RESEARCH PAPER

Screening of Sickle Cell Anaemia among the Indigenous Population under Rani CHC, Guwahati, Assam

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Abstract

Background: Haemoglobinopathies, especially sickle cell disease (SCD), are a major community health issue in India, especially among the tribal groups. Not much region-specific information is found in the northeastern states, such as Assam.

Objectives: To determine the levels of haemoglobin in the sample, and determine the prevalence of sickle cell anaemia in the local population under Rani Community Health Centre (CHC), Guwahati, Assam.

Methods: A community based descriptive cross-sectional study was done on 400 indigenous people aged 0-40 years, which were chosen by simple random sampling. The level of haemoglobin was measured using a portable haemometer and sickle cell anaemia screening was done through the solubility test. The analysis of data was done through descriptive statistics, which comprised mean, median, standard deviation, frequency and percentage.

Results: The mean haemoglobin level was 8.42 ± 1.43 g/dL, indicating a substantial burden of anaemia in the study population. Screening revealed no cases of sickle cell anaemia, resulting in an observed prevalence of 0%.

Conclusion: No cases of sickle cell anaemia were found; however, anaemia is still a formidable issue among the indigenous population. It is suggested to enhance haematological health outcomes by strengthening screening strategies and anaemia control programmes.

Keywords: Sickle cell anaemia; Haemoglobin level; Indigenous population; Tribal health; Anaemia; Community screening

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1. INTRODUCTION

Haemoglobinopathies are widespread inherited genetic disorders that pose a serious global health issue in the world and are the main problem of world health [1,2]. An estimate of the global population that carries an abnormal haemoglobin gene is estimated to be close to 7%, and about 300,000–500,000 infants are born with a severe haemoglobin defect each year [2,3]. These are the three types of haemoglobinopathies with syndromes of thalassaemia and structural forms of haemoglobin, such as haemoglobin S (HbS), haemoglobin D, and haemoglobin E [4]. One of such disorders is the sickle cell disease (SCD), which is one of the most clinically severe and life-limiting inherited blood disorders [5].

Sickle cell disease is caused by a point mutation at the β-globin gene that results in the formation of haemoglobin S that polymerises under hypoxic conditions and results in the red cells taking the sickled shape [4]. Such abnormal cells are susceptible to haemolysis and vaso-occlusion, leading to chronic anaemia, painful crises, frequent infections, organ injury, and high mortality [5,6]. However, contrary to the traditional sub-Saharan African legacy, SCD is very common in India, the Middle East, and some parts of South-East Asian regions [1]. India is especially a significant contributor to the number of SCD births in the world [7].

There is no even distribution of SCD within India. It is mostly observed among marginalised and tribal groups, and the prevalence of sickle cell trait has been reported to be 1 to 40% among some communities [8]. The population of tribes is also poorly covered because of the genetic clustering, endogamy, socio-economic disadvantage, malnutrition, and a lack of healthcare services [9,10]. In light of this, the MoHFW Expert Committee on Tribal Health listed sickle cell disease among the top ten priority health conditions that disproportionately impact the tribal communities [9].

The intrinsic element of controlling and managing sickle cell disease is screening and early diagnosis [2]. Population-based screening allows finding the affected individuals and carriers, and allows genetic counselling, early clinical management, and disease transmission prevention [6,8]. In India, in 2016, systematic programmes within the framework of the National Health Mission were established to enhance prevention, screening, and control of haemoglobinopathies [11]. Nonetheless, it is not very consistently implemented, especially in remote areas and in tribal regions with a lack of medical facilities and awareness of their presence [10].

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Along with genetic screening, the analysis of the haemoglobin levels is imperative to comprehend the overall load of anaemia in the risk groups. Nutritional deficiency, parasitic infections, and inherited blood disorders are the primary causes of anaemia that affect a significant population of vulnerable people in rural and tribal communities in India [12,13]. Long-term anaemia has a negative impact on bodily development, intellectual progress, the health of the mothers, and employment output [2]. Thus, simultaneous estimation of haemoglobin levels when the problem of sickle cell screening is performed will give a complete picture of the haematological health of the community.

