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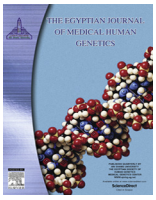

Review

Gene frequencies of ABO and Rh blood groups in Nigeria: A review

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ABSTRACT

Background: ABO and Rhesus factor (Rh) blood type are germane in human life in genetics and clinical studies.
Aim of the study: The review was undertaken with the objective to provide data on the ABO and Rh(D) blood group distribution and gene frequency across Nigeria which is vital for blood transfusion and susceptibility to disease.
Materials and methods: Literature search for ABO/Rh blood distribution in Nigeria was done and allele frequencies of A, B, O, D and d were calculated from the frequency recorded from six geopolitical zones in Nigeria. We reported frequency of ABO and Rhesus blood type from 318,940 and 280,514 individuals respectively. Prevalence were reported as percentage and Hardy-Weinberg equilibrium was tested using Chi square test and p was set at 0.05 unless otherwise stated.
Results: We reported ABO blood group frequencies in the order O > A > B > AB (52.93%, 22.77%, 20.64% and 3.66%) while prevalence of Rh+ was 94.90% from total population studied. Our reported frequencies did not differ from Hardy-Weinberg equilibrium (goodness-of-fit X^2 for ABO = 1.74 df = 3, $p < 0.05$). Allelic frequencies for A(p), B(q) and O(r) are 0.143, 0.130 and 0.728 respectively.
Conclusion: The study provides information on the distribution/frequency of ABO/Rh(D) blood group and their corresponding allelic proportion in a large Nigeria study. It also revealed how the Nigerian populations in the North, South, West and East vary with respect to genetic traits. This vital information will be important for population genetics and anthropology studies and may be helpful in planning for future health strategy and blueprint, particularly planning with regards to disease management and blood transfusion medicine.

Contents

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1. Introduction

Blood transfusion resulted in high mortality before the discovery of ABO blood groups because there was no knowledge of the difference in the blood composition among individuals in human population [1]. Later study by Landsteiner [2] made it possible to type/group blood to ABO class (A, B and O) based on the presence or absence of surface antigens on red blood cell (RBC). The last type (AB) was discovered in 1902 by DesCasterllo and Sturli [3]. These germane discoveries lead to reduced mortality due to blood transfusion. Human ABO type is a classic example of multi-allelism because it has three alleles (A, B and O) and its phenotype could be O, A, B or AB. The composition for an individual ABO blood type is always based on inheritance of gene on chromosome 9(9q34) which encodes glycosyl transferases that transfer some oligosaccharides residues to H antigen, resulting in the formation of group A and B antigens but O individuals lack such activity [4].

Rh blood type (Rhesus) is second to ABO blood group in its importance in blood transfusion biology. It is highly polymorphic because it contains more than forty-four different antigens but the most clinical significant polymorphism is the presence or absence of the Rh (D) antigen on the red blood cell.

Environmental factor does not change individual blood during life except in rare cases of certain diseases like Acute Leukemia [5–7] or bone marrow transplant. Although ABO blood group is determined by inheritance, natural selection may have influenced the current frequencies of ABO types among populations based on susceptibility to particular diseases or disorders [8–10].

A, B and O (H) are determinants for the antigens on ABO blood group respectively which are complex oligosaccharide (carbohydrate) molecules positioned strategically on the extracellular surface of the red blood cell (RBC) membrane [11]. Apart from their expression on the RBC, ABO antigens are also highly expressed on the surface of a variety of human cells and tissues, including the epithelium, sensory neurons, platelets, and the vascular endothelium [12]. Thus, the biological/clinical importance of the ABO blood group system extends beyond transfusion medicine/immunohaematology because there are accumulating evidence that the ABO blood group also plays a key role in various human diseases such as diabetes, cardiovascular, neoplastic, carcinoma and infectious disorders [8,13–14]. From the foregoing, we can deduce that ABO and Rh blood groups polymorphism are valuable and indispensable tools in contemporary medicine, population genetics and anthropology.

