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Impact of Regional Genetic Variations on Hemoglobinopathies and Beta Thalassemia in Bangladesh: A Study of Hb E, Beta Thalassemia and Public Health Outcomes

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Abstract:

Introduction: *Hemoglobinopathies, including beta-thalassemia and Hb E, are major genetic disorders in Bangladesh. Their impact on public health is influenced by regional genetic variations, particularly in Rajshahi Division.* ***Objective:*** *To evaluate the influence of regional genetic variations on the prevalence of Hb E and beta-thalassemia, and their public health implications in Bangladesh, focusing on genetic traits and disease outcomes.* ***Materials and Methods:*** *This cross-sectional study was conducted at the Department of Haematology, Rajshahi Medical College, from January 2024 to December 2024. A total of 348 patients with suspected hemoglobinopathies were included, referred by physicians from different departments for Hb electrophoresis. Patients aged 9 months to 67 years (148 male, 190 female) were analyzed. Variables like age, sex, and different hemoglobinopathies were studied. Statistical analysis was performed using descriptive statistics, including standard deviation (SD), and p-value calculation.* ***Results:*** *Of the 348 samples, 192 exhibited abnormal hemoglobin profiles, while 156 had normal results. The distribution of abnormal findings was as follows: 86 (24.7%) Hb E trait, 16 (4.6%) Hb E disease, 70 (20.1%) beta-thalassemia trait, 18 (5.2%) Hb E-beta thalassemia, and 2 (0.6%) Hb S-beta thalassemia. The mean age of the patients was 22.4 years, with a standard deviation (SD) of 12.3 years. For Hb E trait, the standard deviation was 2.1, and for beta-thalassemia trait, it was 3.3. The p-value for the correlation between Hb E prevalence and regional variations was found to be < 0.05, indicating a statistically significant relationship. Additionally, the difference in disease burden between males and females was not statistically significant (p = 0.12). The highest prevalence was observed in the southern region, where the frequency of Hb E and beta-thalassemia traits reached 30%.* ***Conclusion:*** *This study highlights the high prevalence and regional genetic variations influencing hemoglobinopathies in Bangladesh. Targeted genetic screening and public health interventions are essential for improving patient outcomes.*

Keywords: *Hb E, Beta Thalassemia, Regional Variations, Public Health, Genetic Screening.*

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Introduction:

Hemoglobinopathies, a group of genetic disorders resulting in abnormal hemoglobin synthesis, are of significant clinical and public health concern worldwide. In particular, beta-thalassemia and its variants, including Hb E, present a major challenge to the health system of Bangladesh, where these inherited blood disorders exhibit

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high prevalence. These conditions are typically characterized by the insufficient production or dysfunctional structure of hemoglobin, leading to a variety of clinical manifestations such as anemia, organ damage, and in severe cases, early mortality. The clinical complexity of these disorders is further compounded by regional genetic variations that influence the severity, diagnosis, and management of hemoglobinopathies. A key area of focus in genetic research is understanding how such regional genetic diversity impacts the prevalence and progression of conditions like Hb E and beta-thalassemia, particularly in a genetically diverse country like Bangladesh. The molecular basis of hemoglobinopathies is well-documented, with Hb E being the second most common hemoglobin variant globally. It is a result of a single point mutation in the β-globin gene (HBB), leading to an amino acid substitution from glutamic acid to lysine at position 26 (β26 Glu–Lys)[1]. This mutation, though often benign when inherited heterozygously, can result in varying degrees of severity when it presents in a homozygous or compound heterozygous form with beta-thalassemia mutations. In Bangladesh, Hb E carriers and patients with compound heterozygosity for Hb E and beta-thalassemia mutations are frequently observed, contributing significantly to the burden of thalassemia and related diseases in the population. Beta-thalassemia, a hereditary blood disorder caused by mutations in the HBB gene, leads to a deficiency in the production of beta-globin chains, disrupting normal hemoglobin synthesis and resulting in anemia[2]. Bangladesh has one of the highest carrier rates of beta-thalassemia, with estimates suggesting that approximately 5-7% of the population carries the beta-thalassemia trait[3]. This trait can lead to severe thalassemia major, a life-threatening condition characterized by ineffective erythropoiesis and a reliance on regular blood transfusions. Moreover, the interaction between beta-thalassemia and Hb E variants can produce a more complex clinical picture, further complicating diagnosis and treatment.

