

Prevalence of Glucose-6-Phosphate Dehydrogenase (G6PD) Deficiency in India: A Systematic Review

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Abstract

Glucose-6-Phosphate Dehydrogenase (G6PD) deficiency is the most common enzyme deficiency of human erythrocyte affecting more than 400 million people worldwide. In India, G6PD deficiency was first reported in 1963 and since then various investigations have been conducted across country. The objective of this work was to study the prevalence of G6PD deficiency in different ethnic, caste and linguistic groups of Indian population. A systematic search of published literature was undertaken and the wide variability of G6PD deficiency has been observed ranging from 0% - 30.7% among the different caste, ethnic, and linguistic groups of India. It was observed that the incidence of G6PD deficiency was found to be considerably higher among the tribes (9.86%) as compared to other ethnic groups (7.34%) and significantly higher in males as compared to females.

Keywords

Glucose-6-Phosphate Dehydrogenase, G6PD, Deficiency, India, Prevalence

1. Introduction

G6PD deficiency is the X-chromosome linked erythrocyte enzyme deficiency. G6PD deficiency causes a hematologic disorder, namely haemolytic anaemia, and it was as a result of investigation of haemolytic anaemia that brought this common enzymatic deficiency to light. In 1973, it was estimated that about 300 million people worldwide were G6PD deficient, but now these numbers have been increased [1]. G6PD deficiency being an X-linked condition, males may be either G6PD normal or G6PD deficient hemizygotes, whereas females can be

normal homozygotes or deficient homozygotes or heterozygotes.

1.1. Detection of G6PD deficiency

Glucose-6-phosphate dehydrogenase(G6PD; EC 1.1.1.49) enzyme plays a vital role in the generation of NADPH and ribose-5-phosphate in the pentose phosphate pathway [1]. NADPH functions as an electron donor and provides the reducing energy required for regeneration of reduced Glutathione which ultimately protects the cells against oxidative damage. Though G6PD deficiency affects every cell in the body, its primary effects are hematological because in the erythrocyte this pathway is the only source of NADPH [2]. There are various methods available for detection of G6PD deficiency, but quantitative measurement of G6PD enzyme by measuring the reduction of NADP to NADPH using ultraviolet spectrophotometer is the basic diagnostic approach used commonly for detection of G6PD deficiency. Other than that, in a dye reduction test, the reduction of NADPH was linked to the reduction of the visible dye brilliant cresyl blue [1]. Various other tests such as methylene blue, MTT tetra sodium, dichloro-indophenol or methemoglobin were also developed [3] [4]. In recent times, fluorescent spot test is more popular for rapid testing of deficiency in which reduction of NADPH is observed directly by virtue of its fluorescence, instead of linking the reduced pyridine nucleotide to a dye [5]. These screening procedures are quite robust in the detection of the fully developed defect in males, but they fall short in the determination of female heterozygotes and in patients with relatively mild forms of G6PD deficiency.

1.2. Occurrence of G6PD Deficiency

G6PD deficiency affects around 10% of the total population of world. The highest prevalence of G6PD deficiency mainly regards in tropical Africa, the Middle East, tropical and subtropical Asia, Papua New Guinea and various Mediterranean regions [1] [6] [7].

India, a south Asian country having second largest population in the world, varying in various castes, ethnic and linguistic groups. Also geographically and environmentally India has a great variation, which is also responsible for difference among population. In India investigations on G6PD deficiency have been started after it was firstly reported by Baxi *et al.* in 1961 [8]. Since then, various studies regarding prevalence of G6PD deficiency among various population groups have been conducted across India. India being a malarial endemic country, the treatment course requires primaquine drugs which is generally conducted without routine G6PD screening. This makes patients vulnerable to prescription of potentially haemolytic drugs, especially putting G6PD deficient individuals at risk of serious complications. Therefore, in current report existing literature regarding occurrence of G6PD deficiency have been reviewed to estimate the prevalence of G6PD deficiency across India and highlighting the areas where more research is needed.