The distribution of these two blood groups has been repeatedly investigated in various populations all over the world and their frequencies exhibited considerable variation in different geographic locations, reflecting the underlying genetic and ethnic diversity of human populations [15]. A multi race/ethnic study in the United State reported that blood type O is the most prevalent (46.6%) with White non-Hispanic, Hispanic, Black non-Hispanic, Asian and North American Indian having varying percentage of 45.5, 56.5, 50.2, 39.8 and 54.6 respectively [15]. Other studies in Turkey, Mauritania, Iran, Ethiopia, Colombia, Cameroun, Bangladesh, Madagascar, Morocco, Guinea and Northern India have reported varying percentage in ABO and Rh blood types [15–26].

Nigeria is a highly populated country comprising of different ethnic groups. As with many other genetic traits, the gene frequency of ABO and Rh blood group varies significantly within the six geopolitical zones in Nigeria [27–34]. Therefore, this study reviewed the distribution of ABO and Rh blood groups and determined it gene frequency in different parts of Nigeria to serve as a reference/database that contains information on ABO and Rh(D) phenotype for accurate ABO/ Rh(D) phenotype/allelic frequencies for the six geo-political zones in Nigeria.

2. Materials and methods

A search engine for ABO and Rh(D) distribution/prevalence/frequency of different blood type in Nigeria was done and used for our data analysis on frequency and allele distribution of ABO and Rh(D) in Nigeria.

We assigned p, q and r to allele A, B, and O respectively for the allele frequencies of ABO blood group genes. Their frequencies were calculated under Hardy-Weinberg (H-W) assumptions as $[(p + q + r)^2 = p^2 + q^2 + r^2 + 2pq + 2pr + 2pq = 1]$ as p^2 $(I^AI^A) + 2pr$ $(I^AI^O) + q^2$ $(I^BI^B) + 2qr$ $(I^BI^O) + 2pq$ $(I^AI^B) + r^2$ (I^OI^O) while allele D and d in rhesus type were assigned p and q respectively and their frequencies were also calculated using H-W equilibrium $p^2 + 2pq + q^2 = 1$ [35].

Allele frequencies were calculated under the assumption of H-W equilibrium and prevalence were expressed as percentages. Chi-square test was used to compare observed allelic and genotypic frequency distributions of the blood group and Rh antigens to that expected under the H-W equilibrium [35].

3. Results

ABO and Rh phenotype frequencies from different states/locations and geopolitical zones were compared and their corresponding allelic frequencies (A, B, O, D and d) were computed with data compiled from each studies. A total of 318,940 and 280,514 individuals were compared for ABO and Rh(D) respectively in this study. Total data collated from Nigeria showing their distribution and percentages (Table 1) revealed that the ABO blood group frequencies were found in the order O > A > B > AB (52.93%, 22.77%, 20.64% and 3.66%) while prevalence of Rh+ was 94.90% (Table 2). We observed a similar trend when we compared them across six geopolitical zones except that B > A in North-West (Table 1). As shown in Table 1, the frequency of allele A, B and O are 0.143, 0.130 and 0.728 respectively.

As shown in Table 1, we found that the distribution and proportion of individuals having ABO blood antigens did not differ from those expected under Hardy–Weinberg equilibrium for overall total in Nigeria, South-West (SW), North-West (NW), and South-East (SE) (goodness-of-fit X^2 for ABO = 1.74, 1.28, 1.29 and 6.97 respectively df = 3, $p < 0.05$), however; the distribution and proportion of individuals having ABO blood antigens differ from those expected under Hardy–Weinberg equilibrium for North-Central, South-South and North-Eastern part of Nigeria (goodness-of-fit X^2 for ABO = 928.91, 222.00 and 12.05 respectively, df = 3, $p < 0.05$). As expected the frequency of Rh+(D) recorded for overall total in Nigeria from this study was 94.9%. The distribution and proportion of individuals having Rh blood antigens for overall total in Nigeria and all six geopolitical zones did not differ from those expected under Hardy–Weinberg equilibrium at df = 1 and $p < 0.01$ (Table 2).