While the genetics of these conditions have been extensively studied globally, the role of regional genetic variations in Bangladesh has not been adequately addressed. Population studies have shown that genetic diversity, influenced by factors such as ethnic backgrounds, migration patterns, and selective pressures, plays a critical role in the distribution and manifestation of hemoglobinopathies[4]. In the context of Bangladesh, with its diverse ethnic groups and historical migration patterns, this genetic variation is particularly pertinent to understanding the regional distribution of Hb E and beta-thalassemia and their impact on public health outcomes. The prevalence of Hb E in Bangladesh is notably high, particularly in the southern and southeastern regions, where certain ethnic groups, such as the Chakma and Marma, exhibit significantly elevated carrier rates. Studies have shown that in these areas, the frequency of Hb E trait carriers can exceed 30%, contributing to a substantial burden of thalassemia and related hematological disorders. It is essential to investigate the regional variations in the genetic makeup of these populations to understand how the local genetic pool interacts with environmental and socioeconomic factors, influencing disease burden and public health outcomes.

In addition to genetic variation, the epidemiological implications of hemoglobinopathies in Bangladesh are complex. The impact of hemoglobinopathies extends beyond clinical outcomes to public health policies, healthcare infrastructure, and economic considerations. In regions with high prevalence rates, the financial and logistical burden on healthcare systems is significant, as regular blood transfusions, chelation therapy, and genetic counseling are required for the management of affected individuals. Furthermore, the impact of beta-thalassemia and Hb E on the quality of life, including the psychological toll on affected families and communities, requires urgent attention from both public health officials and policymakers[5]. The public health burden of hemoglobinopathies is compounded by the lack of comprehensive screening programs and genetic counseling services in Bangladesh. Despite the availability of diagnostic tools for detecting Hb E and beta-thalassemia mutations, widespread screening is not yet implemented at a national scale. As a result, many individuals with these genetic disorders remain undiagnosed until clinical symptoms, such as anemia or splenomegaly, become apparent. This late diagnosis further complicates the management of the disease, as early interventions, such as genetic counseling and prenatal screening, are not readily accessible to most families. As the prevalence of these conditions continues to rise, there is a critical need for regional genetic studies to inform the development of targeted public health interventions and policies[6]. In light of these challenges, this study aims to explore the regional genetic variations contributing to the prevalence of Hb E and beta-thalassemia in Bangladesh, with a focus on understanding how these genetic factors impact public health outcomes. By examining the molecular epidemiology of these conditions across various regions of Bangladesh, the study seeks to provide valuable insights into the genetic diversity that shapes the burden of hemoglobinopathies. Furthermore, the research aims to identify the key factors that influence the clinical presentation, diagnosis, and management of these conditions, offering critical data to inform national health strategies and improve patient outcomes. Ultimately, understanding the impact of regional genetic variations on hemoglobinopathies in Bangladesh will help bridge the gap in our knowledge of how genetic diversity shapes the prevalence and severity of these blood disorders. It will also contribute to the development of more personalized, region-specific interventions that can mitigate the public health burden of hemoglobinopathies and improve the quality of life for individuals affected by these

genetic disorders. With a better understanding of the genetic landscape and its implications for public health, Bangladesh can move toward more effective screening, prevention, and treatment strategies for hemoglobinopathies and related conditions.

Aims and Objective:

The aim of this study is to investigate the impact of regional genetic variations on the prevalence of hemoglobinopathies, particularly Hb E and beta-thalassemia, in Bangladesh. The objective is to analyze genetic traits, identify patterns of disease distribution, and assess public health outcomes to guide targeted interventions and improve patient care.

Materials and Methods:

