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Epidemiology of sickle cell disease in Iraq (2010–2015): Incidence, age-standardized rates, and emerging nanotechnology-based diagnostic perspectives

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Public health care concerns patients with sickle cell anemia, which has been classified under the International Classification of Diseases (ICD-10) as sickle cell disorders (D57). This group requires special care due to the extent of patient suffering and the likelihood of survival, as well as protection from all types of environmental and biological contamination they may be exposed to as a result of blood transfusions, which could be life-threatening. Therefore, this group of patients requires high levels of specialized healthcare, including tracking cases and deaths, providing care centres, treating pain, and improving their quality of life. In this study, we address some aspects of healthcare for sickle cell disorders patients in Iraq, related to the registration of disease cases according to (ICD-10). This is achieved by calculating the age-standardized rate (ASR) per 100,000, a rare measure for sickle cell disorders, and calculating the incidence rate between males and females. The other part is calculating the percentage for the period (2010-2015). In addition to conventional epidemiological surveillance, recent advances in nanotechnology offer promising tools for the early diagnosis, monitoring, and management of sickle cell disease (SCD). Nanotechnology-based biosensors, nanoparticle-assisted hemoglobin detection, and nano-enabled imaging platforms have demonstrated high sensitivity in detecting hemoglobin variants and cellular deformability associated with SCD. Integrating population-level epidemiological data with emerging nanotechnological approaches may enhance early detection strategies, improve disease monitoring, and support targeted interventions in high-burden regions such as Iraq.

Keywords: Public health; Sickle cell disorders; Healthcare.

1. INTRODUCTION

About 100 thousand people in the United States have sickle cell disease (SCD), a rare genetic blood illness caused by a mutation in the hemoglobin gene (US) [1-3]. SCD is one of the most common disorders found during newborn screening and affects around 100,000 people in the US. Due to compromised splenic function, sickle cell disease is made up of several hemoglobinopathies with variable phenotypes that carry a risk of excruciating crises and serious infection [4-10]. One of the most frequent and significant side effects of SCD, particularly in young children, is acute chest syndrome (ACS) [11-15]. SCD is an inherited blood condition that primarily affects African and Caribbean populations. The condition is well-known for its painful episodes (also known as vaso-occlusive crisis or sickle crisis) that result in a large number of hospital admissions and readmissions each year. SCD is the most common and fastest increasing hereditary disorder in England, with 12 500 people living with the condition and 240 000 having SCD features [16, 17]. SCD is a hereditary condition characterized by the predominance of hemoglobin S (Hb S) in red blood cells. In Brazil, it is seen as a major public health issue. 1–3 Sickle cell anemia (SCA, Hb SS) is the most frequent form of SCD worldwide [18, 19]. To conclude, patients with SCA exhibit the most severe phenomenon of CT. The heterozygous marriage of Hb S with the other variant Hbs is itself a spectrum of SCD (Hb SC, SS and others) [20, 21]. When thalassemia is associated with (Hb S), various forms of the SCD phenotype are generated which appear in a relative proportion according to an ethnic origin of a population [4, 22]. SCD is the most common genetic haematological disorder in the world and it has an autosomal recessive pattern of inheritance [23]. The variation is present in more than 2% of the population, and its homozygosity occurs in 1.12 per 1000 births; it is thus a challenge for decades to come. Several genotypes can give rise to the phenotype, with homozygous S-haemoglobin (SS) being the most common and accounting for up to 70% of cases [24]. The mutant allele produces a defective hemoglobin subunit which polymerizes under certain conditions causing the patient's red blood cells to take on a sickle shape. Because occlusion of capillaries by sickled RBCs is a well-established phenomenon, patients are potentially vulnerable to episodes of acute ischemia in downstream organs and tissues [25]. These painful episodes, or vaso-occlusive crisis (VOC), are responsible for the repeated episodes of short-term pain lasting from hours to no longer than days. SCD is characterized by chronic hemolysis with resulting anemia, vasculopathy and end organ damage and the predisposition to infection because of functional asplenia [5, 26]. Sickle-cell disease is the first known disorder whose molecular basis is recognized, a change in one particular base (of four possible per supposed nucleotide) within its chromosomal gene encoding the beta-globin subunit (2), a gene whose allele-specific single message product it encodes having been described in western literature for at least possibly as long as close to a century… SCD is an established disorder with multiple clinical features [27]. Homozygous S is the most severe form of sickle-cell disease (SCD) in Jamaica, with an allele frequency of 0.055 and a disorder prevalence of about three per 1000 live births [28]. The trait for sickle cell (Hb AS) is approximately 10% in Jamaicans. The phenotype of the disease is related to age and genotype [29]. Children dactyl sclerosis and splenic sequestration are significant, in under 5 years; during adolescence, strokes and leg ulcers manifest, whereas chronic affected organ prevails among adult males [30]. Clinical presentation is very heterogenous in different genotypes [31]. In a hospital-based study in Jamaica, SCD is the fourth leading cause of hospitalization among children at rural tertiary MIHS [32]. However, it's murky for adults. One of the common chronic diseases in Jamaica is sickle cell disease. It presents with several clinical manifestations that could lead to a large number of hospitalized [33]. Yet, factors predicting prolonged hospital stay and/or death have not yet been established [34]. And some deaths may have been preventable, too. The proportion of all medical admissions to the University Hospital in Jamaica with SC are also investigated for 5 years by inclusion of clinical risk factors and their impact on LOS in hospitals as well as mortality [6,35]. SCD is one of the most common genetic diseases in Brazil, with a higher frequency within the population of Brazilians deriving from Africans. It is due to the mutation in beta globin chain gene resulting in