4. Discussion

This study investigated the distribution and gene frequencies of ABO and Rh (D) blood group systems in most parts of Nigeria with representatives in each of the six geopolitical zones. The data collated revealed that the ABO blood group frequencies were found in the order O > A > B > AB (52.93%, 22.77%, 20.64% and 3.66%) respectively among Nigeria population. Our data is in agreement with other reports from most parts of the world as reported from a study on 3,086,215 individuals belonging to different race/ethnic groups in USA (O;46.6%, A;37.1%, B;12.2% and AB;4.1%) [15]. Also in congruent with studies from Mauritania, Morocco, Cameroun,

Table 1
Phenotypic distribution of ABO blood group system and allele frequencies in Nigeria.

Zone	States	Place of Research	O(%)	A(%)	ABO SYSTEM		Total	Allele			References
					B(%)	AB(%)		p	q	r	
North Central	Kwara	Ilorin (2004–2009)	5605(58.13)	1800 (18.67)	1699(17.62)	539(5.59)	9643.00	0.114	0.124	0.762	[32]
	Plateau	Jos	1442(41.48)	799(22.99)	1064(30.61)	171(4.92)	3476.00	0.159	0.197	0.644	[28]
	FCT	Abuja	144(47.21)	66(21.64)	80(26.23)	15(4.92)	305.00	0.143	0.170	0.687	[44]
	Minna	Niger (2008–2012)	6196(44.46)	3560 (25.54)	2689(19.29)	1492910.71)	13937.00	0.170	0.163	0.667	[34]
Total (NC)			13387 (48.93)	6225 (22.75)	5532(20.22)	2217(8.10)	27361.00	0.147	0.153	0.699	
South Western	Lagos	Lagos (1998–2009)	12609 (52.91)	5504 (23.09)	5072(21.28)	64792.71)	23832.00	0.144	0.128	0.727	[33]
	Lagos	UNILAG	83(55.33)	38(25.33)	25(16.67)	4(2.67)	150.00	0.154	0.102	0.744	[45]
	Lagos	UNILAG(2008/2009)	304(67.26)	64(14.16)	70(15.49)	14(3.10)	452.00	0.082	0.098	0.820	[46]
	Ogun	Abeokuta	1074(53.70)	428(21.40)	419(20.95)	79(3.95)	2000.00	0.134	0.133	0.733	[47]
	Ogun	Ayetoro	62(59.05)	20(19.05)	18(17.14)	5(4.76)	105.00	0.115	0.116	0.768	[48]
	Osun	Osogbo	9605(53.58)	3787 (21.12)	3825(21.34)	710(3.96)	17927.00	0.132	0.136	0.732	[49]
	Osun	Bowen Univ., Iwo	49(51.58)	28(29.47)	15(15.79)	3(3.16)	95.00	0.182	0.100	0.718	[50]
	Oyo	Ogbomosho (1995–2000)	3824(49.97)	1750 (22.87)	1629(21.29)	450(5.88)	7653.00	0.147	0.147	0.707	[30]
	Oyo	LAUTECH	596(53.12)	239 (21.300	255(22.73)	32(2.85)	1122.00	0.134	0.137	0.729	[51]
	Oyo	Ibadan (1988–1992)	2575(54.23)	1023 (21.55)	1017921.42)	13392.80)	4748.00	0.134	0.129	0.736	[27]