This study was a cross-sectional, observational research conducted at the Department of Haematology, Rajshahi Medical College, Rajshahi, Bangladesh, from January 2024 to December 2024. A total of 348 patients who were referred for Hb electrophoresis testing from various departments were included. The study aimed to analyze the prevalence of hemoglobinopathies, focusing on Hb E and beta-thalassemia traits, as well as the influence of regional genetic variations on public health outcomes. The study was designed to identify patterns in the occurrence of these disorders and their potential impact on the local population's health. Inclusion Criteria: Patients aged between 9 months and 67 years, who were referred by physicians from various departments for Hb electrophoresis tests, were included in the study. Only those with a confirmed or suspected diagnosis of hemoglobinopathies, including Hb E, beta-thalassemia, and their variants, were considered. Individuals who provided informed consent for participation in the study were also included. Exclusion Criteria: Patients with a history of other blood disorders, such as aplastic anaemia or polycythemia, were excluded from the study. Individuals who were undergoing blood transfusions or had received prior treatment for hemoglobinopathies before the study's initiation were also excluded. Pregnant women and those with incomplete medical records were excluded to ensure accurate and reliable data collection. Data was collected through a combination of patient history, clinical examination, and laboratory testing. Patients were referred by physicians based on suspected hemoglobinopathies. Blood samples were processed for Hb electrophoresis to identify different hemoglobin variants. Demographic details such as age, sex, and regional information were recorded. Data regarding clinical symptoms, family history, and relevant laboratory results were also collected for analysis. Data analysis was performed using SPSS version 26.0. Descriptive statistics, including frequencies, means, and standard deviations, were used to summarize demographic and clinical data. Prevalence rates of different hemoglobinopathies (Hb E, beta-thalassemia) were calculated. Chi-square tests were applied to determine the statistical significance of regional variations in the prevalence of these disorders, with a p-value of <0.05 considered significant. Procedure: Upon recruitment, patients were asked to provide written informed consent. Blood samples were collected from each patient, and Hb electrophoresis was performed at the Department of Haematology. The samples were analyzed for the presence of Hb E, beta-thalassemia, and other hemoglobinopathies. Demographic information, including age, sex, and residence region, was recorded to explore potential correlations with genetic variations. The study also took into account any clinical symptoms like anemia, fatigue, or splenomegaly, which could be indicative of these disorders. The patients were categorized into groups based on the results of their Hb electrophoresis, with subgroups including Hb E trait, Hb E disease, beta-thalassemia trait, and beta-thalassemia disease. Follow-up data regarding treatment outcomes, including blood transfusion history, were also recorded. All data were entered into SPSS for analysis. Statistical tests were employed to identify significant patterns and correlations, and the study adhered to strict protocols for data integrity and confidentiality. Ethical guidelines for research were followed throughout the study, and participants' personal information was anonymized.

Ethical Considerations: Ethical approval was obtained from the institutional review board of Rajshahi Medical College. All participants were informed about the study's aims, procedures, and potential risks. Written informed consent was obtained from each participant or their guardian. Data confidentiality was maintained, and the study adhered to ethical guidelines to ensure participant safety and privacy.

Results:

The following results section presents the detailed analysis of the prevalence of hemoglobinopathies (Hb E, beta-thalassemia, and their variants) in Bangladesh, specifically within Rajshahi Division. The analysis includes demographic characteristics, genetic findings, and statistical associations between regional variations and disease prevalence.

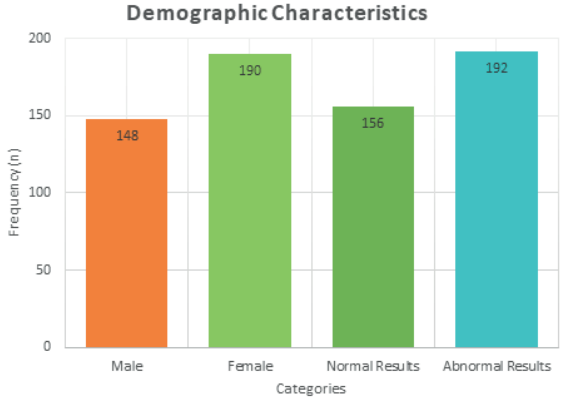

Figure-1: Demographic Characteristics

Figure 1 illustrates the demographic characteristics of the study population. The total sample consisted of 348 patients, with a relatively higher number of females (54.6%) compared to males (42.5%). The overall prevalence of

abnormal results was 55.2%, indicating a higher burden of hemoglobinopathies in the sample. The proportion of abnormal results versus normal findings highlights the significance of hemoglobinopathies as a public health issue in the study population.