production of variant abnormal hemoglobin, HbS [36]. VOC is one of the most common complications associated with away from normal Hb, manifested by acute attacks of abdominal, chest and bone pain as well as chronic hemolytic anemia in some cases7 37. After the latter, hospitalization of VOC in particular is needed. Disease tends to develop very differently from one patient ot the other, and this heterogeneity seems associated with genetic and environmental factors, including socioeconomic conditions [38]. While some patients' conditions advance without symptoms, others are more prone to problems, and a small subset has high rates of VOC and requires recurrent hospital stays [39]. According to several studies, greater admission rates are connected with a worse prognosis and increased death [40]. Sickle cell disease causes early death, particularly in Brazil, where more than 60% of deaths from the condition occurred in people under the age of 29 between 1996 and 2000 [41]. According to one North American study, the risk of death among 10 to 19-year-olds with SCD is eight times higher than in the general population of the same age and race [42]. A high number of symptoms is linked to a poor prognosis and early mortality [43]. Patients with SCD who have a lot of unpleasant episodes are more likely to die young [7, 44]. The World Health Organization has classified it as Sickle Cell Disorders and assigned the code D57 to it in Chapter 3 Diseases of the Blood and Blood-Forming Organs and Certain Disorders Involving the Immune System, within Hemolytic Anemias [8, 45].

Beyond traditional clinical and laboratory diagnostics, nanotechnology has emerged as an innovative field with significant potential in sickle cell disease research and care. Nano-scale materials and devices have been developed to detect abnormal hemoglobin polymerization, assess red blood cell deformability, and identify biomarkers of hemolysis and vaso-occlusive crises with enhanced precision. Nanotechnology-based diagnostic platforms may be particularly valuable in resource-limited settings by enabling rapid, low-cost, and point-of-care screening. When combined with national registry data, such technologies could strengthen surveillance systems and support earlier diagnosis, risk stratification, and improved disease management. This study aims to record the incidence of sickle cell disorders in Iraq from 2010 to 2015, divided by sex and age group according to the International Classification of Diseases (Icd-10), as well as the duration of survival for people with this disease in relation to the quality of health care provided.

2. METHODOLOGY

The primary study compared the role and efficiency of national population-based sickle-cell disease registration in Iraq. Iraqi registration is carried out in accordance with ICD-10. The registration system is critical in the control of sickle-cell illnesses through prevention, early detection, and treatment options. Sickle-cell diseases, as defined by WHO in ICD-10, are grouped by gender and age group.