2. Methods

A systematic literature search from 1961 to 2016, through PubMed/MEDLINE, Google scholar, Wiley online library databases was performed in as follows. Relevant publications were identified through free text search using keywords such as Glucose-6-Phosphate Dehydrogenase (G6PD) deficiency, India, Prevalence without any restriction on the year and language of publication. Various combinations of these keywords such as “G6PD in India”, “Prevalence of G6PD in India”, “Glucose-6-Phosphate Dehydrogenase (G6PD) deficiency”, “Prevalence of Glucose-6-Phosphate Dehydrogenase (G6PD) deficiency”, “Prevalence of Glucose-6-Phosphate Dehydrogenase (G6PD) deficiency in Indian population”, “G6PD deficiency incidence and India”, “Incidence of G6PD deficiency in India”, “Incidence of Glucose-6-Phosphate Dehydrogenase deficiency in India”, “Incidence of G6PD deficiency in Indian population”, “Distribution of G6PD deficiency in India” etc. were used. Although there was no bar on language, English was more preferred. Additionally articles were also obtained through citation tracking of reviews, articles and original papers along with direct receipt of full text articles from some authors or co-authors. The duplicated articles were eliminated from the above mentioned search. Titles and abstracts of each identified article was then checked for eligibility based on the following criteria:

Inclusion criteria:

- Primary data, population based epidemiological study
- Hospital based study

Exclusion criteria:

- Age group of subjects: less than 15 years
- Studies related to only clinical manifestation of G6PD deficiency

The epidemiological studies of G6PD deficiency in Indian population were included for this systematic review. Hospital based prevalence studies were also selected. Although, studies carried out amongst neonates, children and young adults (less than 15 years of age) were excluded. Studies based on clinical manifestations of G6PD deficiency were also excluded as they mainly focused on clinical aspects and hardly provided information regarding the incidence of G6PD deficiency. Review articles regarding prevalence or clinical manifestations of G6PD deficiency were also excluded.

Finally, the full text of eligible articles and reports were evaluated to obtain detailed information regarding the prevalence of G6PD deficiency in various ethnically and regionally diverse population of India. The data was evaluated and the systematic review was conducted according to PRISMA guidelines.

3. Results

3.1. Selection Procedure

Figure 1 shows the PRISMA flow diagram of systematic search. Among the 360 records identified and retrieved from databases and other sources, 134 articles were found to be associated with G6PD deficiency in India after initial screening

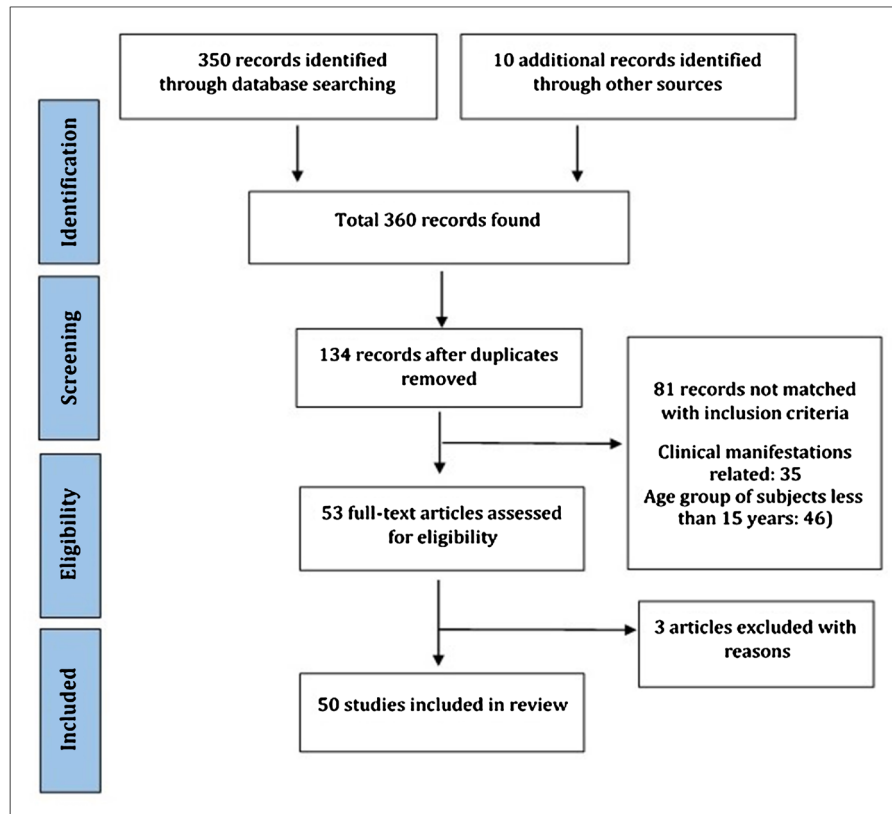


Figure 1. PRISMA Flow diagram of systematic review search.

and removal of duplicates. These articles were manually checked by titles and abstracts and 81 articles were found to be irrelevant to the inclusion criteria. Of remaining 53 articles, 3 articles were excluded-1 for incomplete information, 1 for lack of publishing in peer reviewed journal, 1 for duplication of data. Finally 50 original articles were included for this systematic review.