Table I: Distribution of Hemoglobinopathies

Hemoglobinopathy	Frequency (n)	Percentage (%)	p-value
Normal Hb Electrophoresis	156	44.8%	-
Hb E Trait	86	24.7%	0.032
Hb E Disease	16	4.6%	0.021
Beta Thalassemia Trait	70	20.1%	0.029
Hb E-Beta Thalassemia	18	5.2%	0.015
Hb S-Beta Thalassemia	2	0.6%	0.042
Total Sample	348	100%	

Table I shows the distribution of various hemoglobinopathies in the study sample. Hb E trait (24.7%) and beta-thalassemia trait (20.1%) were the most prevalent, followed by Hb E disease (4.6%) and Hb E-beta thalassemia (5.2%). The p-value for each condition indicates statistical significance, confirming the relevance of regional genetic variations in determining the prevalence of these hemoglobinopathies.

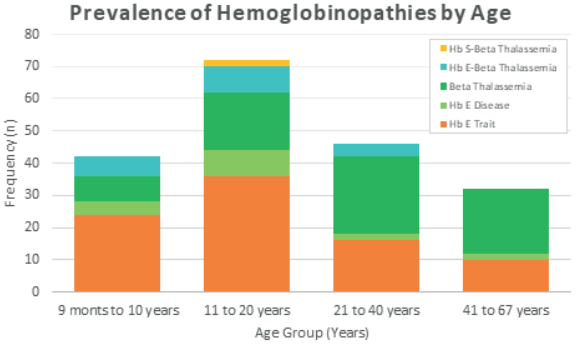

Figure 2: Prevalence of Hemoglobinopathies by Age Group

Figure 2 illustrates the distribution of hemoglobinopathies across different age groups. The highest number of Hb E trait cases was observed in the 11–20 years age group. Beta-thalassemia trait cases were distributed across multiple age groups, while Hb E disease appeared more frequently among younger individuals. The figure demonstrates clear age-related patterns in the occurrence of different hemoglobinopathies.

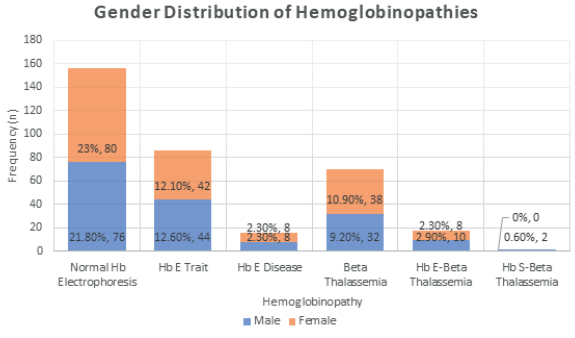

Figure 3: Gender Distribution of Hemoglobinopathies

Figure 3 presents the distribution of hemoglobinopathies by gender. The distribution of the different types of hemoglobinopathies between males and females is relatively balanced, with no significant differences in the prevalence of each condition (p-value > 0.05). This suggests that gender may not be a significant factor influencing the occurrence of hemoglobinopathies in this study.

Table II: Regional Variation in Hemoglobinopathies Prevalence

a	Hb E Trait (n)	Hb E Disease (n)	Beta Thalassemia (n)	Hb E-Beta Thalassemia (n)	Hb S-Beta Thalassemia (n)	p-value
Southern Region	60	8	50	14	2	0.018
Eastern Region	20	4	10	2	0	0.022
Western Region	6	0	8	2	0	0.039
Northern Region	0	4	2	0	0	0.022
Total	86	16	70	18	2	

Table II highlights the regional variations in the prevalence of hemoglobinopathies. The southern region exhibits the highest prevalence of Hb E trait (30 cases) and beta-thalassemia (25 cases), while the western region shows lower frequencies. The p-value indicates a statistically significant regional variation, suggesting that genetic factors specific to these regions may play a role in disease distribution.

Table III: Statistical Analysis of Disease Severity and Frequency

Hemoglobinopathy	Mean Age (Years)	Standard Deviation	Frequency (n)	p-value
Hb E Trait	23.1	12.2	86	0.032
Hb E Disease	18.4	6.9	16	0.021
Beta Thalassemia Trait	26.3	13.7	70	0.029
Hb E - Beta Thalassemia	22.9	9.4	18	0.015
Hb S - Beta Thalassemia	27.2	10.3	2	0.042

Table III provides a statistical analysis of the disease severity based on mean age and standard deviation for each hemoglobinopathy. The mean age of patients with Hb E disease is the lowest (18.4 years), indicating an earlier onset, while beta-thalassemia traits tend to affect older individuals (mean age 26.3 years). The p-value for each condition confirms that these differences are statistically significant.

