

## Systematic Review

# Distribution of ABO and Rh (D) blood group and allele frequency in North-East India: a systematic review

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## ABSTRACT

Despite several reviews on ABO and Rh (D) blood group frequencies across different regions of India, a comprehensive analysis from North-Eastern states of India is lacking. This systematic review analysed the distribution and allelic frequencies of ABO and Rh (D) antigens among the states and ethnic groups in North East India. Databases including PubMed, Google Scholar, Web of Science, Science Direct and the library web portal of Sikkim University were searched for articles published between 1958 and 2024. After screening for titles, abstracts, and full texts, 24 original research articles were included for review. The allelic frequency of blood antigens was calculated using Hardy-Weinberg equilibrium model. Studies from seven states of North East India, including a total of 40,513 individuals' ABO data, were analyzed. Blood group O (36.07%) was found to be most prevalent followed by A (30.72%), B (24.66%), and AB (8.55%). Blood group O was dominant in Arunachal Pradesh, Assam, Manipur, Sikkim and Nagaland; A in Meghalaya; and B in Tripura. The allelic frequencies for  $I^A$  (p),  $I^B$  (q) and i(r) were found to be 0.22, 0.18 and 0.60 respectively. A total of 98% individuals were Rh(D) positive, while 2% were Rh(D) negative. A notable variation was observed for ABO frequency among the various ethnic populations of North-East India. Even though variations were observed in blood group frequency among the ethnic groups and states of North East India, overall frequency was found to be in the order: O>A>B>AB.

**Keywords:** Blood group, North-East India, Frequency

## INTRODUCTION

The North-East India is one of the most culturally diverse regions of India. It consists of eight states, namely Arunachal Pradesh, Assam, Nagaland, Manipur, Mizoram, Tripura, Sikkim, and Meghalaya.<sup>1</sup> These states span 255,128 square kilometers and are located between 22°00' and 29°30' N and 89°40' and 97°25' E. According to the 2011 census, the region has a total population of 45,161,611, with a non-uniform distribution.<sup>1</sup> The Brahmaputra plains, the Barak Rivers in Assam, the Imphal plain in Manipur, and the western portion of Tripura are the most densely populated areas of North-East India.<sup>2</sup> Based on their ethnicity, Sengupta (2003) divided the people of North-East India into two groups: the Indid

and the Mongoloid.<sup>1</sup> The Indid group consists primarily of Hindu castes and Muslims, who are thought to be Caucasoid in origin. The Mongoloids, on the other hand, previously occupied nearly the entire region e. g., Biates (also known as Mizo Chinnlung or Sianglung) Panggi, Komkar, Padam etc.<sup>3</sup> Languages belonging to the Tibeto-Burman family, Austro-Asian family, and the Indo-Aryan family are spoken in the North-East India.<sup>1</sup> Endogamy and exogamy form the foundation of the tribal community of North-Eastern India.<sup>1</sup> Endogamous marriage customs have been documented among many of the tribes, such as the Chakhesang Naga tribe, Thadou-Kuki tribe in Manipur and Mizoram, Adi (mixed) tribe of Arunachal Pradesh, which may have contributed to genetic isolation and unique traits within the communities.<sup>4-6</sup> Conversely,

consanguineous practices are observed among Kabui and Muslims.<sup>4</sup>

Blood in the human body is considered to be the identity of all.<sup>7</sup> Out of the different blood group systems, ABO and Rh stand out as the most crucial for transfusion and transplantation. The selection of blood antigens in a given area can be influenced by factors such as race, ethnicity, geographical conditions, genetic drift, and the frequency of population migration.<sup>8</sup> Moreover, environmental factors and natural selection play a role in determining the distribution of blood groups to ensure the survival of the population in that region.<sup>8</sup>

The ABO blood group frequency in the Indian population has been reviewed previously, with O (34.56%) accounting as the most dominant blood group, followed by B (34.10%), A (23.16%), and AB (8.18%), while Rh(D)-positive blood group was the most dominant (94.13%) over Rh(D)-negative (5.87%).<sup>8</sup> Even though the study included data from 23 states (out of 29 states) of India however, some limitations exist in the study as far as North-East India is concerned. They are; (i) inclusion of only four states from North-Eastern India (Assam, Manipur, Sikkim, and Tripura), (ii) non-consideration of ethnicity for the analysis of ABO frequency distribution from North-Eastern India. Thus, the study does not comprehensively describe the blood group frequency of North-East India.