2.1 Study setting

The study is designed as a retrospective data collection to assess the pattern of Sickle-cell disease incidence in Iraq. To carry out the study, various administrative affiliations are filled out and submitted to the Iraqi Ministry of Health and Environment.

2.2 Study sample

The study included 12879 sickle-cell patients from all throughout Iraq. In incidence, data is split by age and gender. In order to estimate the age standardization of the sickle-cell disease registry, the sample is efficiently and readily represented in the underlying study.

2.3 Study tools

To compare sickle-cell disease incidence across distinct populations or time points, a summary measure that incorporates the schedule of age-specific rates in different registries and across time is required. The crude rate does not account for the underlying populations' varied age patterns. As a result, the age-standardized rate is used to enable risk comparisons between registries that are not influenced by age [9].

2.3.1 Incidence rates

Incidence rates are the most commonly used measure of sickle-cell disease occurrence. These statistics calculate the number of newly diagnosed cases in a given population over a certain time period. In most cases, incidence rates are reported per 100,000 individuals per year.
Age-specific incidence (per 100 000 person-years) is generated and examined for 12 sites in Iraq by sex and age to detect any abnormal fluctuations in the expected patterns, such as an unexpected drop in the rate of increase in incidence in older age groups, which may be indicative of under ascertainment within these groups. These curves can also show flaws in the source data used to calculate the amount of the population at risk in different age groups [46, 47].
To calculate the incidence rate, it requires:

- A count of the number of new cases which have occurred in the population during the period under study [12-14]

$$Incidence\ rate\ = \frac{No.of\ new\ cases\ of\ disease}{Person-years\ at\ risk} \times\ 100000 \quad (1)$$

- An estimate of the person-years at risk.

2.3.2 Age standardization

Comparisons of incidence rates among populations with various ages of composition are made easier by age standardization. Application of age-specific rates in the populations of interest to a standard set of weights based on the typical age distribution is the typical method for age standardization in surveillance data. This takes into account the fact that the populations being compared have different age structures and gives a hypothetical rate that would be seen in each population if its age composition are the same as that of the general population. A population's rate would be summarized as an age-standardized rate (ASR) if it had a standard age structure. Age-standardized rates can only be compared between populations when the same age standard is used for all of them. Table 2.2 displays the global data that are standardized to the IARC's 1960 world standard population. In contrast, statistics on cancer incidence and death in the US and several European nations that have been published elsewhere have been normalized to the respective US and European standard populations of 2000 [9, 48].
The age-standardized rate (ASR), which is stated per 100,000 population, is determined by multiplying the age-specific rates by the selected reference standard population of the same age segment [49]. It serves as a synthesis of the rates that a population would exhibit under a fictitious (standard) age structure [50]. When comparing populations with different age structures or for the same population through time, standardization is required [12, 13].
To calculate age standardization (ASR), require;

- Calculate age-specific rates λ_i in population of interest.
- Multiply λ_i by weights w_i from standard population.
- Calculate $\sum(\lambda_i\ w_i\ )$ **,** the sum of above.
- Calculate $\sum\ w_i$ the sum of the weights w_i
- Calculate ASR (per 100000 person-years) [14, 51]

$$ASR = \frac{\sum(\lambda_i w_i)}{\sum w_i} \times 100000 \quad (2)$$

2.3.3 Validation analysis

Following the collection of the data, it is edited and entered into the Excel 2010 program for evaluation, analysis, and computation of the crude rate and ASR.

2.3.4 Data collection

In order to conduct the study, data on the incidence of sickle-cell disease cases in Iraq is officially collected by the Iraqi Ministry of Health and Environment. Data from the sickle-cell disease registry is gathered from 2010 to 2015. The source for the incidence of sickle-cell disorders is a hospital-based registry that uses the ICD-10 categorization. The registry comprises local pathology labs, doctors, surgeons, and the incidence of public and private hospitals. ICD-10 classification, in particular, codes for sickle-cell diseases (D57).

2.4 Ethical clearance

To carry out the study, certain administrative affiliations are filled out and sent to the Iraqi Ministry of Health and Environment.

