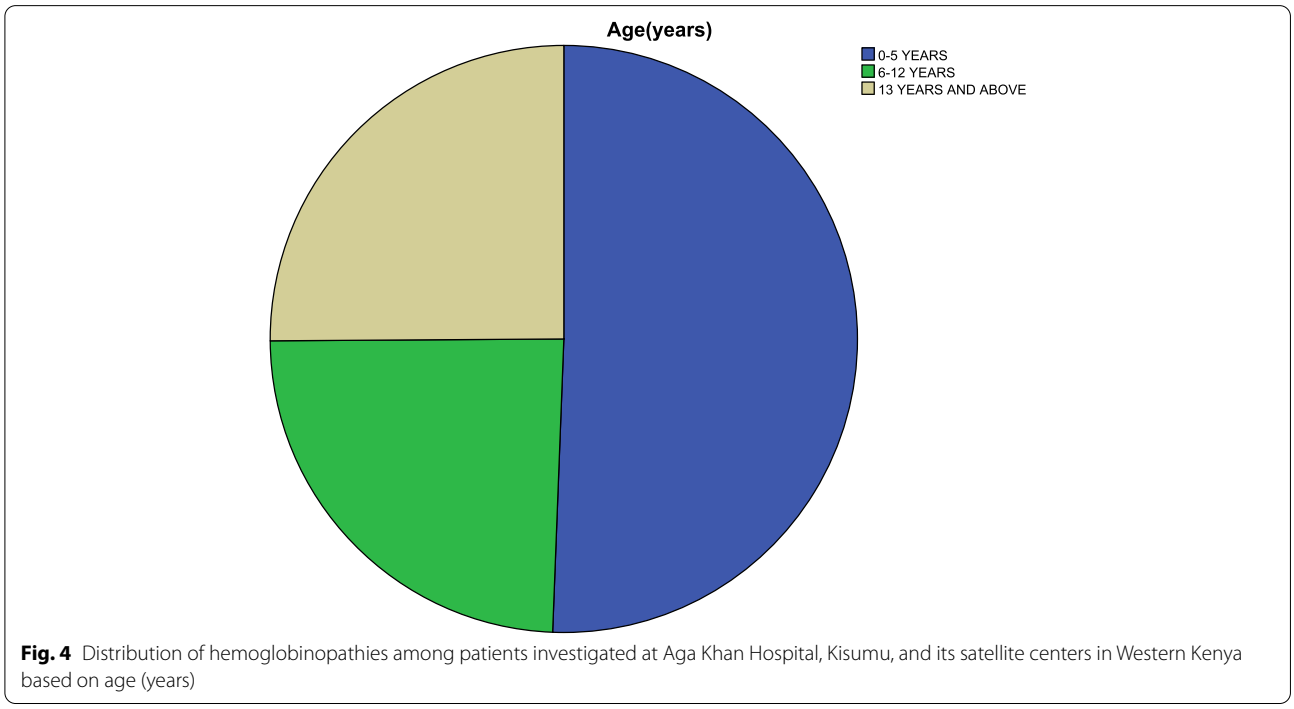

Fig. 4 Distribution of hemoglobinopathies among patients investigated at Aga Khan Hospital, Kisumu, and its satellite centers in Western Kenya based on age (years)

done among adolescents whose median age was 17 years old in Bungoma county that showed SCT prevalence of 18.7% ($n=42$), while the Hb AA was 81.3% ($n=183$), and proportions of males with SCT were 20.7% ($n=24$) and females with SCT was 16.5% ($n=18$). The differences of these findings could be attributed to differences in study designs. Those who tested SCT and were aware of family history of SCD were 50% ($n=6$), and those with no family history were 16.9% ($n=36$) [21]. The study recommended prioritizing health education and screening as the primary intervention to control SCD in Bungoma.

The present study recorded low proportions of hemoglobinopathies in Kitale, Kakamega, Kisii, and Migori stations. The literature reviewed indicate that no prevalence study on hemoglobin disorders has ever been conducted in these regions, making the present study the first ever attempt to determine proportions of hemoglobinopathies within the malaria-holoendemic regions, thus suggesting hemoglobinopathies maybe an ethnically and geographically driven disorder in Western Kenya whose population-based study is needed urgently to give credence to these findings.