Although there is significant data on the need in central and western India on the burden of sickle cell disease [7,8]. Epidemiological data are scarce in such northeastern states as Assam. The Assamese tribal people form a huge percentage of the rural population, but there is limited information on the occurrence of disease in the region. Lack of localised baseline data curtails the evidence-based planning, specific screening approaches, and healthcare resource distribution. In addition, not many community-based studies have measured both haemoglobin levels and sickle cell prevalence of the indigenous communities of this area concomitantly. This is a major research gap in terms of the haematological health condition of tribal people in Assam.

Rani Community Health Centre (CHC) is situated in the Kamrup (Metropolitan) district of Assam, which is a tribal-dominated area. Considering the identified susceptibility of tribal populations to haemoglobinopathies and anaemia, routine screening conducted on this population is of high importance to the overall health condition. The creation of local data plays a significant role in enhancing early detection measures in national elimination programmes.

In view of the identified research gap and public health relevance, the objectives of study are:

1. To compute the amount of haemoglobin on the indigenous population of Rani CHC, Guwahati, Assam.
2. To determine how common sickle cell anaemia is in the indigenous population under Rani CHC, Guwahati, Assam.

The findings of this study are expected to provide baseline epidemiological evidence to guide local health authorities and contribute to broader national efforts aimed at reducing the burden of SCD and anaemia in tribal populations.

2. METHODOLOGY

Study Design

It was a community based descriptive cross sectional study whose aim was to estimate the level of haemoglobin and how prevalent sickle cell anaemia was among the local community that fell under the Rani Community Health Centre (CHC), Guwahati, Assam. The descriptive design was considered appropriate since the aim of the study was to quantify present state of haemoglobin and to determine occurrence of the sickle cell anaemia in a specific population of a specific time with no intervention whatsoever.

Study Setting

This research was conducted within the field practice site of Rani Community Health Centre, the headquarters of Kamrup (Metropolitan) district of Assam. The area is mostly covered with indigenous tribal populations, and a significant percentage of its population is Scheduled Tribes (ST). It is a totally rural area that falls under the public health delivery system by being served using sub-centre and primary health outreach services that are organized by the CHC. This setting was chosen due to its dominance over the tribes and the application of sickle cell screening to vulnerable people of the indigenous community.

Study Population

The target population included all indigenous tribal people who live within the territory of Rani CHC. The population that was available was the age group of 0-40 years that was available during the study period and agreed to participate. The age group was chosen based on the premise of early onset of haemoglobinopathies and the necessity of early detection of haemoglobinopathies in order to prevent and counsel.

Sample Size and Sampling Technique

The study involved 400 participants. The study period was used to determine the sample size because it was feasible, and there were resources and the capacity to reach the study participants. In order to get the most probable sampling technique that guaranteed every individual within the sampling frame a fair chance of being chosen, a simple random sampling method was applied. The assistance of the local health workers was used to get the household listings, and random selection procedures were used to select eligible participants in order to reduce selection bias.

Inclusion and Exclusion Criteria

The participants of the study were individuals who are members of indigenous tribal communities, aged 0-40 years, and reside under Rani CHC and were willing to give informed consent (or assent with parental consent in the case of minors). Individuals who were too sick during time of data collection, refused participation, and were not available on multiple visits were excluded.

Study Variables

The major study outcomes were the level of haemoglobin (in g/dL) and the presence or absence of sickle cell anaemia. The level of haemoglobin was considered as a continuous variable. The cases of sickle cell anaemia were evaluated as a qualitative variable (present/absent).

The sociodemographic details (age, gender, marital status, educational status, occupation, caste, income, residence, and previous blood transfusion history) were taken to explain the population of the study and provide contextual interpretation to findings.

Data Collection Tools and Procedure

The data were taken in a structured and pre-tested proforma that helped in capturing demographic data and other important clinical data. Community sensitization was conducted before the data collection, and the purpose and the importance of the screening were explained with the help of the local health workers.

Aseptic precautions of a haemometer were applied in estimating haemoglobin. The method of collecting blood samples was by capillary through a finger prick. The values of haemoglobin were taken in grams per decilitre (g/dL). The measurement was done in accordance with standard operating procedures in order to make it accurate and reliable.