2.5 Statistical analysis

In a follow-up study, the variations in the incidence of sickle-cell disorders between 2010 and 2015 are examined. Data is analyzed using the MS-Excel 2010 tools. The MS-Excel 2000 tool is used to enter and maintain data in order to display data in simpler pictures comparing gender, age groupings, and sickle-cell diseases [52-54]. The analysis includes age-standardization and incidence-age distribution. The following statistical analysis is used to describe the data:
A: Descriptive statistics used to explain the pattern, scale, and prevalence of sickle-cell disorders over the six years analyzed include the incidence rate, rate ratio, age standardization, and percent [55].
B: Analyzing statistical data. The percentages of each sickle-cell disorder are computed by gender and age group. In most situations, percentages are used to describe the severity of sickle-cell disorders.

a. Incidence rate (IR): The incidence rate is a rough percentage for the general population. It is computed by dividing the number of casualties in a given group by the number of individuals in that category multiplied by 100,000. It is a benchmark for different age groups and can be used to compare age groups in one location.
b. Age standardization is used to compare various communities at different times, taking into account variances in society's age structure.

3. RESULT AND DISCUSSION

According to Iraqi national population statistics, this is an important Sickle Cell Disease SOD research paper. Some perspectives are taken into consideration for this perfect goal: Providing data to identify trends and potential causes of D57 in the community; and evaluating the impact of the D57 registry program on residents' overall health. Data for Iraqi D57 incidence registration from 2010 to 2015, classified as described in ICD-10, is obtained from the Ministry of Health and Environment. The incidence crude rate and ASR rates of D57 are calculated using data analysis. The sample size is 12879. The results revealed that the highest incidence is reported for females (6895), with a percentage of 54 percent, while males had a percentage of 45 percent over the six years analysed, as shown in Figure 1 [56,57].

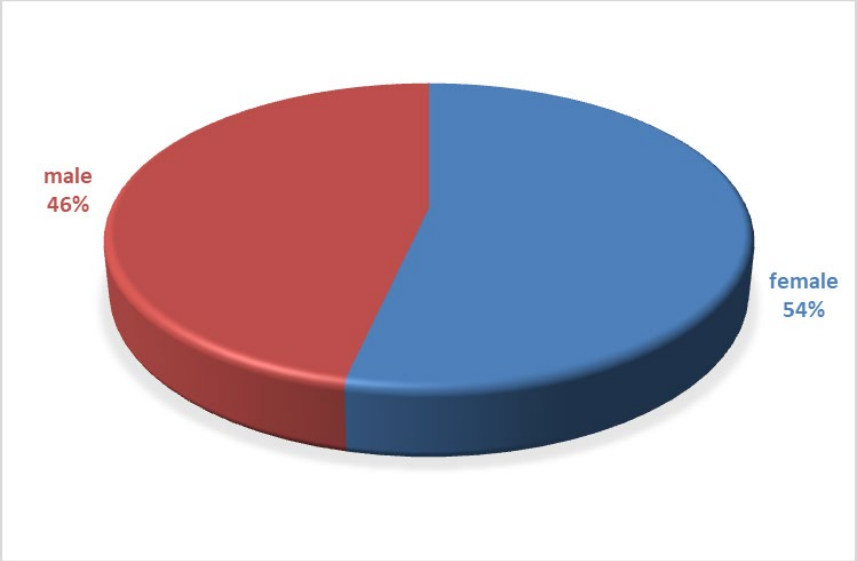

Figure 1 The prevalence of sickle cell disease in males and females.