	Oyo	Ibadan	8756(49.93)	3850 (21.95)	4197(23.93)	735(4.19)	17538.00	0.141	0.152	0.707	[28]
	Ekiti	Ado-Ekiti (2009–2014)	5290(70.05)	972(13.42)	950(13.12)	30(0.41)	7242.00	0.075	0.070	0.855	[52]
Total (SW)			44827 (54.10)	17703 (21.36)	17492 (21.11)	2842(3.43)	82864.00	0.133	0.131	0.736	
South South	Akwalbom	Uyo	227(44.51)	149(29.22)	111(21.76)	23(4.51)	510.00	0.191	0.141	0.667	[53]
	Bayelsa	NDU	98(49.00)	44(22.00)	44(22.00)	14(7.00)	200.00	0.143	0.157	0.700	[54]
	Delta	Abraka	455957.23)	175(22.01)	148(18.62)	17(2.14)	795.00	0.134	0.110	0.757	[55]
	Edo	Benin	85376 (53.22)	38056 (23.72)	32235 (20.09)	4764(2.97)	160431.00	0.148	0.123	0.729	[31]
	Rivers	Port Harcount	342(55.16)	142(22.90)	106(17.10)	30(4.84)	620.00	0.141	0.116	0.743	[56]
	Rivers	PH (Niger Delta)	94(46.08)	54(26.47)	48(23.53)	8(3.92)	204.00	0.173	0.148	0.679	[57]
	Rivers	MUTH, Elele	102(52.85)	52(26.94)	31(16.06)	8(4.15)	193.00	0.166	0.107	0.727	[58]
Total (SS)			86694 (53.20)	38672 (23.73)	32723 (20.08)	4864(2.98)	162953.00	0.148	0.123	0.729	
North West	Kano	Kano	2860(57.20)	1025 (20.50)	1035(20.70)	8091.60)	5000.00	0.125	0.119	0.756	[59]
	Sokoto	Sokoto	2949(46.68)	1401 (22.17)	1725(27.30)	243(3.85)	6318.00	0.147	0.170	0.683	[28]
	Zamfara	Gusau	277(55.40)	88(17.60)	119(23.80)	16(3.20)	500.00	0.110	0.146	0.744	[60]
	Kaduna	ABUTH Kaduna (2000–2004)	6194 (49.200	2681 (21.30)	3059(24.30)	655(5.20)	12589.00	0.138	0.160	0.701	[25]
Total (NW)			12280 (50.31)	5195 (21.28)	5938(24.33)	994(4.07)	24407.00	0.137	0.154	0.709	
South East	Enugu	Enugu	2421(56.88)	1077 (25.31)	650(15.27)	108(2.54)	4256.00	0.152	0.093	0.754	[28]
	Abia	Umudike	356(63.12)	130(23.05)	65(11.52)	13(2.30)	564.00	0.134	0.072	0.794	[61]
	Ebonyi	Abakaliki	1898(57.81)	724(22.05)	593(18.06)	68(2.07)	3283.00	0.133	0.106	0.760	[62]
Total (SE)			4675(57.69)	1931 (23.83)	1308(16.14)	189(2.33)	8103.00	0.143	0.097	0.760	
North East	Borno	Maiduguri	3481(55.62)	1481 (23.67)	1083(17.31)	213(3.40)	6258.00	0.145	0.110	0.746	[28]
	Adamawa	Yola	769950.59)	250(16.45)	326(21.45)	175(11.51)	1520.00	0.107	0.181	0.711	[63]
	Yobe	Nguru	2695(49.23)	1166 (21.30)	1424(26.01)	189(3.45)	5474.00	0.138	0.160	0.702	[64]
Total (NE)			6945(52.41)	2897 (21.86)	2833(21.38)	577(4.35)	13252.00	0.138	0.138	0.724	
Overall total			168808 (52.93)	72623 (22.77)	65826 (20.64)	11683(3.66)	318940.00	0.143	0.130	0.728	This study