The presence of sickle cell anaemia was further screened in the participants by the solubility test method in order to determine whether the abnormal haemoglobin (HbS) was present. Those patients who were positive in screening were to be referred to a higher centre to undergo confirmatory testing, such as high-performance liquid chromatography (HPLC). In this research, however, prevalence estimation was made on the screening results obtained in the field visits.

Ethical Considerations

The study was conducted with the ethical approval of the authority involved. All participants gave informed consent to data collection. The information that the participants provided was kept confidential, and their involvement was purely voluntary. Respondents who were diagnosed with low haemoglobin or abnormal screening were referred to consult additional medical care.

Data Management and Statistical Analysis

The information was coded and entered into a statistical software package in order to facilitate analysis. Descriptive statistics were used as a summary of the findings. The mean, the median and the standard deviation were considered as the continuous variables; such as the haemoglobin level. Frequency and percentage distribution were the established methods of presenting categorical variables. Proportion of those screened to obtain a positive outcome of the overall study population was the calculated prevalence of sickle cell anaemia. The results were presented in a tabular and graphical format to make them easier to understand.

3. RESULTS

Baseline Characteristics of the Study Population

It involved 400 indigenous participants who lived within the jurisdiction of a community health centre named Rani. The age distribution indicated that 58.3% of the participants were of the age group of 21-30 years, and 28.3% were of the age group 11-20 years. The children aged ≤10 years were 8.3% of the study population, and 5.3% fell between the ages of 31 and 40 years. None of the participants was older than 40 years.

Regarding the gender representation, 54.7% and 45.3% of the total number of participants were male and female, respectively. Most of the respondents (66.8%) were married, with 32.8% being single and 0.5% being separated.

On the aspect of education, 40.3% of the participants were of primary education, 34.0% were of middle school education, 17.7% of higher secondary education, and 8.0% of graduate education. The respondents were all rural dwellers (100%).

In terms of caste distribution, 92.5% were of the Scheduled tribes, with 7.5% of the backward classes. Regarding monthly income, 37.8% of them had reported ₹10,000, 26.7% had reported ₹15,000, 16.7% had reported ₹17,000, 9.8% had reported ₹18,000, and 9.0% had reported ₹20,000. In the occupation, 37.2% had been employed, 32.5% unemployed, and 30.3% students.

Only a small percentage (4.8%) of the participants had their previous blood transfusion, with the rest (95.2%) having no prior history of blood transfusion. The socio-demographic characteristics of the participants, including age, gender, caste, marital status, educational status, income, occupation, and previous blood transfusion, are illustrated in Figures 1–8. Table 1 shows the socio-demographic features of the study participants in detail.

Table 1. Socio-demographic Characteristics of Study Participants (N = 400)

Variable	Category	Frequency (n)	Percentage (%)
Age (years)	≤10	33	8.3
	11–20	113	28.3
	21–30	233	58.3
	31–40	21	5.3
Gender	Male	219	54.7
	Female	181	45.3
Marital Status	Married	267	66.8
	Single	131	32.8
	Separated	2	0.5
Education	Primary	161	40.3
	Middle School	136	34.0
	Higher Secondary	71	17.7
	Graduate	32	8.0
Residence	Rural	400	100
Income (₹)	10,000	151	37.8

	15,000	107	26.7
	17,000	67	16.7
	18,000	39	9.8
	20,000	36	9.0
Caste	Scheduled Tribe	370	92.5
	Backward Class	30	7.5
Occupation	Employed	149	37.2
	Unemployed	130	32.5
	Student	121	30.3
Previous Transfusion	Yes	19	4.8
	No	381	95.2

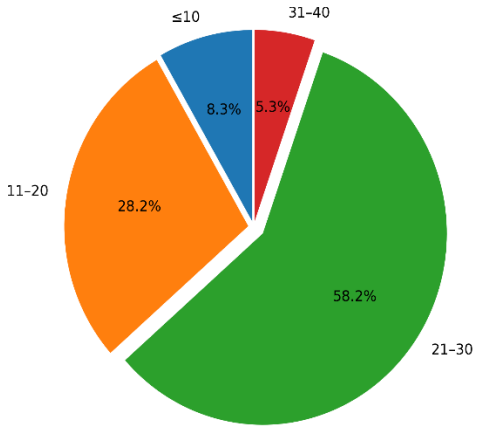

Figure 1. Percentage distribution of participants according to age (N = 400)