Statistics on the frequency and survival of diagnosed sickle cell disorders in the general population can be a valuable resource for sickle cell disorder prevention. For registration purposes, Iraq is divided into three age groups: childhood, adulthood, and old age. Due to its pathophysiologic features, D57 has a significant impact on the patient [58]. The majority of patients have significant lifelong morbidities as a result of the underlying hemolysis and vascular damage, which causes acute (eg, vaso-occlusive crises and acute chest syndrome) and chronic injury to multiple end organs, including the brain (eg, stroke and silent infarcts), kidney (eg, renal failure), and the cardiopulmonary system (eg, pulmonary hypertension) [15]. These acute and chronic injuries result in higher outpatient and inpatient health care resource utilization, functional physical and cognitive impairments, and patient-reported losses in quality of life, school attendance, and work productivity [16, 59]. D57 is linked to major and costly long-term problems, decreased life expectancy, and early death during puberty [17, 60]. This is what we find in Iraq, where it is similar to worldwide data, in addition to the severe political situations it endured from 2010 to 2015, which resulted in a lack of health treatment for this segment of patients, as indicated in Table 1. During this period, the number and survival rates appear for all age stages, with the survival rate during childhood appearing to be less than twenty years to reach around 70% of all incidence, while this percentage declines during maturity (20–44 years) to reach 45 percent of total cases. In the elderly (45–65 years old), the survival rate is less than 10% of the overall incidence.

Table 1 The incidence and survival rates for both sexes at various age stages of sickle cell disease (D57).

Years	Sex	Total	Childhood	%	Adulthood	%	Old age hood	%
2010	F	925	524	57%	341	37%	60	6%
2010	M	873	548	63%	269	31%	56	6%
2011	F	804	476	59%	252	31%	76	9%
2011	M	837	553	66%	224	27%	60	7%
2012	F	1368	646	47%	593	43%	129	9%
2012	M	1057	729	69%	253	24%	75	7%
2013	F	1335	625	47%	575	43%	135	10%
2013	M	1066	697	65%	282	26%	87	8%
2014	F	1358	627	46%	602	44%	129	9%
2014	M	1095	739	67%	282	26%	74	7%
2015	F	1105	586	53%	404	37%	115	10%
2015	M	1056	716	68%	270	26%	70	7%

Of course, the previous table shows that girls have greater survival rates than males, which is consistent with global statistics [18]. As previously said, the survival rate for this condition is low due to the physical and psychological disorders that accompany it, as well as the quality of health treatment provided and the overall quality of life [19, 20]. Studies show that the incidence of sickle cell disease varies depending on the ethnic background of individuals, with African and Hispanic individuals being more prone to infection if the Asian genetic component is present. The study found that females are more susceptible to infection than males, [21] and during the research period, this is what we can also observe for Iraq (2010-2015). The ICD-10 system is used to determine the age standardization rate (ASR per 100,000) for sickle cell diseases, which is represented by D57 [22]. There are numerous studies that compute ASR, particularly for cancer research, [14] but I is unable to locate any that did so for sickle cell illness. As indicated in Figure 2, the highest ASR rate in 2012 for males is during childhood (3.77 per 100,000), whereas the highest ASR rate in 2012 for females is during the same stage (3.53 per 100,000) [23-26].