Therefore, this systematic review was performed with the objective to review the retrospective studies and delineating the patterns of phenotypic and allelic frequency distribution of ABO and Rh blood antigens in

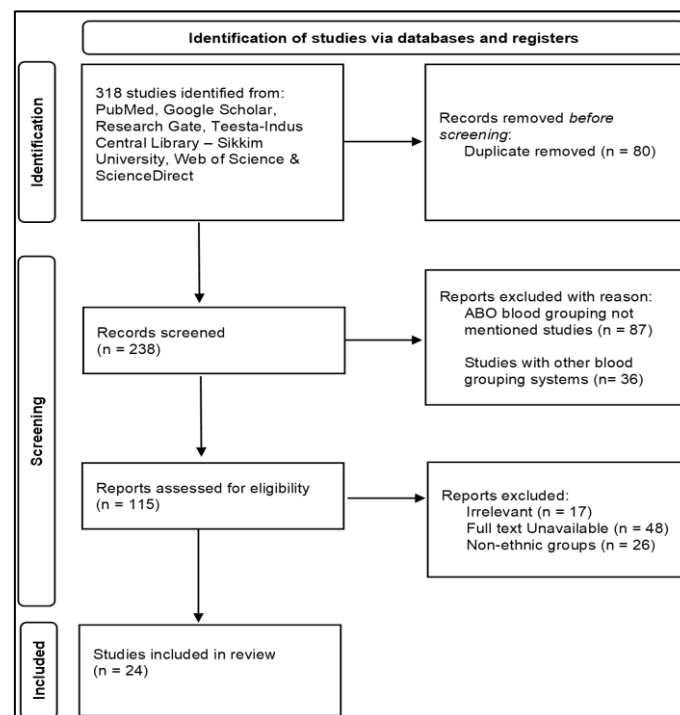
North-East India. Further, the study tries to critically evaluate the results of previous studies with their limitations and outline the future course of studies to better understand the distribution of ABO and Rh blood group among the populations of North-East India.

## METHODS

The review was conducted as per the guidelines laid down in the 'preferred reporting items for systematic reviews and meta-analysis (PRISMA) statement'.<sup>9</sup> The goal of the search was to retrieve studies that reported phenotype and allelic frequency of ABO and Rh(D) among the populations of North-East India.

### Database searches/literature search

The literature was searched using various search engines, like PubMed, Google Scholar, Research Gate, Teesta-Indus Central library web portal of Sikkim University, Web of Science, and ScienceDirect. The search terms like "Blood Group", "ABO and Rh (D)", "Distribution/Frequency", along with the name of various North-East States of India", "Importance of ABO Blood group", "Disease association with ABO Blood group" were used to identify relevant original research and review articles. The search was performed during the period of January 2024 to August 2024 and restricted to the English language. Initially, the literature obtained from the search was screened by title, followed by abstract, and finally full-text articles were further screened. The Full text of the peer-reviewed journal articles was then selected for review (Figure 1). All relevant studies from 1958 to 2024 were considered for the review.



**Figure 1: PRISMA-compliant flow chart showing the studies that were filtered, chosen, and included.**

### **Criteria for eligibility of studies**

Research articles published only in the English language from 1958 to 2024 describing the ABO and Rh (D) frequency from the states of North-East India were selected. All the authors independently determined the eligibility for inclusion of the articles. The abstract from the conference and letters to the editors were not included for review. In case of more than one study describing the ABO from a particular state, the results were compiled in order to obtain the overall frequency in a particular state. Additionally, the total count of individuals with the same blood group from all states was compiled for the analysis. The allelic frequency was calculated with the method as describe elsewhere.<sup>8</sup>

### **Data extraction and grouping**

Pertinent data were extracted from the chosen research articles and stored in Excel spreadsheet. Names of authors, publication year, research region, ethnicity, study design, sample size, participant type, and observed ABO and Rh(D) frequencies were among the information that was retrieved. The studies were grouped based on eight states of North-East India. All the studies describing the distribution/prevalence/frequency of ABO and Rh(D) from a particular state of North-East India were grouped in a single table. Individuals with matching blood groups from all studies published in a particular region were added to calculate the frequency of blood groups of that region. The blood group distribution percentages were calculated based on the total number of participants.

### **Determination of allelic frequency**

Allelic frequencies of different blood antigens were determined using the Hardy-Weinberg model, as described elsewhere.<sup>8</sup> Under the premise that the ABO blood type system is defined by three alleles of a single gene (A, B, and O), where A and B are autosomal-dominant over the O allele and co-dominant with each other, this principle also predicts the highest likelihood ratio. Based on the allelic frequency data, expected phenotypic frequencies for different blood antigens were computed. The chi-square test was then used to assess the discrepancies between the observed and expected frequencies of the blood antigens.

## **RESULTS**

### **Search results**

The initial database searches yielded 318 articles (Figure 1). After screening the titles, abstracts, and full texts, and removing duplicates, 24 original research articles which described the ABO frequency of populations from North-East India, consisting of 40,513 participants across seven states (Arunachal Pradesh, Assam, Manipur, Meghalaya, Nagaland, Sikkim, Tripura) were selected for review (Table 1). In total, 5 studies from Arunachal Pradesh, 7

studies from Assam, 4 studies from Manipur, 1 study of Meghalaya, 3 studies from Nagaland, 3 studies from Sikkim, and 1 study from Tripura were found to describe the ABO blood group frequency. No study was available from Mizoram.