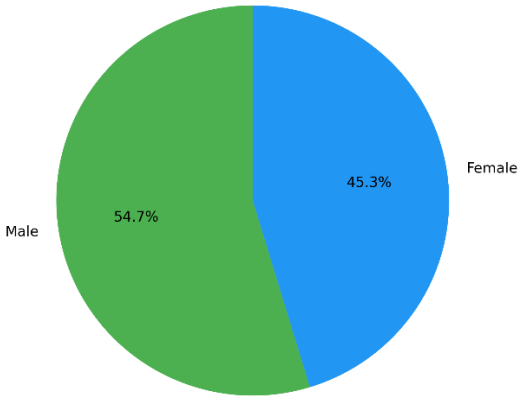

Figure 2. Percentage distribution of participants according to gender (N = 400)

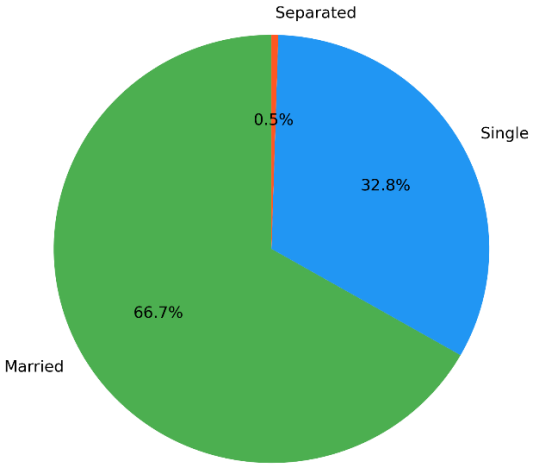

Figure 3. Distribution of study participants according to marital status (N = 400).

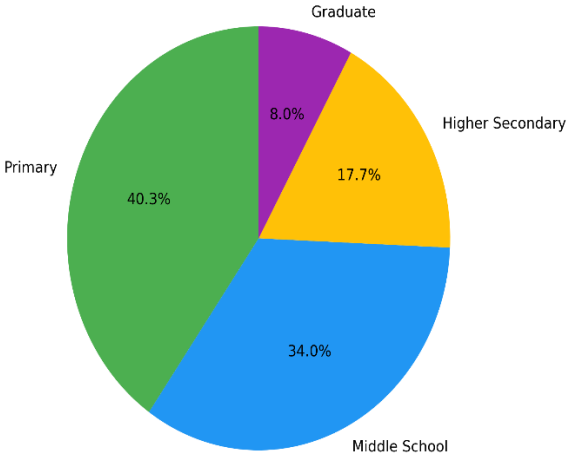

Figure 4. Percentage distribution of participants according to educational status (N = 400).

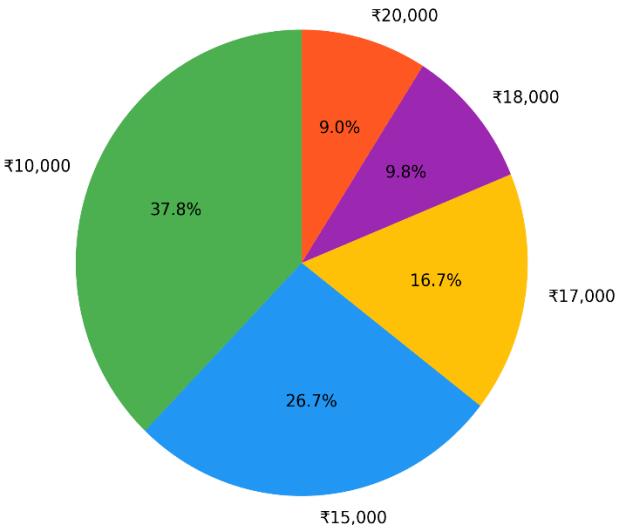

Figure 5. Percentage distribution of participants according to monthly income (N = 400).