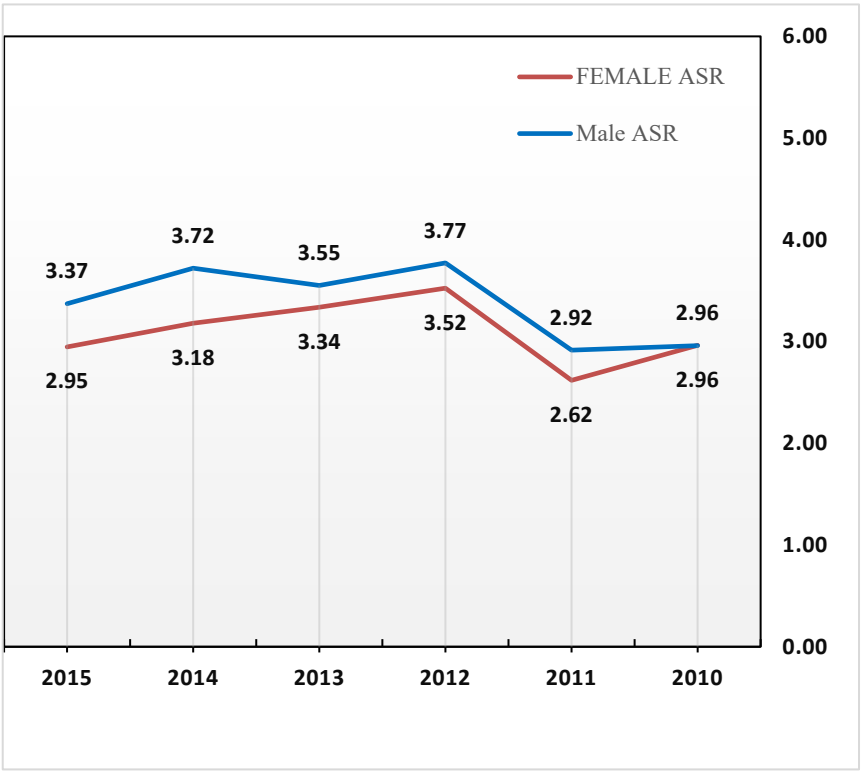

Figure 2 The age-standardized rate of sickle cell disease in children from 2010 to 2015.

In adulthood, girls had the greatest ASR rate (4.55 per 100,000) in 2012, while males had the highest rate (1.84 per 100,000) in 2010, as shown in Figure 3.

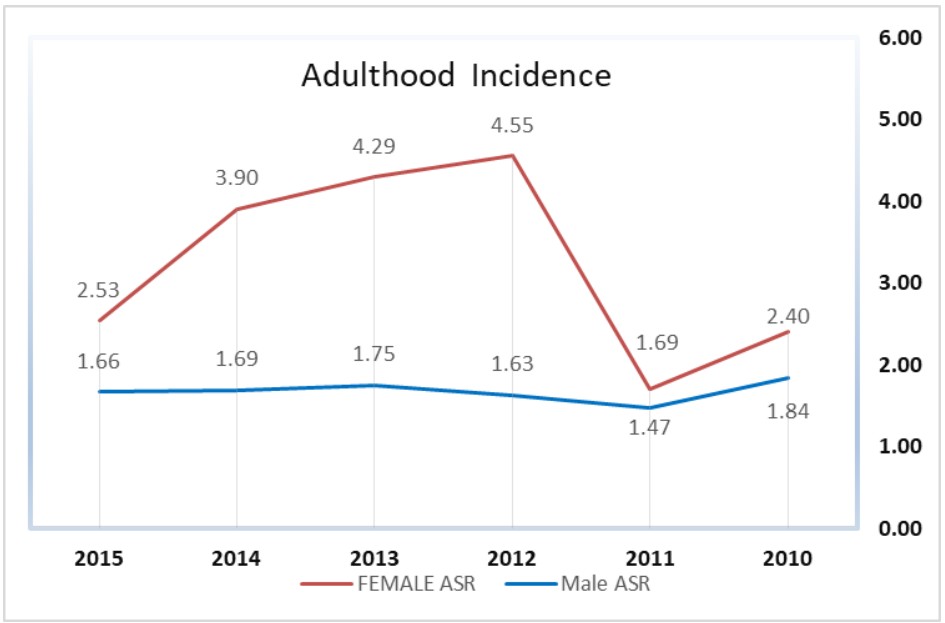

Figure 3 The age standardization rate for adults with sickle cell disease between 2010 and 2015.

As indicated in Figure 4, females had the greatest ASR rate in old age (1.54 per 100,000) in 2012, while males had the highest rate (1.10 per 100,000) in 2013 [27-35].