Tunisia, Ethiopia and Iran where they reported same order (O > A > B > AB) as ours [17–19,21,24,36] (Table 3). However, our results are slightly different from study in Madagascar and Guinea that reported this trend (O > B > A > AB) as shown in Table 3 [23,25]. Our report is also different from studies in India and Bangladesh where prevalence of B is highest followed by O and the least was AB (B > O > A > AB) [22,26]. Higher prevalence of blood group B in Bangladesh might be due to protection against disease because studies have shown that Cholera infections are particularly severe for blood group O individuals [37–39]. Lastly, our result is also not in congruent with data from Turkey and Colombia where they reported a trend that A > O > B > AB [16,20]. Difference observed might be due to genetic and environmental factors

Table 2
Phenotypic distribution of Rh blood group system and allele frequencies in Nigeria.

Zone	States	Place of Research	Rh+ve	Rh−ve	Total	d(q)	D(p)	References
North Central	Kwara	Ilorin (2004–2009)	9209 (95.5)	434 (4.5)	9643	0.212	0.788	[32]
	Plateau	Jos	3326 (95.68)	150 (4.32)	3476	0.208	0.792	[28]
	FCT	Abuja	292 (95.7)	13 (4.3)	305	0.206	0.794	[44]
	Minna	Niger (2008–2012)	13,480 (96.7)	457 (3.3)	13937	0.181	0.819	[34]
Total (NC)			26307(96.1)	1054 (3.9)	27361	0.198	0.802	
South Western	Lagos	Lagos (1998–2009)	23,053 (97.0)	711 (3.0)	23764	0.173	0.827	[33]
	Lagos	UNILAG	141 (94)	9 (6)	150	0.245	0.755	[45]
	Lagos	UNILAG (2008/2009)	421 (93.14)	31 (6.86)	452	0.262	0.738	[46]
	Ogun	Abeokuta	1867 (93.35)	133 (6.65)	2000	0.258	0.742	[47]
	Ogun	Ayetoro	102 (97.1)	3 (2.9)	105	0.169	0.831	[48]
	Osun	Osogbo	NR	NR	NR	NR	NR	[49]
	Osun	Bowen Univ., Iwo	89(93.7)	6(6.3)	95	0.251	0.749	[50]
	Oyo	Ogbomosho (1995–2000)	6823 (96.7)	230 (3.3)	7053	0.181	0.819	[30]
	Oyo	LAUTECH	1047 (93.32)	75(6.68)	1122	0.259	0.741	[51]
	Oyo	Ibadan (1988–1992)	4520 (95.2)	228 (4.8)	4748	0.219	0.781	[27]
	Oyo	Ibadan	16505 (94.11)	1033 (5.89)	17538	0.243	0.757	[28]
	Ekiti	Ado-Ekiti (2009–2014)	NR	NR	NR	NR	NR	[52]
Total (SW)			54568(95.7)	2459(4.3)	57027	0.208	0.792	
South South	Akwa Ibom	Uyo	481(94.3)	29(5.7)	510	0.238	0.762	[53]
	Bayelsa	NDU	196 (98)	4 (2)	200	0.141	0.859	[54]
	Delta	Abraka	781(98.2)	14 (1.8)	795	0.133	0.867	[55]
	Edo	Benin	150,769(94.0)	9,662 (6.00)	160431	0.245	0.755	[31]
	Rivers	Port Harcount	600(96.8)	20 (3.2)	620	0.180	0.820	[56]
	Rivers	PH (Niger Delta)	190 (93)	14 (7)	204	0.262	0.738	[57]
	Rivers	MUTH, Elele	177 (91.7)	16 (8.3)	193	0.288	0.712	[58]
Total (SS)			153194(94.0)	9759(6.0)	162953	0.245	0.755	
North West	Kano	Kano	4741 (94.8)	259 (5.2)	5000	0.228	0.772	[59]
	Sokoto	Sokoto	6220 (98.45)	98 (1.55)	6318	0.125	0.875	[28]
	Zamfara	Gusau	494 (98.80)	6 (1.2)	500	0.110	0.890	[60]
	Kaduna	ABUTH Kaduna (2000–2004)	NR	NR	NR	NR	NR	[25]
Total (NW)			11455(96.9)	363(3.1)	11818	0.175	0.825	
South East	Enugu	Enugu	4065 (95.51)	191 (4.49)	4256	0.212	0.788	[28]
	Abia	Umudike	534 (94.7)	30 (5.3%)	564	0.231	0.769	[61]
	Ebonyi	Abakaliki	3145(95.8)	138(4.2)	3283	0.205	0.795	[62]
Total (SE)			7744(95.6)	359(4.4)	8103	0.210	0.790	
North East	Borno	Maiduguri	6138 (98.08)	120 (1.92)	6258	0.138	0.862	[28]
	Adamawa	Yola	1480 (97.4)	40 (2.6)	1520	0.162	0.838	[63]
	Yobe	Nguru	5222(95.4)	252(4.6)	5474	0.215	0.785	[64]
Total (NE)			12840(96.9)	412(3.1)	13252	0.176	0.824	
Overall Total			266108(94.9)	14406(5.1)	280514	0.227	0.773	This study

Table 3
Comparative analysis of phenotypic distribution of ABO and Rhesus antigens in different population.