Based on our analysis, O (36.07%) is observed to be the most frequent blood group in North-East India, followed by A (30.72%), B (24.66%), and AB (8.55%). Rh positive individuals (98.14%) were more frequent than the Rh-negative individuals (1.86%). The overall allelic frequencies for I<sup>A</sup> (p), I<sup>B</sup> (q) and i (r) were found to be 0.22, 0.18, and 0.60 respectively. Additionally, O was found to be the most frequent blood group in Arunachal Pradesh, Assam, Manipur, and Nagaland, A is found to be dominant in Meghalaya, and Sikkim, while B was found to be frequent in Tripura. A notable variation was observed for ABO frequency among the various ethnic populations of North-East India.

### **Characteristics of studies included in systematic review**

This systematic review comprised 24 papers, with a total sample size of 40,513. Most studies were population-based, focusing on the distribution of ABO and Rh blood groups in specific regions. Most of the studies were performed on the ethnic tribal populations from different states of North-East India, such as Arunachal Pradesh, Assam, Manipur, Meghalaya, Nagaland, Sikkim, and Tripura, while a few studies were published without mentioning the ethnicity of the population. All studies assessed the distribution of ABO blood groups (A, B, AB, O), while few studies did not mention about distribution of Rh(D) antigens. The primary outcome of interest was the percentage distribution of ABO blood groups and Rh factor. Secondary outcomes included the correlation between specific blood groups and disease prevalence in certain regions. Only one study describing the ABO frequency among Biates tribe was found, while even though one study was found from Tripura it included six tribal populations. In twelve studies, the sex of the participants was mentioned. The method of blood typing is mentioned in fourteen studies. Molecular typing was employed in none of the studies.

### **Frequency distribution of ABO and Rh(D) in the states of North-East India**

#### **Arunachal Pradesh**

The maximum number of studies used in this review was published from Arunachal Pradesh. Overall, the most frequent blood group observed in Arunachal Pradesh is O (40.33%), followed by A (29.15%), B (22.87%), and AB (7.65%). Therefore, the ABO blood group frequencies in Arunachal Pradesh follow the sequence of O>A>B>AB. However, among the 20 ethnic groups in Arunachal Pradesh, studies indicated that blood group O predominates among the tribes including Nyishi and Galo, Komkar, Padam, Nocte, Wangcho, Tangsa, Singpo, Nishi,

Gallong, Idu Mishmi, Khampti, Tagin, and Tاراon, among others (Mikir, Sartang, Miji, Singpo, Puroik, Sherdukpen, Tutsa).<sup>6,10-12</sup> Conversely, blood group A is prevalent among tribes such as Panggi, Apatanis, and Adi.<sup>6,10,13</sup> Blood group B was notably common among the Monpa Tawang and Membra (Table 2).<sup>10,11</sup> The overall allelic frequency of I<sup>A</sup> (p), I<sup>B</sup>(q) and i(r) was observed to be 0.20, 0.17 and 0.63 respectively.

#### Tripura

The overall distribution of ABO blood groups in Tripura indicates that blood group B is most prevalent at 32.80%, followed by blood group A at 27.65%, blood group O at 26.95%, and blood group AB at 12.60%. Therefore, the ABO blood group frequencies in Tripura follow the sequence of B>A>O>AB (Table 3). Among the different tribal population, blood group B is the most frequent among Noatia, Rieng, and Morsam tribes, while O is most common among Rankhal and Kaiping tribes. The Tippera tribe, on the other hand, shows the highest prevalence of blood group A.<sup>14</sup> The overall allelic frequency observed for I<sup>A</sup> (p), I<sup>B</sup>(q), and i(r) was found to be 0.23, 0.26, and 0.51 respectively.

#### Assam

Overall, the distribution of ABO blood groups in Assam shows that O is the most common (37.44%), followed by B (28.12%), A (25.88%), and AB (8.56%). Thus, the hierarchy of ABO blood group frequencies in Assam is O>B>A>AB (Table 4). Moreover, among the 26 ethnic groups in Assam, the prevalence of blood group O is notably highest in ethnic populations such as Brahmin, Kalita, Jogi, Kayastha, Bishya, Kumar, Keot, Hira, Muslim, Ahom, Rajbanshi, Lalung, Chutia, Sonwals, Aiton, Turung, and Khamyang.<sup>15-17</sup> Blood group B predominates among the Kaibarta, Moran, Kachari, Garo<sup>15</sup> and Khamti,<sup>17</sup> while blood group A is most prevalent among the Rabha, Mikir, Deuri, and Mishing communities.<sup>15,16</sup> The general distribution of ABO blood groups in Assam shows that O is 37.60%, A is 24.80%, B is 31.69%, and AB is 5.91%.<sup>18-20</sup> The overall allelic frequency of I<sup>A</sup> (p), I<sup>B</sup>(q) and i(r) was observed to be 0.18, 0.21, and 0.61 respectively.