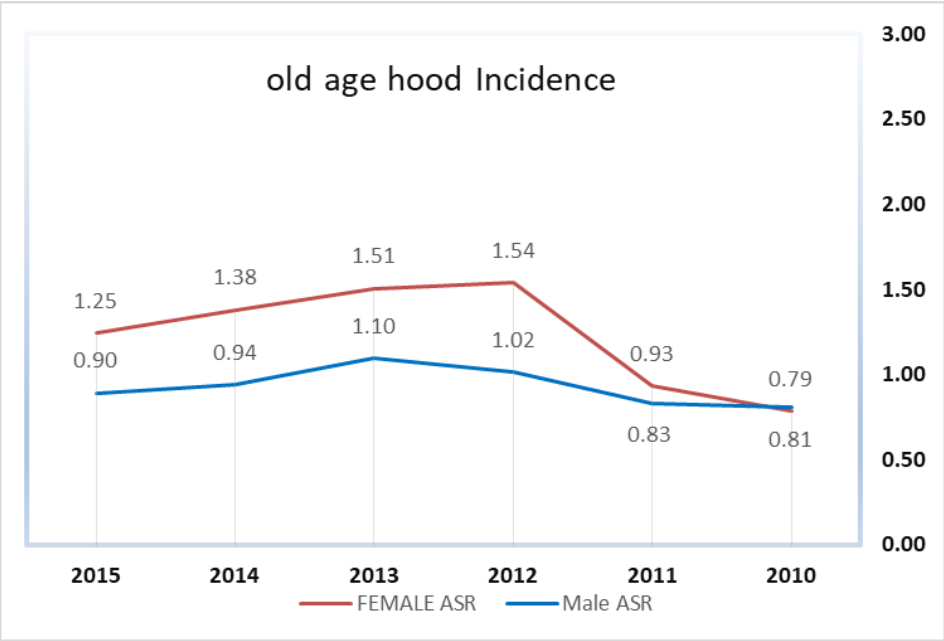

Figure 4 The age standardization rate for sickle cell disease from 2010 to 2015.

3.1 Implications of nanotechnology for sickle cell disease surveillance

Table 2 summarizes emerging nanotechnology-based diagnostic tools that could complement epidemiological surveillance of sickle cell disease. These technologies offer potential mechanisms to explain observed variations in incidence, survival, and disease severity across demographic groups [61-63].

Table 2 Potential nanotechnology-based diagnostic tools relevant to sickle cell disease surveillance.

Nanotechnology Tool	Target Biomarker	Clinical Purpose	Relevance to Epidemiology
Gold nanoparticle biosensors	HbS polymerization	Early diagnosis	Explains incidence variation
Nano-fluidic devices	RBC deformability	VOC risk detection	Links to hospitalization trends
Magnetic nanoparticles	Hemolysis markers	Disease severity monitoring	Supports survival analysis
Lab-on-chip nano platforms	Multiple biomarkers	Point-of-care screening	Enhances registry accuracy

Table 3 highlights the advantages of nanotechnology-based diagnostic approaches compared to conventional methods, emphasizing their potential role in enhancing sickle cell disease surveillance and management in resource-limited settings.

Table 3 Comparison between conventional diagnostics and nanotechnology-based approaches Suggested Table Structure.

Diagnostic Aspect	Conventional Methods	Nano-based Methods
Sensitivity	Moderate	High
Time to result	Hours–days	Minutes
Sample volume	Large	Minimal
Suitability for screening	Limited	High
Use in surveillance	Indirect	Direct integration possible

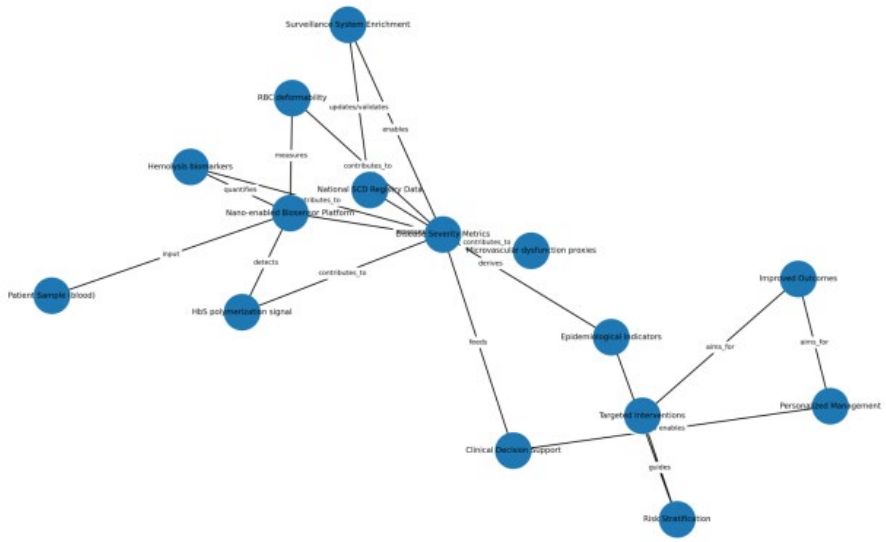

Figure 5 Conceptual framework of nanotechnology-assisted diagnosis in sickle cell disease.