3.2. Prevalence of G6PD Deficiency in India

In the current review, the distribution of G6PD deficiency in the various population groups from total 20 states and 3 union territories of India have been summarized below which have been categorized into Northern India, Southern India, Western India, Eastern India, Central India, North-eastern India and Island regions. These studies have been carried out in total 49,929 subjects among which 22,431 subjects belong from urban population and 27,498 from tribal population. From compilation of these studies, it has been observed that the prevalence of G6PD deficiency highly varies from 0 to 30.7% among the different caste, ethnic, and linguistic groups of India (**Table 1**) [8]-[59].

3.3. Northern India

Northern India consists of states of Jammu & Kashmir, Punjab, Haryana, Uttaranchal, Uttar Pradesh and union territories of Delhi and Chandigarh. According to census 2011 the tribes are not found in regions of Punjab, Haryana,

Table 1. Distribution of G6PD deficiency in the different population groups in India.

Area	Population Type	Caste/race	No. of tested			No. of G6PD deficient			Prevalence (%)			Reference Range
			Male	Female	Total	Male	Female	Total	Male	Female	Total	
Northern India												
Jammu	Urban	Hindu			1250	105	10	115			9.2	[9]
Jammu	Urban	Muslim			342	22	4	26			7.6	[9]
Jammu	Urban	Sikh			322	20	2	22			6.83	[9]
Jammu	Urban	Christian			86	4	1	5			6.87	[9]
Himachal Pradesh	Urban	Rajput	65			1			1.54			[10]
Himachal Pradesh	Urban	Brahmin	47			1			2.12			[10]
Delhi	Urban	Mixed			300	8	3	11			3.66	[11]
Delhi	Urban	Mixed			810	32	18	50	3.95	2.22	6.17	[12]
Delhi	Urban	Tamil brahmin	68	79	147	3	1	4	4.40	1.30	2.72	[13]
Punjab	Urban	Sikhs	242	258	500			11	2.06	2.32	2.20	[14]
Punjab	Urban	Jat Sikh			182			2			1.10	[15]
Punjab	Urban	Brahmin			55			0			0.00	[15]
Punjab	Urban	Khatri			50			1			2.00	[15]
Punjab	Urban	Aggrawal			47			0			0.00	[15]
Punjab	Urban	Balmiki			34			1			2.94	[15]
Punjab	Urban	Rajputs			10			0			0.00	[15]
Punjab	Urban	Mixed			122			0			0.00	[15]
Haryana	Urban	Jat	87	49		10	3		11.49	6.13		[16]
Haryana	Urban	Brahmin	96	56		10	4		10.42	7.14		[16]
Uttar Pradesh	Urban	Muslims	110	90	200	18	8	26	16.36	8.89	13.00	[17]
Uttar Pradesh	Urban	Mixed Scheduled castes	103	97	200	11	9	20	10.7	9.3	10.00	[18]
Uttar Pradesh	Tribe	Danguria Tharu	32	24	56	13	0	13	40.63	0	23.21	[19]
Southern India												
Karnataka	Urban	Mixed	93	7	100	0	0	0	0.00	0.00	0.00	[20]
Andhra Pradesh	Urban	Dhobi	115	85	200	9	0	9	7.82	0.00	4.50	[21]
Andhra Pradesh	Tribe	Kolam	226	228		26	3		11.50	1.32		[22]
Andhra Pradesh	Tribe	Nayakpod	20	20	40	2	0		10.00	0.00		[23]
Andhra Pradesh	Tribe	Koyadora	71	61	132	6	0		8.45	0.00		[23]
Andhra Pradesh	Tribe	Koyadora	131			16			12.21			[24]
Kerala	Tribe	Kannikar	43	66	109				4.65	6.06	5.50	[25]
Tamilnadu	Tribe	Mixed tribes	1125			61			5.40			[26]
Tamilnadu	Tribe	Badagas	970			170			18.00			[27]