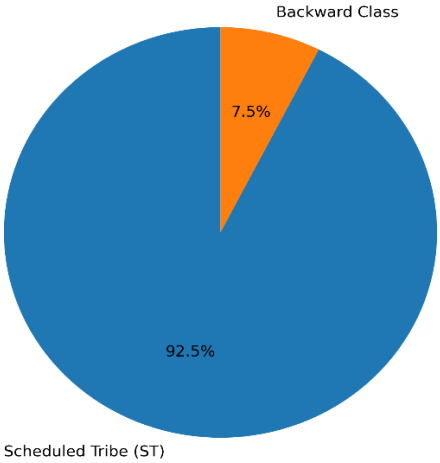

Figure 6. Percentage distribution of participants according to caste (N = 400)

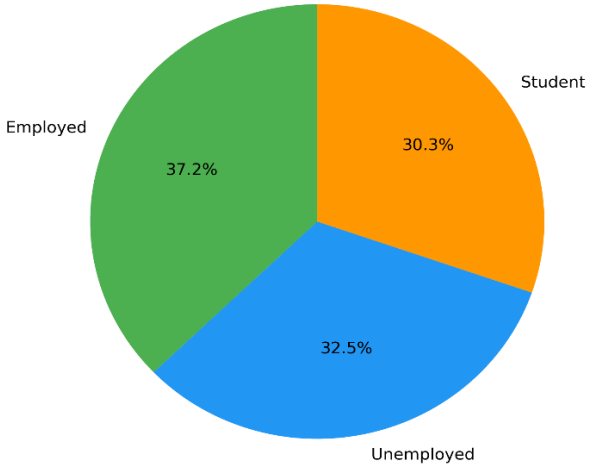

Figure 7. Percentage distribution of participants according to occupation (N = 400).

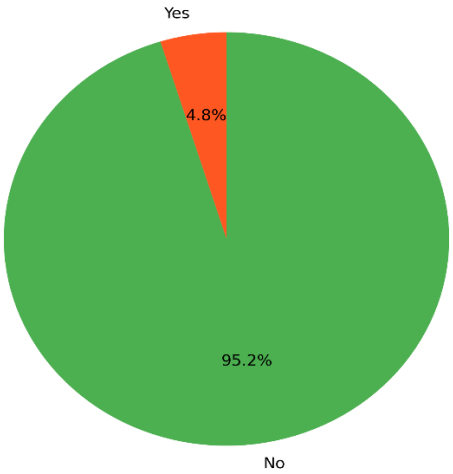

Figure 8. Percentage distribution of participants according to previous blood transfusion (N = 400).

Haemoglobin Level among the Indigenous Population

As outlined in the methodology, the haemoglobin levels of the 400 indigenous participants were determined using a portable haemometer. The average haemoglobin concentration of the study group was 8.42 ± 1.43 g/dl, with the median of 8.20 g/dl.

The measured mean haemoglobin value shows that a significant percentage of the population being studied had haemoglobin levels that were below the reference range, which is indicative that there is a significant burden of anaemia among the screened indigenous population. The standard deviation of 1.43 g/dL

indicates that there is moderate variation in the levels of haemoglobin among the subjects.

In addition to the estimation of haemoglobin, the mean body weight of the participants was estimated and the median was 52.0 kg at a standard deviation of 16.66 kg. Figure 9 depicts the general haemoglobin distribution of the participants.