#### Nagaland

Cumulatively, in Nagaland, blood group O is the most common, accounting for 46.24% of the population,

followed by blood groups A (28.85%), B (20.31%), and AB (4.60%). Therefore, the prevalence of ABO blood groups in Nagaland ranks in the order of O>A>B>AB (Table 5). Blood group O is consistently prevalent across all seven major ethnic tribes, viz. Chekhesang, Sumi, Naga, Angami, Ao, Mao, and Lotha-Nagas.<sup>5,21,22</sup> The A blood group is the second most common among all tribes, except for Ao and other Naga tribes, where blood group B ranks as the second most prevalent. The overall allelic frequency of I<sup>A</sup> (p), I<sup>B</sup>(q), and i(r) was observed to be 0.19, 0.13 and 0.68 respectively.

#### Manipur

Overall, blood group O (43.63%) is the most prevalent in Manipur. Following O, blood group A accounted for 25.80%, while B and AB comprised 21.30% and 9.27%, respectively (Table 6). Therefore, the prevalence of ABO blood groups in Manipur ranks in the order of O>A>B>AB. Among the tribal groups such as Maram, Mao Naga, Purum, Pangan and Kabui, blood group O is prevalent, whereas blood group A is common among Meitei and Brahmin populations.<sup>4,23-25</sup> The overall allelic frequency of I<sup>A</sup> (p), I<sup>B</sup>(q) and i(r) was observed to be 0.17, 0.17, and 0.66 respectively.

#### Meghalaya

In Meghalaya, it was found that the Baites tribe has a high frequency of blood group A (41.40%) followed by O (25.30%), B (22.80%), and AB (10.50%). The blood group frequency was in the order A>O>B>AB (Table 7).<sup>3</sup> The overall allelic frequency of I<sup>A</sup> (p), I<sup>B</sup>(q) and i(r) was observed to be 0.31, 0.19, and 0.50 respectively.

#### Sikkim

The distribution of ABO and Rh (D) blood groups showed that blood group O had the highest prevalence at 34.29% in Sikkim, followed by blood group A at 33.23%, B at 23.73%, and AB at 8.75%. Therefore, the frequency among the surveyed population was ranked as O>A>B>AB (Table 8). With regard to different ethnic communities, blood group A was most prevalent among Lepcha, Rai, Subba, Sherpa, Manger, Pradhan, and Bhujel.<sup>26</sup> Blood group O was predominant among Bhutia, Tamang, Sanayasi, Jogi, Rawat, Chettri, Gurung, Sharma and Kami, while blood group B is common in Mukhia.<sup>26,27</sup> The overall allelic frequency of I<sup>A</sup> (p), I<sup>B</sup>(q) and i(r) was observed to be 0.25, 0.15, and 0.60 respectively.

**Table 1: Comparison of frequency percentage of ABO in different states of North-East India.**

North-East states	Blood groups frequency (%)				No. of individuals	Order of distribution	References
	O	A	B	AB			
<b>Arunachal Pradesh</b>	40.33 (2357)	29.15 (1995)	22.87 (1444)	7.65 (538)	6334	O>A>B>AB	Goswami et al, 1990 <sup>13</sup> ; Kotal et al, 2003 <sup>12</sup> ; Krithika et al, 2006 <sup>6</sup> ; Nanda et al, 2021 <sup>10</sup> ; Vokendro and Devi, 2012 <sup>11</sup>
<b>Tripura</b>	26.95 (179)	27.65 (205)	32.8 (220)	12.6 (82)	686	B>A>O>AB	Gupta, 1958 <sup>14</sup>

Continued.



North-East states	Blood groups frequency (%)				No. of individuals	Order of distribution	References
	O	A	B	AB			
Assam	37.44 (8751)	25.88 (5895)	28.12 (7188)	8.56 (1612)	23446	O>B>A>AB	Das et al, 1985 and 1987 <sup>15,16</sup> ; Devi et al, 2023 <sup>18</sup> ; Kumbhakar, 2016 <sup>19</sup> ; Shyamacharan Singh and Phookan, 1990 <sup>17</sup> ; Talukdar and Sarma, 2014 <sup>20</sup>
Nagaland	46.24 (372)	28.85 (259)	20.31 (138)	4.6 (40)	809	O>A>B>AB	Kiewhuo et al, 2019 <sup>21</sup> ; Murry et al, 2001 <sup>22</sup> ; Pojar, 2018 <sup>5</sup>
Manipur	43.63 (987)	25.80 (596)	21.30 (483)	9.27 (230)	2296	O>A>B>AB	Meitei et al, 2010 <sup>4</sup> ; Panmei et al, 2014 <sup>23</sup> ; Singh and Singh, 2007 <sup>25</sup> ; Soram et al, 2014 <sup>24</sup>
Meghalaya	25.30 (41)	41.40 (67)	22.80 (38)	10.50 (16)	162	A>O>B>AB	Haloi 2011 <sup>3</sup>
Sikkim	34.29 (2325)	33.23 (2253)	23.73 (1609)	8.75 (593)	6780	O>A>B>AB	Chamlagai et al, 2024 <sup>27</sup> ; Mathur and Lamichaney, 2017 <sup>37</sup> ; Singh and Rai, 2017 <sup>26</sup>
Mizoram	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Total	36.07%	30.72%	24.66%	8.55%	40,513	O>A>B>AB	

Table 2: ABO and Rh (D) distribution among the different ethnic populations of Arunachal Pradesh.