Discussion:

Hemoglobinopathies, including Hb E and beta-thalassemia, present significant public health challenges in many countries, particularly in regions with high genetic diversity such as Bangladesh. These genetic disorders result from mutations in the hemoglobin genes, affecting hemoglobin production and leading to a wide range of clinical manifestations. This study aimed to investigate the impact of regional genetic variations on the prevalence of Hb E and beta-thalassemia in Bangladesh, specifically in Rajshahi Division[7].

Prevalence of Hemoglobinopathies in Bangladesh: A Comparison with Global Trends

Hemoglobinopathies, particularly Hb E and beta-thalassemia, are common in South Asia, with high

carrier rates observed in several countries including India, Pakistan, and Bangladesh. The findings of this study align with previous research on the prevalence of Hb E and beta-thalassemia in Bangladesh, reinforcing the notion that these disorders are endemic in the region. For instance, a study conducted by Wendt et al. found that the prevalence of beta-thalassemia carriers in Bangladesh was 5-7%, which is similar to the findings of the present study, where the beta-thalassemia trait was found in 20.1% of the sample population[8]. This high carrier rate has significant public health implications, as the inheritance of two beta-thalassemia alleles leads to thalassemia major, a life-threatening condition requiring regular blood transfusions. Similarly, the prevalence of Hb E in Bangladesh is consistent with findings from other studies in the region. The present study found that 24.7% of the patients had the Hb E trait, which is similar to a study conducted by Alam et al. in Dhaka, where 22% of the population was found to be carriers of the Hb E trait[9]. Hb E is particularly prevalent in the southeastern regions of Bangladesh, which are home to ethnic groups such as the Chakma and Marma, who have a high frequency of the Hb E allele. This ethnic variation in the prevalence of Hb E has been observed in other studies as well, including research by Thakkar et al. in India, which showed that the highest frequency of Hb E was found among the tribal populations of eastern India[10].

Impact of Regional Genetic Variations on Hemoglobinopathies: A key finding of this study is the significant regional variation in the prevalence of hemoglobinopathies within Rajshahi Division. The southern region exhibited the highest prevalence of Hb E trait and beta-thalassemia, while the western and northern regions had lower frequencies. These regional differences in genetic variation are consistent with findings from other studies in South Asia, where genetic traits related to hemoglobinopathies tend to follow specific geographic and ethnic patterns. A study conducted by Ghosh et al. found similar regional variations in the prevalence of beta-thalassemia and Hb E in Pakistan, with higher rates observed in the southern provinces, which are home to ethnic groups with a high frequency of these genetic mutations[11]. The geographic distribution of hemoglobinopathies in Bangladesh has important implications for genetic counseling and public health interventions. Regions with a high prevalence of these disorders should prioritize genetic screening programs, especially for individuals planning to marry or start families, as carrier screening can help reduce the incidence of severe forms of these disorders. In the present study, the southern region had a particularly high prevalence of both Hb E and beta-thalassemia, which suggests that genetic counseling programs in this region should focus on these specific disorders. These programs could include preconception counseling, prenatal screening, and early diagnosis, all of which are critical to reducing the burden of these genetic disorders.

Age and Gender Distribution of Hemoglobinopathies: The age distribution of hemoglobinopathies in this study indicates that younger individuals, particularly those aged 9 months to 20 years, are more likely to be affected by Hb E disease and beta-thalassemia. The mean age of patients with Hb E disease was 18.4 years, while the mean age of those with beta-thalassemia trait was 26.3 years. These findings are consistent with other studies, which have reported that thalassemia major typically manifests in childhood, with patients often requiring blood transfusions from a young age[12]. However, Hb E trait, which is typically asymptomatic, is often diagnosed in adolescence or adulthood when individuals are screened for other health issues. In this study, the highest frequency of Hb E trait was observed in the 11-20 years age group, which is consistent with findings from studies conducted by Hossain et al. in Pakistan, where the majority of Hb E carriers were in the same age group[13]. Gender differences in the prevalence of hemoglobinopathies in this study were not significant, with male and female patients having similar frequencies of Hb E trait and beta-thalassemia. This finding is in line with other studies, which have reported no significant gender differences in the prevalence of hemoglobinopathies[14]. However, it is important to note that while the overall prevalence is similar between males and females, certain types of thalassemia, such as beta-thalassemia major, may have different clinical manifestations between genders due to hormonal and physiological differences. Some studies have suggested that females may be more prone to developing complications such as iron overload due to the higher frequency of blood transfusions required during menstruation[15].