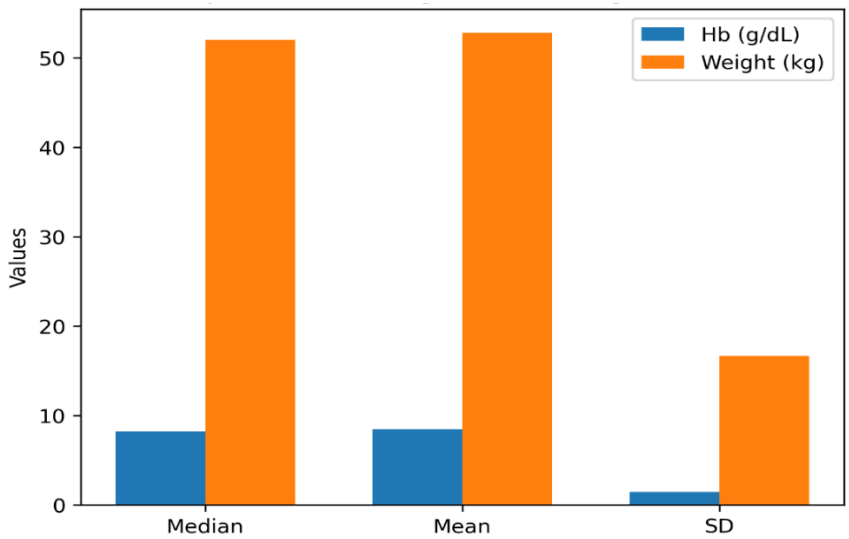

Figure 9. Assessment of Haemoglobin Level among Participants (N = 400)

Prevalence of Sickle Cell Anaemia

The 400 indigenous subjects were screened for sickle cell anaemia under the solubility test methodology as outlined in the methodology. The outcomes of the screening indicated that all the participants were negative for sickle cell anaemia. Those who were tested (100%) were negative for the presence of abnormal haemoglobin (HbS) during the study period. Table 2 provides the distribution of the results of the screening in detail in the form of frequencies and percentages.

Table 2. Prevalence of Sickle Cell Anaemia among the Study Population (N = 400)

Screening Result	Frequency (n)	Percentage (%)
Positive	0	0.0
Negative	400	100.0

4. DISCUSSION

The current community-based cross-sectional technique evaluated the level of haemoglobin among the indigenous group under Rani CHC, Assam. The results demonstrated an average haemoglobin value of 8.42 ±1.43 g/dL, meaning that there was a high burden of anaemia in the screened population. Nonetheless, none of the 400 participants had positive cases of sickle cell anaemia, and hence the prevalence was observed at 0%. In rural and tribal populations in India, anaemia has also been noted to be very high because of nutritional deficiencies, parasites, and socio-economic factors [14,15]. Undernutrition, lack of nutritional variety in food intake, and inadequate access to health care services tend to be more prevalent among tribal groups and lead to chronic anaemia [16]. Moreover, anaemia could be even more burdened by environmental and infectious factors that prevail in rural areas [17]. The results of the study thus highlight the necessity of combined nutritional and community health programs in the target region.

To the contrary of the expectation, regarding the studies in central and western India, where the prevalence rate of sickle cell anaemia among tribal populations is between 5 and 30 percent in some areas [18,19], no cases of sickle cell anaemia were detected in the study. Various reasons can explain this observation. There is, first, geographical heterogeneity in the spreads of the HbS gene mutations in India [20]. The northeastern part, such as Assam, might have a relatively lower gene frequency when compared to the central tribal belts of India. Second, the screening test of solubility that is applicable in the field is not effective at identifying every variant haemoglobin or low-level carrier [21]. Third, the sample size is sufficient to do an initial screening, but it might fail to represent the infrequent genetic disorders in certain subgroups.

The fact that no cases of sickle cell trait or other haemoglobin variants were detected in this study does not mean that there are no cases of this condition in the general population. Carrier diseases, especially heterozygous sickle cell trait, can be asymptomatic, and these diseases can only be confirmed by more sensitive diagnostic techniques, e.g., high-performance liquid chromatography (HPLC) or molecular testing [22]. Screening programs in other areas have demonstrated that, although the overt prevalence of disease is low, carrier screening is still relevant to genetic counselling and prevention programs [23].

As a public health-related issue, two aspects can be noted based on the findings. To begin with, anaemia seems to be a less distant and apparent haematological issue within this community. Intensifying anaemia control interventions, such as iron supplementation, deworming, and nutrition education, can have significant health outcomes [24]. Second, it is still significant that sickle cell disease is monitored, especially after the national elimination plan focuses on detecting the disease early in life and genetic counselling [25]. Localized epidemiological information generated will be essential in designing region-specific screening policy instead of relying on the extrapolation of the information in other states.