Ethnic groups	No. of individuals	Phenotype frequency (%)				Allele frequency			Rhesus (%)	
		O	A	B	AB	I <sup>A</sup> (p)	I <sup>B</sup> (q)	I(r)	Rh (Pos)	Rh (Neg)
Panggi	113	33.6	43.4	13.3	9.70	0.32	0.12	0.56	NA	NA
Komkar	72	55.5	22.2	12.5	9.80	0.18	0.11	0.71	NA	NA
Padam	100	61.0	18.0	13.0	8.00	0.14	0.11	0.75	NA	NA
Nocte	332	47.6	31.6	16.6	4.20	0.20	0.11	0.69	NA	NA
Wangcho	330	41.8	35.1	16.6	6.50	0.23	0.12	0.65	NA	NA
Tangsa	391	45.8	21.5	29.0	3.70	0.14	0.18	0.68	NA	NA
Singpo	267	36.7	33.7	25.5	4.10	0.21	0.16	0.63	NA	NA
Nishi	242	33.9	32.2	25.2	8.70	0.23	0.19	0.58	NA	NA
Monpa Tawang	438	29.0	27.8	29.5	13.7	0.23	0.24	0.53	NA	NA
Apatani	332	27.4	41.5	22.0	9.10	0.30	0.17	0.53	NA	NA
Gallong	441	40.5	31.5	20.8	7.20	0.21	0.15	0.64	NA	NA
Idu Mishmi	322	45.3	26.7	17.7	10.3	0.20	0.15	0.65	NA	NA
Khampti	293	44.7	22.2	25.5	7.60	0.16	0.18	0.66	NA	NA
Nyishi	378	41.5	30.7	20.10	7.70	0.20	0.15	0.65	98	2
Galo	81	43.2	19.8	28.4	8.6	0.14	0.20	0.66	100	0
Tagin	51	33.3	29.4	25.5	11.8	0.22	0.20	0.58	98	2
Adi	1992	30.5	35	24.3	10.2	0.25	0.20	0.55	NA	NA
Memba	4	25.0	25.0	50.0	0.00	0.20	0.30	0.50	NA	NA
Mishing (Taroan)	143	48.25	30.77	16.78	4.20	0.19	0.11	0.70	100	0
Others	12	42.0	25.0	25.0	8.0	0.16	0.19	0.65	0	0
Total	6334	40.33	29.15	22.87	7.65	0.20	0.17	0.63	99	1

\*NA=Not Available.

Table 3: ABO and Rh (D) distribution among the different ethnic population of Tripura.

Ethnic groups	No. of individuals	Phenotype frequency (%)				Allele frequency			Rhesus (%)	
		O	A	B	AB	I <sup>A</sup> (p)	I <sup>B</sup> (q)	I(r)	Rh (Pos)	Rh (Neg)
Tippera	150	21.33	41.33	25.33	12.01	0.32	0.22	0.46	NA	NA
Riang	150	22.01	27.33	37.33	13.33	0.23	0.30	0.47	NA	NA
Rankhal	100	46.00	33.00	15.00	6.00	0.22	0.11	0.67	NA	NA
Kaiping	100	38.00	24.00	26.00	12.00	0.17	0.21	0.62	NA	NA
Noatia	142	16.21	28.87	40.84	14.08	0.27	0.33	0.40	NA	NA
Morsam	44	18.19	11.36	52.27	18.18	0.12	0.43	0.45	NA	NA
Total	686	26.95	27.65	32.80	12.60	0.23	0.26	0.51	-	-

\*NA=Not Available.