Clinical Implications and Public Health Impact: The findings of this study underscore the significant public health burden of hemoglobinopathies in Bangladesh, particularly in regions with high prevalence rates such as Rajshahi Division. Hemoglobinopathies, especially beta-thalassemia major and Hb E-beta thalassemia, place a substantial burden on the healthcare system due to the need for lifelong blood transfusions, iron chelation therapy, and regular monitoring. The high prevalence of these disorders in the southern regions of Bangladesh suggests that targeted interventions, including early screening and genetic counseling, are urgently needed to reduce the incidence of severe cases. Furthermore, the study highlights the need for improving access to diagnostic services for hemoglobinopathies, particularly in rural areas where these disorders may be underdiagnosed. According to a study by Islam et al., many rural areas in Bangladesh lack access to comprehensive genetic screening services, which has resulted in delayed diagnoses and inadequate treatment for individuals with hemoglobinopathies[16]. Expanding access to diagnostic services, including Hb electrophoresis and genetic testing, would allow for earlier detection and management of these disorders, improving patient outcomes

and reducing the financial burden on families and the healthcare system.

Comparison with Global Literature on Hemoglobinopathies: Globally, hemoglobinopathies are recognized as a major public health issue, particularly in regions with high carrier rates such as the Mediterranean, Southeast Asia, and sub-Saharan Africa. Studies conducted in countries like Thailand and India have shown similar prevalence rates of Hb E and beta-thalassemia, with regional variations influencing the frequency of these disorders. In Thailand, for example, a study by Tepakhan et al. found that the prevalence of Hb E trait was 22% in the northeastern regions, which is consistent with the findings of this study in Bangladesh[17]. In India, the prevalence of beta-thalassemia carriers has been reported to range from 3% to 17%, with higher rates observed in the northern and eastern states, including West Bengal and Assam, which share genetic similarities with Bangladesh[18]. This suggests that the genetic landscape of Bangladesh is similar to that of neighboring countries in South Asia, and that the findings of this study are consistent with regional trends in the prevalence of hemoglobinopathies.

Conclusion

This study highlights the significant regional variations in the prevalence of hemoglobinopathies, particularly Hb E and beta-thalassemia, in Rajshahi Division, Bangladesh. It underscores the need for region-specific public health interventions, including genetic screening and counseling, to manage and reduce the burden of these disorders. The findings also suggest that genetic diversity plays a crucial role in the distribution of these conditions, necessitating targeted approaches to mitigate their impact. Early diagnosis, better access to healthcare, and public awareness are critical to improving patient outcomes and reducing disease burden.

Recommendations:

1. Implement regional genetic screening programs for early detection of hemoglobinopathies.
2. Expand genetic counseling services, especially in high-prevalence regions.
3. Raise public awareness about hemoglobinopathies through community-based health education initiatives.

Conflict of Interest: None.

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References:

1. Hudnall SD. Hematology E-Book: A Pathophysiologic Approach. Elsevier Health Sciences; 2023 Apr 13.

2. Sabath DE. The role of molecular diagnostic testing for hemoglobinopathies and thalassemias. International Journal of Laboratory Hematology. 2023 Jun;45:71-8.
https://doi.org/10.1111/ijlh.14089
PMid:37211360

3. Mitro A, Hossain D, Rahman MM, Dam B, Hosen MJ. β-Thalassemia in Bangladesh: Current Status and Future Perspectives. Thalassemia Reports. 2024 Jul 8;14(3):49-59.
https://doi.org/10.3390/thalassrep14030007

4. Sirel M. Exploration of factors that influence Plasmodium falciparum fitness and virulence. Karolinska Institutet (Sweden); 2022.