This paper has its limitations, which cannot be ignored. First, the cross-sectional design does not allow making causal inferences and only estimates point prevalence. Second, the screening based on a solubility test, in the absence of a confirmatory HPLC or molecular analysis, could have had low sensitivity in detecting carriers or rare variants [21]. Third, the scope of the research was also limited to a single CHC region and would not apply to all Assam tribal populations. Also, possible nutritional and infectious etiologies of anaemia were not studied thoroughly, and it was impossible to identify particular etiologies.

Future researchers should use bigger, multicenter samples in various Assam districts in order to establish regional differences in haemoglobinopathies. The inclusion of confirmatory diagnostic methods like HPLC would improve diagnostic accuracy, and carrier states could be detected. Evidence-based interventions could be further reinforced with longitudinal studies that determine the determinants of anaemia and the nutritional status and genetic counselling results. Educational programs about community awareness, combined with systematic screening and referral processes, would be a good addition to the early detection and prevention measures. It can also be helpful to create a district-level haemoglobinopathy registry to aid in continuing surveillance and policy development.

In conclusion, no sickle cell anaemia was found among the current population, but the unfortunate result is a significant level of anaemia. Follow-up surveillance, advanced methods of diagnosis, and specific health interventions based on individual health support of the indigenous Assam population are justified in solving haematological health issues.

5. CONCLUSION

The current community-based research presents significant groundwork information on the haematological condition of the native people in the area of Rani Community Health Centre, Guwahati, Assam. It was found that anaemia had a significant burden, as indicated by the low mean haemoglobin levels among the participants. This brings out the issue of anaemia as a health crisis among the tribal communities as a group that is likely to be caused by nutritional deficiency, socioeconomic reasons, and lack of healthcare accessibility. No sickle cell anaemia cases were reported in the population screened, but the fact that no case was identified does not remove the necessity of further surveillance. The issue of regional genetic variation, as well as the constraint of the screening procedures based in the field, should be used with great caution. More effective screening strategies that include confirmatory diagnostic methods and the coverage of more and more individuals would increase the accuracy of detection. The whole study signifies that communities should have combined interventions that target anaemia, nutritional well-being, community knowledge, and regular haemoglobinopathy screening. These steps will be needed to enhance haematological health outcomes and evidence-based planning of indigenous populations in Assam.

References

1. Piel FB, Hay SI, Gupta S, Weatherall DJ, Williams TN. Global burden of sickle cell anaemia in children under five, 2010–2050: modelling based on demographics, excess mortality, and interventions. PLoS medicine. 2013;10(7):e1001484.
2. WHO. Haemoglobin concentrations for the diagnosis of anaemia and assessment of severity [Internet]. 2011 [cited 2026 Feb 24]. Available from: https://www.who.int/publications/i/item/WHO-NMH-NHD-MNM-11.1
3. Modell B, Darlison M. Global epidemiology of haemoglobin disorders and derived service indicators. Bull World Health Organ. 2008 Jun 1;2008(6):480–7. doi:10.2471/BLT.06.036673
4. Rees DC, Williams TN, Gladwin MT. Sickle-cell disease. The Lancet. 2010;376(9757):2018–31. doi:10.1016/S0140-6736(10)61029-X
5. Ware RE, Montalembert M de, Tshilolo L, Abboud MR. Sickle cell disease. The Lancet. 2017 Jul 15;390(10091):311–23. doi:10.1016/S0140-6736(17)30193-9 PubMed PMID: 28159390.
6. Piel FB, Steinberg MH, Rees DC. Sickle Cell Disease. Longo DL, editor. N Engl J Med. 2017 Apr 20;376(16):1561–73. doi:10.1056/NEJMra1510865
7. Balgir RS. The burden of haemoglobinopathies in India and the challenges ahead. Current science. 2000;1536–47.
8. Colah RB, Mukherjee MB, Martin S, Ghosh K. Sickle cell disease in tribal populations in India. Indian Journal of Medical Research. 2015;141(5):509–15. doi:10.4103/0971-5916.159492
9. Ministry of Health and Family Welfare. Report of the expert committee on tribal health. Government of India [Internet]. 2018 [cited 2026 Feb 24]. Available from: https://nhm.gov.in/index1.php?lang=1&level=1&sublinkid=1110&lid=630
10. Jain D, Gupta M, Madkaikar M, Jena RK, Khargekar N, Saraf SL, et al. Sickle cell disease in India: current status and progress. The Lancet Haematology. 2024;11(5):e322–3. doi:10.1016/S2352-3026(24)00109-1