**Table 4: ABO and Rh (D) distribution among the different ethnic population of Assam.**

Ethnic groups	No. of individuals	Phenotype frequency (%)				Allele frequency			Rhesus (%)	
		O	A	B	AB	I <sup>A</sup> (p)	I <sup>B</sup> (q)	I(r)	Rh (Pos)	Rh (Neg)
Brahmin	1323	40.0	20.0	30.0	10.0	0.17	0.23	0.60	NA	NA
Kalita	1427	37.9	24.7	30.4	7.0	0.18	0.21	0.61	NA	NA
Kaibarta	603	30.0	20.0	40.0	10.0	0.16	0.26	0.58	NA	NA
Kayastha	492	40.0	20.0	33.0	7.0	0.15	0.22	0.63	NA	NA
Baishya	302	47.0	23.0	26.0	4.0	0.15	0.16	0.69	NA	NA
Jogi	302	43.0	27.0	26.0	4.0	0.18	0.17	0.65	NA	NA
Kumar	114	35.0	32.0	30.0	2.0	0.22	0.22	0.56	NA	NA
Keot	138	35.0	23.0	26.0	16.0	0.17	0.20	0.63	NA	NA
Hira	209	49.0	22.0	21.0	8.0	0.15	0.13	0.72	NA	NA
Muslim	727	40.0	26.0	25.0	9.0	0.18	0.18	0.64	NA	NA
Ahom	348	46.0	25.0	21.0	8.0	0.17	0.16	0.67	NA	NA
Moran	200	32.0	29.0	32.0	7.0	0.21	0.23	0.56	NA	NA
Kachari	532	28.7	25.9	32.8	12.6	0.20	0.25	0.55	NA	NA
Rabha	834	25.0	33.0	30.0	12.0	0.26	0.24	0.50	NA	NA
Raj Banshi	166	37.0	17.0	34.0	12.0	0.13	0.23	0.64	NA	NA
Garos	269	25.0	27.0	33.0	15.0	0.22	0.27	0.51	NA	NA
Lalung	208	32.0	29.0	32.0	7.0	0.23	0.24	0.53	NA	NA
Mikir	245	20.0	33.0	26.0	11.0	0.24	0.20	0.56	NA	NA
Chutia	184	47.0	32.0	17.0	4.0	0.20	0.11	0.69	NA	NA
Deuri	200	28.5	44.0	19.5	8.0	0.31	0.16	0.53	NA	NA
Mishing	196	33.0	38.0	21.0	8.0	0.27	0.16	0.57	NA	NA
Sonowals	107	35.5	31.0	27.0	6.5	0.21	0.19	0.60	NA	NA
Aiton	204	50.5	17.6	25.0	6.9	0.129	0.171	0.700	NA	NA
Turung	210	59.5	16.7	21.4	2.4	0.10	0.127	0.773	NA	NA
Khamyang	248	45.6	14.1	35.5	4.8	0.10	0.226	0.674	NA	NA
Khamti	157	31.2	24.2	33.1	11.5	0.195	0.253	0.552	NA	NA
General population	13500	37.60	24.80	31.69	5.91	0.18	0.21	0.61	97.02	2.98
Total	23446	37.44	25.88	28.12	8.56	0.18	0.21	0.61	97.02	2.98

\*NA=Not Available.

**Table 5: ABO and Rh (D) distribution among the different ethnic populations of Nagaland.**

Ethnic groups	No. of individuals	Phenotype frequency (%)				Allele frequency			Rhesus (%)	
		O	A	B	AB	I <sup>A</sup> (p)	I <sup>B</sup> (q)	I(r)	Rh (Pos)	Rh (Neg)
Chekhesang	251	42.2	37.1	16.7	4.00	0.24	0.11	0.65	99.6	0.4
Sumi	18	55.5	38.8	5.5	0.00	0.23	0.03	0.74	96.6	3.4
Angami	16	63.0	19.0	12.0	6.00	0.11	0.10	0.79	100	0.0
Ao	30	33.0	20.0	30.0	17.0	0.16	0.27	0.57	100	0.0
Mao	14	36.0	36.0	28.0	0.00	0.25	0.20	0.60	100	0.0
Naga (Others)	30	47.0	20.0	33.0	0.00	0.20	0.12	0.68	100	0.0
Lotha-Nagas	450	47.0	31.0	17.0	5.00	0.19	0.12	0.69	97.6	2.4
Total	809	46.24	28.85	20.31	4.60	0.19	0.13	0.68	99.1	0.9

**Table 6: ABO and Rh (D) distribution among the different ethnic population of Manipur.**

Ethnic groups	No. of individuals	Phenotype frequency (%)				Allele frequency			Rhesus (%)	
		O	A	B	AB	I <sup>A</sup> (p)	I <sup>B</sup> (q)	I(r)	Rh (Pos)	Rh (Neg)
Maram	180	35.0	20.0	27.2	17.8	0.15	0.25	0.60	65.0	35.0
Mao Naga	775	46.3	23.9	18.0	11.8	0.22	0.18	0.60	97.0	7.0
Pangan (Muslim)	303	49.5	22.5	24.0	4.00	0.15	0.15	0.70	98.1	1.9
Purum (Chothe)	400	47.8	24.6	20.0	7.60	0.17	0.15	0.68	99.3	0.7
Kabui	127	61.0	23.0	16.0	0.00	0.22	0.18	0.60	100	0.0
Meitei	209	31.1	31.6	25.4	11.9	0.30	0.20	0.50	99.5	0.5
Brahmin (Bamon)	302	34.5	35.1	18.5	11.9	0.24	0.16	0.60	98.1	1.9
Total	2296	43.63	25.80	21.30	9.27	0.17	0.17	0.66	94.0	6.0

**Table 7: ABO and Rh (D) distribution among the different ethnic population of Meghalaya.**

Ethnic groups	No. of individuals	Phenotype frequency (%)				Allele frequency			Rhesus (%)	
		O	A	B	AB	I <sup>A</sup> (p)	I <sup>B</sup> (q)	I(r)	Rh (Pos)	Rh (Neg)
<b>Biates (Mizo)</b>	162	25.30	41.40	22.80	10.50	0.31	0.19	0.5	98.8	1.2
<b>Total</b>	162	25.30	41.40	22.80	10.50	0.31	0.19	0.5	98.8	1.2

\*NA=Not Available.