Continued

Western India												
Maharashtra	Urban	Bhanushali (cutchee)	139	90		17	3		12.2	3.33		[28]
Maharashtra	Urban	Mixed	81	29	110	6	9	15	7.41	31.03	13.64	[8]
Maharashtra	Urban	Visa oswal jain			107			3			2.80	[29]
Maharashtra	Urban	Audich brahmin			141			5			3.50	[29]
Maharashtra	Urban	Lad vania			128			1			0.78	[29]
Maharashtra	Urban	Bohra	67								0.00	[30]
Maharashtra	Urban	Khoja	108								2.00	[30]
Maharashtra	Urban	Moplah	94								0.00	[30]
Maharashtra	Urban	Misgar	75								0.50	[30]
Maharashtra	Urban	Mixed muslim	120								2.00	[30]
Maharashtra	Urban	Baniya	51	82		0	0		0.00	0.00		[31]
Maharashtra	Urban	Bhandari	50	95		0	0		0.00	0.00		[31]
Maharashtra	Urban	Bhaiya	41	25		1	0		2.43	0.00		[31]
Maharashtra	Urban	Muslim	318	220		3	0		0.94	0.00		[31]
Maharashtra	Urban	Brahmin	361	403		5	0		1.38	0.00		[31]
Maharashtra	Urban	Jain	207	281		3	0		1.45	0.00		[31]
Maharashtra	Urban	Sikh	91	110		1	0		1.10	0.00		[31]
Maharashtra	Urban	Kayastha	36	52		1	0		2.77	0.00		[31]
Maharashtra	Urban	Lohana	117	45		9	1		7.69	0.22		[31]
Maharashtra	Urban	Maratha	593	515		1	0		0.17	0.00		[31]
Maharashtra	Urban	Christian	45	161		2	0		4.44	0.00		[31]
Maharashtra	Urban	Parsi	19	26		2	1		10.53	3.85		[31]
Maharashtra	Urban	Artisan	259	247		2	1		0.77	0.40		[31]
Maharashtra	Urban	Schedule caste	294	233		2	0		0.68	0.00		[31]
Maharashtra	Urban	Dhangar	1385			3			0.22			[32]
Maharashtra	Urban	Nava-budha			51			0			0.00	[33]
Maharashtra	Urban	Parsis			133			23			17.30	[33]
Maharashtra	Urban	Chitpavan Brahmin			81			1			1.23	[33]
Maharashtra	Urban	Deshastha regvedi brahmin			76			1			1.31	[33]
Maharashtra	Urban	Chandra seniya kayastha prabhu			96			2			2.08	[33]
Maharashtra	Urban	Maratha			13			0			0.00	[33]
Rajasthan	Urban	Mixed			1798			126			7.00	[34]
Rajasthan	Urban	Mixed			3810			216			5.67	[35]
Gujarat	Urban	Vataliya prajapati	272	113	385	76	11	87	27.94	9.73	22.60	[36]
Gujarat	Urban	Brahmin			4			0			0.00	[37]