In general, the present study recorded SCT having the highest proportion of 41.7% ($n = 103$), a signal that there may be increased burden of severe forms of sickle cell in the future as suggested by previous studies that carriers have 25% probability of passing major genes to offspring, making it difficult to prevent the disease [1]. A similar finding done in Western Kenya found overall HbS hemoglobinopathy prevalence of 18.7% for HbS (HbAS 17.1% and HbSS 1.6%) and 48.1% for α-thalassaemia (homozygous, 9.6% and heterozygous, 38.5%) [11]. Around the same time, a population survey of hemoglobinopathy was done among children in Kombewa, Western Kenya, which reported an overall HbS prevalence of 19.9% (HbAS, 19.0% and HbSS, 0.9%) and 53.2% for α-thalassaemia (homozygous, 8.8% and heterozygous, 44.4%) [12]. Another population Kenya survey of children, conducted in Kilifi County, reported prevalence of 8.6% for HbS (HbAS homozygous, 0.8% and HbAS heterozygous,7.8%) plus 65.5% for α-thalassaemia (homozygous, 16.9% and heterozygous,48.6%) [3]. The study reported, further, a prevalence of 14.2% for HbSS+α-thalassaemia homozygous and 40.2% for HbSS+ α-thalassaemia heterozygous. Similarly, a hospital-based survey of children with acute *P. falciparum* recorded a high HbS prevalence of 31.8% (HbSS, 11.1% and HbAS, 20.7%) signifying a future overwhelming burden of hemoglobinopathies in Western Kenya region [10].

With these reports that Western Kenya in general remains a malaria-holoendemic region which is linked to hemoglobinopathies [10], it was interesting to note that regions that are pre-dominated by Bantu-speaking communities that include Bungoma, Kitale, Kakamega, Kisii, and Migori recorded low proportion of hemoglobinopathies compared to Kisumu, Busia, and Homabay regions within Western Kenya. It is generally known that Western Kenya is a Luyha traditional homeland that include Kakamega, Bungoma, Kitale, Vihiga, and Busia regions as documented by Kenyan ethnic geography reports based on the old provinces [17, 22]. The authors document that Nyanza province is dominated by Luo ethnic group that include Siaya, Kisumu, Homabay, Kisii, Nyamira, and Migori regions. However, Kisii and Kuria ethnic groups dominate in Kisii, Nyamira, and Migori regions within the old Nyanza province. In regard to the present study, communities juxtaposed to Lake Victoria seems to be majorly affected by hemoglobinopathies which could be featuring the role of genetic variation among populations groups, especially ethnicity, which goes roughly with the location/satellite where specimens were collected. These findings were in tandem with previous studies on the need to consider ethnicity and geographical location of populations in related research and interventions because of ethnic and regional diversity of the hemoglobin variant gene polymorphism [1].

Limitation

The study was not able to obtain the family history of hemoglobinopathies from the study participants; thus, consanguineous marriages and specific ethnic group prevalence of hemoglobinopathies could not be ascertained.

Conclusion

The study represents the burden of hemoglobinopathies in a malaria-holoendemic region of Western Kenya, and even though the present study did not include ethnicity in data collection, stations from where the data was collected are predominated by different communities; therefore, there may be an ethnic correlation in the variation of hemoglobinopathies in Western Kenya. The communities juxtaposed to the lake seems to be the most affected ethnic group along the Lake Victoria economic block region; thus, it may be erroneous to assume that the entire malaria-holoendemic region of Western Kenya has high prevalence of hemoglobin disorders without factoring ethnicity and geographical location in a properly conducted population-based prevalence study in the wider Western Kenya.

Abbreviations

WHO: World Health Organization; SCD: Sickle cell disease; SCT: Sickle cell trait; PBS: Peripheral blood smear; CBC: Complete blood count; Hb: Hemoglobin; Hb SS: Hemoglobin SS; Hb AS: Hemoglobin AS; Hb F: Hemoglobin F; HPLC:

High-performance liquid chromatography; NACOSTI: National Commission of Science and Technology.

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Authors' contributions
BM Conceptualized the study and wrote the original manuscript. GS Conceptualized the study and reviewed and corrected the manuscript. PO Supervised and reviewed the manuscript. All authors have read and approved the manuscript.

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Availability of data and materials
If data will be needed, it will be made available upon request from the corresponding author.

Declarations

Ethics approval and consent to participate
The study was approved by Masinde Muliro University Ethics Review Committee and by National Commission of Science and Technology (NACOSTI). Permit to collect data was also granted by the Aga Khan Hospital, Kisumu Ethics and Research Review Board.

Consent for publication
Not applicable

Competing interests
The authors declare that they have no competing interests.

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