**Table 8: ABO and Rh (D) distribution among the different ethnic population of Sikkim.**

Ethnic population	No. of individuals	Phenotype frequency (%)				Allele frequency			Rhesus (%)	
		O	A	B	AB	I <sup>A</sup> (p)	I <sup>B</sup> (q)	I(r)	Rh (Pos)	Rh (Neg)
<b>Bhutia</b>	297	41.75	25.59	26.60	6.06	0.18	0.18	0.64	100	0.0
<b>Lepcha</b>	688	33.87	36.48	20.20	9.45	0.25	0.17	0.58	99.7	0.3
<b>Rai</b>	959	29.31	47.97	15.84	6.88	0.45	0.25	0.30	99.9	0.1
<b>Subba</b>	798	28.68	43.98	16.54	10.8	0.32	0.15	0.53	99.7	0.3
<b>Chettri</b>	601	40.93	27.95	25.12	6.00	0.19	0.17	0.64	98.5	1.5
<b>Gurung</b>	658	37.38	32.82	24.92	4.88	0.22	0.17	0.61	100	0.0
<b>Sharma</b>	465	46.02	16.98	30.10	6.90	0.13	0.19	0.68	99.8	0.2
<b>Kami</b>	1640	34.39	24.45	31.62	9.53	0.21	0.24	0.55	97.9	2.1
<b>Tamang</b>	201	40.79	31.34	20.39	7.48	0.21	0.15	0.64	100	0.0
<b>Sherpa</b>	64	21.87	48.43	23.45	6.25	0.37	0.16	0.47	100	0.0
<b>Manger</b>	54	30.00	35.00	22.00	13.00	0.26	0.19	0.55	100	0.0
<b>Pradhan</b>	43	32.55	44.18	18.62	4.65	0.19	0.24	0.57	100	0.0
<b>Mukhia</b>	22	13.60	36.40	40.90	9.10	0.34	0.30	0.36	100	0.0
<b>Sanayasi</b>	14	28.57	50.00	21.43	0.00	0.35	0.12	0.53	100	0.0
<b>Bhujel</b>	8	12.50	62.50	12.50	12.50	0.50	0.15	0.35	100	0.0
<b>Jogi</b>	4	50.00	25.00	0.00	25.00	0.16	0.14	0.70	100	0.0
<b>Rawat</b>	2	50.00	50.00	0.00	0.00	0.30	0.00	0.70	100	0.0
<b>General population</b>	262	34.73	22.90	28.24	14.13	0.17	0.24	0.59	98.47	1.53
<b>Total</b>	6780	34.29	33.23	23.73	8.75	0.25	0.15	0.60	99.8	0.2

\*NA=Not Available.

## DISCUSSION

This systematic review is the first to comprehensively describe the ABO blood group frequency in North-East India. The findings indicate that O (36.07%) is the most common blood group in most of the states in North-Eastern India, while AB is the least common. Thus, the blood group frequency in North-East India follows the order O > A > B > AB. Blood group O is the most common blood group in the Indian population,<sup>8</sup> which corroborates with the present findings. However, unlike the ABO distribution in North East India, B is the second most frequent blood group among the Indian population. Thus, the cumulative blood group distribution in Indian population (O>B>A>AB) does not corroborate with that of North-East India (O>A>B>AB). Nevertheless, the ABO frequency distribution pattern in North-East India aligns with that of Tamil Nadu, Andhra Pradesh, Jammu and Kashmir, Karnataka, Kerala, Maharashtra, Orissa, and Telangana. However, it was found to vary with populations from Uttarakhand, Uttar Pradesh, West Bengal, Chhattisgarh, Delhi, Gujarat, Haryana, Jharkhand, Madhya Pradesh, Punjab, and Rajasthan where the distribution is in the order B>O>A>AB. The reason for the non-agreement in the study may be attributed to ethnic differences between the studied population, as the

population of North-East India undoubtedly shows a dominant Mongoloid influence.<sup>2</sup> It is noted that the frequencies and distribution patterns of the ABO and Rh blood groups vary among populations of diverse ethnic backgrounds and geographical regions over time.<sup>28</sup> It is observed that people with blood type O lack the ability to form rosettes with *Plasmodium falciparum*.<sup>29</sup> Thus, according to 'malaria theory' certain human genetic polymorphisms arise more frequently in specific populations as a defense against malaria infection.<sup>29</sup> The majority of these polymorphisms related to the various characteristics of erythrocytes. Some examples include surface antigen (Duffy blood group protects against vivax malaria) and hemoglobin (thalassemia, hemoglobin S, and hemoglobin E-protects against falciparum malaria), among others. According to a study among the people with Tibetan ancestry, who are primarily blood group O, have a lower risk of developing high altitude pulmonary edema (HAPE), a serious illness marked by the buildup of fluid in the lungs at high altitudes. This indicates that at high elevations, blood group O may offer some protection against HAPE.<sup>30</sup> Conversely, blood group O individuals have lower quantities of factor VIII and von Willebrand factor (vWF). This reduced level of vWF may cause decreased blood viscosity, allowing for greater oxygen transport to tissues, even at high elevations when oxygen