0.00 -
27.94

Continued

Gujarat	Urban	Darbar			14			0			0.00	[37]
Gujarat	Urban	Jain			4			0			0.00	[37]
Gujarat	Urban	Lohana			10			1			10.00	[37]
Gujarat	Urban	Muslim			14			0			0.00	[37]
Gujarat	Urban	Patel			8			0			0.00	[37]
Gujarat	Urban	Sindhi			2			0			0.00	[37]
Gujarat	Urban	Harijan			26			7			26.92	[37]
Gujarat	Urban	Luhar			3			0			0.00	[37]
Gujarat	Urban	Khatri			2			0			0.00	[37]
Gujarat	Urban	Satwara			5			0			0.00	[37]
Gujarat	Urban	Suthar			4			0			0.00	[37]
Gujarat	Urban	Vataliya prajapati	985	659	1644	275	84	359	27.90	12.20	22.00	[38]
Dadra & nagar haveli	Urban	Rajput	47				1			2.13		[39]
Dadra & nagar haveli	Tribe	Warli tribe	79				8			10.10		[40]
Dadra & nagar haveli	Tribe	Dodhia	74				10			13.50		[41]
Rajasthan	Tribe	Kumhar	101	56		5	1		4.95	1.79		[42]
Rajasthan	Tribe	Garasiya			368			56			15.21	[43]
Rajasthan	Tribe	Mixed			4007			509			12.70	[35]
Rajasthan	Tribe	Mixed			1124			203			18.06	[34]
Gujarat	Tribe	Bharwad			16			0			0.00	[37]
Gujarat	Tribe	Koli			22			0			0.00	[37]
Gujarat	Tribe	Rabari			16			2			12.50	[37]
Maharashtra	Tribe	Bhils			215			16			7.44	[33]
Maharashtra	Tribe	Pawras			87			3			3.45	[33]
Maharashtra	Tribe	Katkaris			77			6			7.80	[33]
Eastern India												
West bengal	Urban	Mixed			583	6	2	8	1.23	2.06	1.37	[44]
West bengal	Urban	Bengali			103			4			3.88	[45]
West bengal	Urban	Nepali			25			2			8.00	[45]
West bengal	Urban	Uttarpradeshi and bihari			18			2			11.11	[45]
West bengal	Urban	Muslim			17			1			5.88	[45]
West bengal	Urban	Christian			5			0			0.00	[45]
West bengal	Urban	Punjabi			3			0			0.00	[45]
West bengal	Urban	Marathi			1			0			0.00	[45]
West bengal	Urban	South Indian			1			0			0.00	[45]

0.00 -
30.70

Continued

Orissa	Tribe	Kolha	209		34			15.30			[46]	
Orissa	Tribe	Santal	106		13			12.30			[46]	
Orissa	Tribe	Bathudi	212		24			11.30			[46]	
Orissa	Tribe	Munda	131		16			12.20			[46]	
Orissa	Tribe	Jaunga	380		52			13.70			[46]	
Orissa	Tribe	Gonda	98		7			7.10			[46]	
Orissa	Tribe	Bhuyan	176		25			14.20			[46]	
Orissa	Tribe	Didayi	478		8			1.70			[46]	
Orissa	Tribe	Kandha	625		20			3.20			[46]	
Orissa	Tribe	Bondo	449		2			0.40			[46]	
Orissa	Tribe	Paroja	204		11			5.40			[46]	
Orissa	Tribe	Koya	101		0			0.00			[46]	
Orissa	Tribe	Oroan	121		11			9.10			[46]	
Orissa	Tribe	Holva	190		0			0.00			[46]	
Orissa	Tribe	Kissan	71	20	92			9.78	4.30	14.13	[25]	
Orissa	Tribe	Dudh kharia			422	41	45	86	9.70	10.70	20.40	[47]
Orissa	Tribe	Dhelki kharia			345	54	51	105	15.60	14.80	30.40	[47]
Orissa	Tribe	Paraja Bhuyan			213	32	16	48	15.00	7.50	22.50	[47]
Orissa	Tribe	Paik Bhuyan			244	26	15	41	10.60	6.10	16.80	[47]
Orissa	Tribe	Paudi Bhuyan			379	30	22	52	7.90	5.80	13.70	[47]
Orissa	Tribe	Dudh kharia			422	36	45	89	8.50	10.70	19.20	[48]
Orissa	Tribe	Dhelki kharia			345	55	51	106	15.90	14.80	30.70	[48]
West bengal	Tribe	Rajbangshi			100			12		12.00	[49]	
West bengal	Tribe	Santhal			164			23		14.03	[33]	
Central India												
Madhya Pradesh	Urban	Sindhi			508			4		0.80	[50]	
Madhya Pradesh	Tribe	Bhil	120		8			6.70			[51]	
Chhattisgarh	Tribe	Muria			300	24	6	30	8.00	2.00	10.00	[52]
Chhattisgarh	Tribe	Maria			182	24	3	27	13.18	1.65	14.83	[52]
Chhattisgarh	Tribe	Halba			372	38	7	45	10.21	1.83	12.04	[52]
Chhattisgarh	Tribe	Bhatra			104	16	4	20	15.23	3.85	19.23	[52]
North-eastern India												
Manipur	Urban	Muslim			136			29		21.32	[53]	
Manipur	Urban	Brahmin			115			12		9.44	[53]	
Manipur	Tribe	Kabui			51			4		7.84	[53]	
Nagaland	Tribe	Ao Naga	394	314	708			9.21	1.86		[54]	
Nagaland	Tribe	Angami Naga	85	65	150	23	10	33	27.06	15.39	22.00	[55]