Figure 6 demonstrates how nanotechnology-based diagnostics could be applied differently across age groups, aligning with the age-specific incidence and survival patterns observed in Figures 1–4.

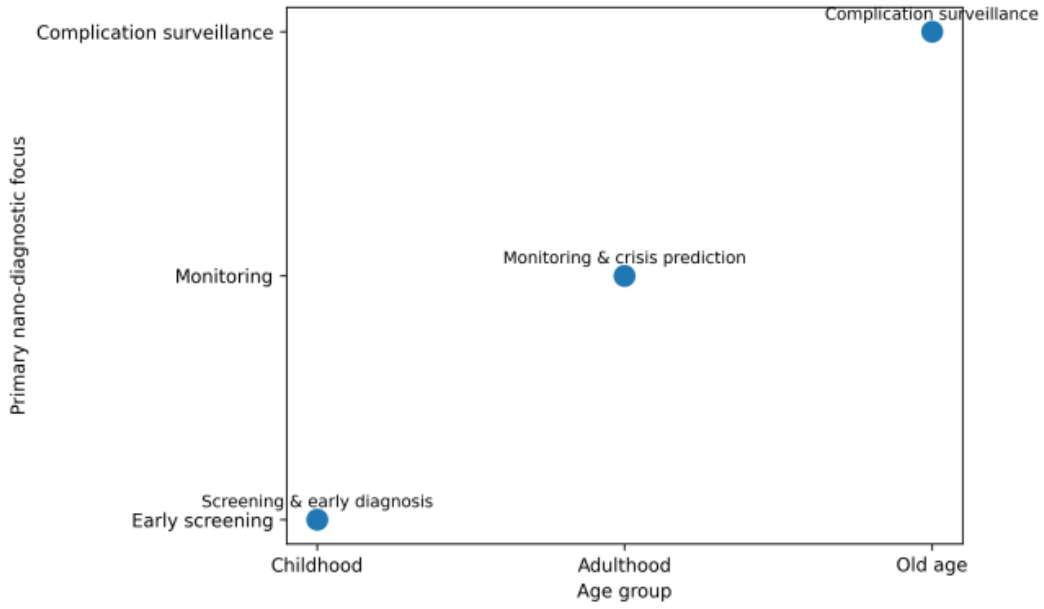

Figure 6 Potential role of nano-diagnostics across age groups in SCD.

In light of the age- and sex-specific variations observed in Figures 1–4 and Table 1, emerging nanotechnology-based diagnostic tools (Figures 5 and 6; Tables 2 and 3) may offer valuable complementary insights by enabling early detection of disease severity and improved monitoring at the population level.

4. CONCLUSIONS

In the six-year study we conducted on the prevalence of sickle cell disease (SCD) in accordance with the ICD 10 international categorization system for diseases, there were 12879 cases in all that were reported, and we discovered that female incidences were more common than male incidences. The survival rate for the adult stage was estimated to be between 25 and 35% of the total incidence, meaning that approximately 60% of all cases before puberty died as a result of this disease. The same is true for the elderly stage, where the survival rate does not exceed 10% in the best case, meaning that 90% die before this stage. For all age groups and study years, we also calculated the age standardization rate (ASR per 100,000), and the year 2012 had practically the greatest incidence rate. Iraqi patients with sickle cell disease require medical care, which calls for the establishment of specialist facilities. In addition to strengthening epidemiological surveillance, future strategies for sickle cell disease control in Iraq may benefit from advances in nanotechnology. Nano-enabled diagnostic tools and biosensors hold promise for improving early detection, monitoring disease progression, and identifying patients at higher risk of complications. Integrating nanotechnology-based diagnostics with population-level data could support more effective screening programs, guide clinical decision-making, and ultimately contribute to reducing morbidity and mortality associated with sickle cell disease.

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