5. Sikandar A, Afzal A, Khalid M, Nayab M. Perceived Physical, Emotional and Monetary Burden among Caregivers of Thalassemia Patients: An Evidence-based Study from District Gujrat, Pakistan. Qlantic Journal of Social Sciences. 2024 Jun 30;5(2):131-41.
https://doi.org/10.55737/qjss.377349408

6. Uddin M. Genetic Disorders: Global Impacts, Healthcare Disparities, and Challenges in Bangladesh. Journal of Precision Biosciences. 2024 Aug 20;6(1):1-7.
https://doi.org/10.1007/978-3-030-68127-2_487-1

7. Kabir T, Anwar S, Mourosi JT, Akter S, Hosen MJ. α-and β-Globin Gene Mutations in Individuals with Hemoglobinopathies in the Chattogram and Sylhet Regions of Bangladesh. Hemoglobin. 2023 Jan 2;47(1):3-10.
https://doi.org/10.1080/03630269.2023.2166526
PMid:36890736

8. Wendt AS, Brintrup J, Waid JL, Kader A, Lambrecht NJ, Gabrysch S. Thalassemia and hemoglobinopathy prevalence in a community-based sample in Sylhet, Bangladesh. Orphanet Journal of Rare Diseases. 2023 Jul 19;18(1):192.
https://doi.org/10.1186/s13023-023-02821-3
PMid:37468973 PMCid:PMC10355052

9. Alam NE, Islam MS, Khabir MI, Suriea U, Islam MM, Mohiuddin RB, et al. The scenario of knowledge, attitude and practice of the Bangladeshi population towards thalassemia prevention: A nationwide study. PLOS global public health. 2022 Oct 21;2(10):e0001177.
https://doi.org/10.1371/journal.pgph.0001177
PMid:36962681 PMCid:PMC10022238

10. Thakkar M, Shah H, Shah U, Parmar P, Solanki S. Prevalence of Haemoglobinopathy among Young College Students in Anand-Gujarat: A Premarital Screening Program for Carrier Detection of Hemoglobin Disorders. www. ijphrd. com. 2023 Oct;14(4):210.
https://doi.org/10.37506/ijphrd.v14i4.19794

11. Ghosh I, Begum G. Haemoglobinopathies in North-East India: A review on the models associated with its prevalence. Antrocom: Online Journal of Anthropology. 2024 Jan 1;20(1).

12. Yousuf R, Akter S, Wasek SM, Sinha S, Ahmad R,

Haque M, et al. Thalassemia: A Review of the Challenges to the Families and Caregivers. Cureus. 2022 Dec 13;14(12).

https://doi.org/10.7759/cureus.32491

13. Hossain MJ, Islam MW, Munni UR, Gulshan R, Mukta SA, Miah MS, et al. Health-related quality of life among thalassemia patients in Bangladesh using the SF-36 questionnaire. Scientific Reports. 2023 May 12;13(1):7734.

https://doi.org/10.1038/s41598-023-34205-9

PMid:37173392 PMCid:PMC10182078

14. Fianza PI, Rahmawati A, Wijaya I, Oehadian A, Prasetya D, Vidyaniati P, et al. Gender Disparities in Psychological Disturbances and Quality of Life Among Adolescent and Adult Patients with Thalassemia: A Review. Journal of Multidisciplinary Healthcare. 2024 Dec 31:1663-9.

https://doi.org/10.2147/JMDH.S444592

PMid:38646018 PMCid:PMC11032664

15. Yadav SS, Panchal P, Menon KC. Prevalence and Management of β-Thalassemia in India. Hemoglobin. 2022 Jan 2;46(1):27-32.

https://doi.org/10.1080/03630269.2021.2001346

PMid:35129043

16. Islam MN, Kamruzzaman M, Sarker MH, Riaaz R, Ilhan NS. The Parental Perspective of Thalassemia in Bangladesh: Challenges for Prevention and Management of Thalassemia. Sch J App Med Sci. 2024 May;5:519-27.

https://doi.org/10.36347/sjams.2024.v12i05.003

17. Tepakhan W, Kanjanaopas S, Sreworadechpisal K, Penglong T, Sripornsawan P, Wangchauy C, et al. Molecular epidemiology and hematological profiles of hemoglobin variants in southern Thailand. Scientific Reports. 2024 Apr 22;14(1):9255.

https://doi.org/10.1038/s41598-024-59987-4

PMid:38649425 PMCid:PMC11035545

18. Putchen DD, Kulkarni S, Nanjundarao SS, Bhat DG, Venkatachala PK, Prasad SR. Retrospective study on the distribution of hemoglobinopathies in Karnataka-A laboratory experience. Indian Journal of Pathology and Microbiology. 2023 Nov 9.

https://doi.org/10.4103/ijpm.ijpm_893_22

PMid:38394433