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15.79

Continued

Mizoram	Tribe	Mizo		490		17.50	[56]	
Assam	Tribe	Laung	81		3	3.70	[57]	
Assam	Tribe	Mikir	83		13	15.66	[57]	
Assam	Tribe	Rabha	57		9	15.79	[57]	
Assam	Tribe	Garo	76		6	7.89	[57]	
Assam	Tribe	Rajbanshi	103		12	11.65	[57]	
Islands								
Andaman and nicobar	Tribe	Jawara		54		0	0.00	[58] 0.00 -
Andaman and nicobar	Tribe	Great anadamaneas		29		1	3.45	[59] 3.45

Chandigarh and Delhi. Hence, the prevalence of G6PD deficiency in these regions have been reported only from urban population which ranges between 0 to 13% [9]-[18]. However prevalence of G6PD deficiency in Danguria Tharu tribe from Uttar Pradesh have been reported up to 23.21%. The same study reported 40.63% prevalence in males but further investigation is required due to small population size [19]. Remarkably a study, conducted in south Indian Brahmins settled in Delhi revealed similarity of frequency of G6PD deficiency among other south Indian caste groups, and also with the migrated population [13].

3.4. Southern India

Southern India consists of states of Andhra Pradesh, Karnataka, Kerala and Tamilnadu. In Southern India, investigations regarding G6PD deficiency have been carried out more in tribal population than the urban populations. In urban population, while a study from Karnataka reported absence of G6PD deficiency in mixed population, the frequency of G6PD deficiency have been reported upto 7% among Dhobis of Andhra Pradesh [20] [21]. Investigations in various tribes have reported frequency of G6PD deficiency ranging from 0% to 12% in Andhra Pradesh, upto 6% in Kerala and about 5% to 18% in Tamilnadu [22]-[27].

3.5. Western India

It is notable that the investigations regarding occurrence of G6PD deficiency have been reported extensively from the Western India comprising of states of Gujarat, Rajasthan, Maharashtra and union territory of Dadra & Nagar Haveli. The occurrence of G6PD deficiency was firstly reported by Baxi *et al.* in 1961 in Bombay suggesting its wide distribution in the country [8]. As it was the very first investigation of G6PD deficiency in Maharashtra let alone in India, it played a key role in starting the investigation on G6PD deficiency in India. In western India, the investigations of this deficiency have been conducted amongst several tribal as well urban populations comprising of Parsees, Cutchee Bhanushalis, Marathas, Dhangars, Bhils, Pawars, Muslims, Hindus, Jains, Christians, Brah-

mins, Katkaris, Sikhs, Kayasthas, Bhandaris, Baniyas, Garasiyas, Kumhars, Damors, Minas, Patidars, Rajputs, Bhois, Panchals, Patels, Lohanas, Bohras, Sompuras, Darbars, Harijans, Luhars, Warlis, Dodhias, and many more [8] [28]-[43]. Although various investigations have reported occurrence of G6PD deficiency frequenting from 0% to 18% in general, frequency of G6PD deficiency have been reported up to 27.9% in Vataliya Prajapati community from Gujarat which is the second highest in country [36]. Also in another study conducted on mixed population, the prevalence of G6PD deficiency was found as high as 26.92% among Harijan population from Gujarat, but further study is required due to less stratified sampling [37]. Even though some reports show high prevalence of G6PD deficiency in certain communities, it is notable that the prevalence of G6PD deficiency in overall population of Gujarat are low with the drastic variation in the prevalence amongst the tribal and urban population.