Population	O	A	B	AB	Rh(D)+	Rh(D)−	References
White non-Hispanic in US	45.20	39.70	10.90	4.10	82.7	17.30	[15]
Hispanic in US	56.50	31.10	9.90	2.50	92.7	7.30	[15]
Black non-Hispanic in US	50.20	25.80	19.70	4.30	92.9	7.10	[15]
Asian in US	39.80	27.80	25.40	7.10	98.3	1.70	[15]
North American Indian in US	54.60	35.00	7.90	2.50	90.3	9.70	[15]
All donors in US	46.60	37.10	12.20	4.10	85.4	14.60	[15]
Turkey	29.70	38.20	14.40	6.80	89.6	10.40	[16]
Northern India	29.10	21.73	39.84	9.33	95.71	4.29	[26]
Mauritania	49.10	28.28	18.56	4.05	94.23	5.77	[17]
Morocco	46.80	32.86	15.80	4.53	91	9.00	[24]
Cameroun	48.62	25.07	21.86	4.45	96.32	3.68	[21]
Madagascar	41.60	22.61	29.66	6.13	98.9	1.10	[23]
Guinea	48.88	22.54	23.86	4.72	95.94	4.06	[25]
Ethiopia	43.08	28.11	23.35	5.44	92.06	7.94	[19]
Iran	40.21	28.48	24.71	6.60	92.38	7.62	[18]
Bangladesh	28.00	27.00	34.00	10.00	99	1.00	[22]
Colombia	37.00	51.18	8.66	3.14	91.33	8.66	[20]
Tunisia	59.27	37.64	22.55	6.71	NA	NA	[36]
Nigeria	52.93	22.77	20.64	3.66	94.9	5.10	This study

From the foregoing we can deduced that our result is in congruent with other studies from other parts of Africa where O is the predominant blood group (O > A > B > AB) but slightly different from data from Madagascar and Guinea (O > B > A > AB). Due to the fact that ABO blood group play germane role in human diseases, it is thus beyond immunohaematology [13]. The higher prevalence of O blood group observed in this study might have an evolutionary advantage in conferring resistance to some disease

Table 4
Frequency of allele A(p), B(q) and O(r) in different population.

Population	p	q	r	Reference
Tunisia	0.195	0.120	0.685	[36]
Mauritania	0.177	0.120	0.702	[17]
Morocco	0.209	0.108	0.684	[24]
Cameroun	0.161	0.142	0.698	[21]
Madagascar	0.156	0.199	0.645	[23]
Guinea	0.147	0.155	0.698	[25]
Ethiopia	0.189	0.157	0.655	[19]
Bangladesh	0.211	0.259	0.531	[22]
Nigeria	0.143	0.130	0.728	This study

like malaria that is peculiar to Nigeria. Thus dominance of O group in Nigeria could be protective against malaria because studies have shown that the erythrocytes of an individual with blood type O might not be suitable for rosette formation by *Plasmodium falciparum* [40–41]. Several studies have supported this by reporting protective nature of blood group 'O' from falciparum infection [41–43]. Lastly, our result is in line with Cserti and Dzik, [42] that reported the distribution of blood group O ranging from 40–80% in malaria prone countries in Africa.

As shown in Table 3, phenotypic distribution of Rh(D) reported in this study is in agreement with others reports from different parts of the world [18–25]. But we observed that Rh phenotype (D) – (14.60) was higher among different ethnic/race in US [15]. Higher prevalence of Rh(D)+ is important because clinical situations like fetomaternal hemorrhage during the course of pregnancy could arise through Rh incompatibility.

As shown in Table 4, the gene frequencies for alleles A, B and O from this study were 0.143, 0.130 and 0.728 respectively. This is comparable to studies from Tunisia, Mauritania, Morocco, Cameroun and Ethiopia [17,19,21,24,36] but slightly different reports were recorded from Madagascar, Guinea and Bangladesh because prevalence of allele B was greater than allele A, though O was still the highest allele [22–23,25] (Table 4).