11. Ministry of Health and Family Welfare. Guidelines on prevention and management of haemoglobinopathies. Government of India. 2016.
12. Kassebaum NJ, Jasrasaria R, Naghavi M, Wulf SK, Johns N, Lozano R, et al. A systematic analysis of global anaemia burden from 1990 to 2010. Blood. 2014 Jan 30;123(5):615–24. doi:10.1182/blood-2013-06-508325
13. Stevens GA, Finucane MM, De-Regil LM, Paciorek CJ, Flaxman SR, Branca F, et al. Global, regional, and national trends in haemoglobin concentration and prevalence of total and severe anaemia in children and pregnant and non-pregnant women for 1995–2011: a systematic analysis of population-representative data. The Lancet Global Health. 2013;1(1):e16–25. doi:10.1016/S2214-109X(13)70001-9
14. Bentley ME, Griffiths PL. The burden of anaemia among women in India. Eur J Clin Nutr. 2003 Jan;57(1):52–60. doi:10.1038/sj.ejcn.1601504
15. Toteja GS, Singh P, Dhillon BS, Saxena BN, Ahmed FU, Singh RP, et al. Prevalence of Anaemia among Pregnant Women and Adolescent Girls in 16 Districts of India. Food Nutr Bull. 2006 Dec;27(4):311–5. doi:10.1177/156482650602700405
16. Pasricha SRS, Flecknoe-Brown SC, Allen KJ, Gibson PR, McMahon LP, Olynyk JK, et al. Diagnosis and management of iron deficiency anaemia: a clinical update. Medical Journal of Australia [Internet]. 2010 [cited 2026 Feb 24];193(9). Available from: https://www.mja.com.au/system/files/issues/193_09_011110/pas10224_fm.pdf
17. Balarajan Y, Ramakrishnan U, Özaltin E, Shankar AH, Subramanian SV. Anaemia in low-income and middle-income countries. The lancet. 2011;378(9809):2123–35. doi:10.1016/S0140-6736(10)62304-5
18. Kate SL, Lingojwar DP. Epidemiology of sickle cell disorder in the state of Maharashtra. International Journal of Human Genetics. 2002;2(3):161–7.
19. Serjeant GR. The natural history of sickle cell disease. Cold Spring Harbor perspectives in medicine. 2013;3(10):a011783. doi:10.1101/cshperspect.a011783
20. Balgir RS. Phenotypic diversity of sickle cell disorders with special emphasis on public health genetics in India. Current Science (00113891). 2010;98(8).
21. Sachdev R, Dam AR, Tyagi G. Detection of Hb variants and haemoglobinopathies in Indian population using HPLC: report of 2600 cases. Indian journal of pathology and microbiology. 2010;53(1):57–62.
22. Bain BJ. Haemoglobinopathy diagnosis: algorithms, lessons and pitfalls. Blood Rev. 2011 Sep;25(5):205–13. doi:10.1016/j.blre.2011.04.001 PubMed PMID: 21596464.
23. Grosse SD, Odame I, Atrash HK, Amendah DD, Piel FB, Williams TN. Sickle Cell Disease in Africa: A Neglected Cause of Early Childhood Mortality. American Journal of Preventive Medicine. 2011 Dec 1;Blood Disorders in Public Health41(6, Supplement 4):S398–405. doi:10.1016/j.amepre.2011.09.013
24. Rahman MM, Abe SK, Rahman MS, Kanda M, Narita S, Bilano V, et al. Maternal anaemia and risk of adverse birth and health outcomes in low-and middle-income countries: systematic review and meta-analysis, 2. The American journal of clinical nutrition. 2016;103(2):495–504. doi:doi.org/10.3945/ajcn.115.107896
25. Goonasekera HW, Paththinige CS, Dissanayake VHW. Population Screening for Haemoglobinopathies. Annual Review of Genomics and Human Genetics. 2018 Aug 31;19(Volume 19, 2018):355–80. doi:10.1146/annurev-genom-091416-035451