3.6. Eastern India

Eastern India consists of states of Bihar, Jharkhand, Orissa and West Bengal. Most of the investigations regarding G6PD deficiency have been done mainly in regions of Orissa and West Bengal. Relatively high prevalence of G6PD deficiency have been reported in Eastern India that ranges between 0 to 30.7% [25] [33] [44]-[49]. Investigation on frequency of G6PD deficiency among urban population have been reported only from West Bengal ranging from 0% to 11% [45]. Whereas in the same region it was found upto 12% and 14% in Rajbangshi and Santhal tribes respectively [33] [49]. Prevalence of G6PD deficiency has been reported upto 30.7% in Dhelki Kharia tribe of Orissa which is the highest found prevalence till date in India [48]. Other than that, investigations have been carried out in various other tribes such as Dudh Kharias, Bhuyans, Marathis, Kissans, Kolhas, Kondhs, Gonds, Bhumiz and several more from Orissa [25] [46] [47] [48].

3.7. Central India

Central India Comprises of Madhya Pradesh and Chhatisgarh states. Frequency of G6PD deficiency have been reported 0.8% among Sindhi community and 6.7% among Bhil tribe from Madhya Pradesh [50] [51]. The frequency of G6PD deficiency ranges from 6% to 19% in various tribes of Chhattisgarh [52].

3.8. North-Eastern India

The North-Eastern region of India consists of the contiguous states of Arunachal Pradesh, Assam, Meghalaya, Manipur, Mizoram, Nagaland and Tripura, which are predominantly inhabited by tribes. Frequency of G6PD deficiency in these area ranges between 0% to 27.6% among various tribes such as Nagas, Mikirs, Rabhas, Garo, Rangbanshi etc. [53] [54] [55] [56] [57].

3.9. Islands of India

Reports regarding G6PD deficiency from Andaman and Nicobar islands are

scarce. A study revealed complete absence of G6PD deficiency in Jawara tribe [58], while in another study frequency of G6PD deficiency was reported 3.4% in Great Andamanese tribes but further study is needed due to small sample size [59].

4. Discussion

Globally more than 400 million people are suspected to be G6PD deficient. The overall G6PD allele frequency is believed to be around 8% and the high population density makes Asia the center of weight of G6PD deficiency-burdened populations [6] [60]. High frequency of G6PD deficiency is mainly found in malaria endemic regions. India being the second highest populated country with great ethnic, geographical and racial diversity is also one of the most malaria affected country worldwide and thus assumed to have high frequency of G6PD deficiency.

The data reported here have been collected from various surveys conducted by different researchers and considerable differences were seen in the methods adopted for field surveys, the mode of collection of blood samples and especially methods for screening of G6PD deficiency. Although, various methods such as quantitative spectrophotometric assays, methemoglobin reduction test, BCB test, MTT linked test, fluorescent spot test etc. are available for detection of G6PD deficiency, detection of heterozygous population is still problematic. Therefore, the work towards developing new methods for enzyme detection-especially in heterozygous females is essential.

In this comprehensive study, the wide variability of G6PD deficiency has been observed ranging from 0% - 30.7% among the different caste, ethnic, and linguistic groups of India. The area wise distribution revealed frequency of G6PD deficiency ranging between 0% - 30.70% in Eastern India to 0% - 27.9% in Western India. The prevalence of G6PD deficiency was found ranging from 0% - 23.21% in Northern India to 0% - 18% in Southern India. Whereas it was found ranging between 1.86% - 15.71% in North-eastern India and 0% - 19.23% in Central India, the range in the island regions of India is reported to be even lower.

It also revealed in this review, that the incidence of deficiency was found to be considerably higher among the tribes (9.86%) as compared to other ethnic groups (7.34%) and significantly higher in males as compared to females. The investigations regarding distribution of G6PD deficiency have been reported extensively from the western parts of India, whereas reports from North-eastern and Islands regions of India are scarce. In Southern India, most of the studies have been carried out among tribal populations, while in Northern India mostly among the urban populations. Although this review is a comprehensive amalgam of data from all over India, wherein studies have been carried out in several regions including Maharashtra, Gujarat, Rajasthan, West Bengal, Orissa, Madhya Pradesh, Tamilnadu, Kerala, Delhi, Haryana, Punjab, Jammu, Uttar Pradesh,

Assam, Nagaland. However, many areas of India are still left unexplored. Moreover, the review includes data from 1969 to 2016 with several reports targeting few ethnic groups. Such discrimination in the sampling might lead to chances of errors in the analyzed disposition to G6PD amongst the population. It is therefore emphasized that further evaluation of the clinical and prognostic aspects of G6PD deficiency among Indian population needs to be explored.

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Conflicts of Interest

The authors declare that there is no conflict of interest.

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