levels are low. However, more research is required to directly relate this component to altitude adaptation in blood group O individuals.<sup>30</sup> Another potential reason for the high prevalence of blood group O among the population of North-East India could be attributed to consanguineous practices, such as those observed in the Kabui tribe, which has high frequency of O blood group (61%).<sup>4</sup> In addition, endogamy within related tribes with smaller populations may also attribute to the high frequency of O blood group due to the founder effect.

On the other hand, blood group B dominance is observed in Tripura. About 70% of the demographic composition of Tripura is mainly dominated by the Bengali community, and traditionally, Bengali ethnic group has a higher incidence of blood group B compared to some other populations.<sup>31</sup> Another possible explanation for prevalence of blood group B in the area is the diverse population of Tripura, which includes Rieng, Noatia, Morsam, and other groups. These groups also consistently exhibit preponderance of blood group B over A in their populations. Frequency of blood group B within population may have been maintained by endogamous marriage practices and social customs common in Tripura communities, which may have effect on overall prevalence of specific blood groups. This could explain preponderance of blood group B over A in their populations.<sup>14</sup>

Unlike the other states, blood group A was found to be the most frequent in Meghalaya. The majority of the denizens of Meghalaya are Tibeto-Mongloids and Paleo-Mongloids whose ancestral roots can be traced back to Southern Tibet.<sup>32-33</sup> The higher prevalence of A blood group in Meghalaya could be due to the fact that the ethnic tribes of Meghalaya (Biates) are Mongoloid tribes of the Tibeto Burman linguistic group, known as the Mizo Chinnlung or Sianglung tribe of North-East India, which are believed to have originated in Burma. Thus, the ancestral roots of the majority of the tribes in Meghalaya may explain the prevalence of blood group A.<sup>3</sup>

In the present study, the frequency of Rh (D) positive and negative phenotypes was 98.00% and 2.00%, respectively, for North-East India. Other studies available in the literature also indicated similar pattern in various states of India and in different other countries.

In the present study, the allelic frequency of AB and O antigens has been estimated under the standard assumption of the Hardy-Weinberg equilibrium model. The overall allelic frequencies of  $i(r)$ ,  $I^A(p)$ , and  $I^B(q)$  were found to be 0.60, 0.22, and 0.18, respectively. The higher allelic frequency of  $i(r)$  in the present study was consistent with findings of 2 previous studies from Indian populations.<sup>8,34</sup>

#### ***ABO studies in North-East India: research gaps and future challenges***

Among all the studies reviewed here, certain limitations exist: (i) Most of the ABO blood group studies conducted

in North-East states have small sample sizes. (ii) To date, out of 153 tribes that live in North-Eastern India, only 60.0% of them have been investigated for ABO frequency distribution. Thus, there is a necessity for thorough and inclusive studies to address knowledge gaps regarding blood group distributions among the different ethnic tribes of North-East India. However, there are certain challenges as well. Firstly, the inclusion of individuals for blood group typing is limited by strict cultural values and conserved society of tribal society of some tribes. Secondly, enrolling female donors in the blood group registry is challenging due to restrictions related to menstruation, anemia, and pregnancy.<sup>35,36</sup> Thirdly, genetic testing of ABO ( $A1$ ,  $A2$ ,  $B$ ,  $O1$ , and  $O2$  alleles) is more accurate, efficient, and yields better results, however, it is costlier and time-consuming compared to serological testing due to which it is lacking from North-East states of India.

#### ***Future directions***

Future studies with the inclusion of more ethnic populations may shed more light on the distribution of ABO and Rh(D) blood groups among the population of North-East India which may improve transfusion services, management of blood banks, and strengthen our understanding of disease associations and help to improve public health programs in North-Eastern India.

#### ***Limitations***

In this systematic review, studies from Mizoram were lacking due to the non-availability of literature, which may limit the conclusions regarding the overall frequency distribution of the ABO blood group in North-East India. Furthermore, ABO and Rh data are unavailable for approximately 40% of the tribal populations from North-East India due to a lack of published literature. Despite this limitation, the present study provides a comprehensive overview of the ABO blood group frequency distribution across North-East India and its diverse ethnic populations.

#### **CONCLUSION**

This study is a comprehensive approach to provide insights into the ABO blood group frequencies in North-East India, which shows notable variation between the states and various ethnic populations. Overall, blood group O is found to be more common, but differences observed among ethnic groups may be due to natural selection, genetic factors, and population migration. These results contribute to a deeper understanding of regional haematological diversity and its potential implications for transfusion medicine and population genetics.

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