5. Conclusion

This large study from Nigeria gives a detailed prevalence/frequency of ABO and Rhesus factor and their allelic distribution. Our results show a similar trend of ABO/Rh (D) blood group profile compared to many African studies suggesting similar evolutionary pattern. The results should be of importance for Nigeria blood bank information system, population genetics and anthropological research. We also showed how blood group might relate to disease burden which in turn might define the approach to future health strategy and blueprint. Thus, the knowledge of the distribution of ABO and Rhesus (Rh) blood groups is important in the effective management of blood banks and safe blood transfusion services.

References

[1] Giangrande PL. The history of blood transfusion. Br J Haematol 2000;110 (4):758–67.
[2] Landsteiner K. Zur kenntnis der antifermentativen, lytischen und agglutinierenden wirkungen des blutserums und der lymphe. Zentbl. Bakt 1900;27:367.
[3] DesCasterllo A, Sturli A. Uber die Isoagglutinine im Serum gesunder und kranker menschen. Mfinch Med Wschar 1902;49:1090–5.
[4] Yamamoto F, Clausen H, White T, Marken J, Hakomori S. Molecular genetic basis of the histoblood group ABO system. Nature 1990;345(6272):229–33.
[5] Hart Mvd, Veer Mvd, Loghem JJv. Change of blood group B in a case of leukaemia. Vox Sang 1962;7:449–53. doi: http://dx.doi.org/10.1111/j.1423-0410.1962.tb03276.x.
[6] Xiros N, Northoff H, Anger B, Heit W, Heimpel H. Blood group change in a patient with blastic transformation of a myelodysplastic syndrome. Blut 1987;54:275–80.
[7] Jahan Sarwer S, Kamruzzaman AKM, Hossain I, Matin A, Hossain Z. Blood group changed in a patient with acute myelocytic leukemia. J Med 2013;14(1):77–9. doi: http://dx.doi.org/10.3329/jom.v14i1.14559.
[8] Cheng Y, Cheng G, Chui CH, Lau FY, Chan PK, Ng MH, et al. ABO blood group and susceptibility to severe acute respiratory syndrome. JAMA J Am Med Assoc 2005;293(12):1450–1.
[9] Hutson AM, Atmar RL, Graham DY, Estes MK. Norwalk virus infection and disease is associated with ABO histo-blood group type. J Infect Dis 2002;185 (9):1335–7.
[10] Shimazu T, Shimaoka M, Sugimoto H, Taenaka N, Hasegawa T. Does blood type B protect against haemolytic uraemic syndrome? An analysis of the 1996 Sakai outbreak of *Escherichia coli* O157:H7 (VTEC O157) infection. The Osaka HUS critical care study group. J Infect 2000;41(1):45–9.
[11] Storry JR, Olsson ML. The ABO blood group system revisited: a review and update. Immunohematology 2009;25:48–59.
[12] Eastlund T. The histo-blood group ABO system and tissue transplantation. Transfusion 1998;38:975–88.
[13] Liumbruno GM, Franchini M. Beyond immunohaematology: the role of the ABO blood group in human diseases. Blood Trans 2013;11:491–9. doi: http://dx.doi.org/10.2450/2013.0152-13.
[14] Gershman B, Moreira DM, Tollefson MK, Frank I, Cheville JC, Thapa P, et al. The association of ABO blood type with disease recurrence and mortality among patients with urothelial carcinoma of the bladder undergoing radical cystectomy. Urol Oncol 2016;34(1). 4-e1–4-e9.
[15] Garratty G, Glynn SA, McEntire R. ABO and Rh (D) phenotype frequencies of different racial/ethnic groups in the United States. Transfusion 2004;44 (5):703–6.
[16] Kayiran SM, Oktem O, Kayiran PG, Paloglu E, Gurakan B. Frequency of ABO and Rhesus blood groups among neonates born at a private hospital in Istanbul. Southeast Asian J Trop Med Public Health 2012;43(2):467–70.
[17] Hamed CT, Bollahi MA, Abdelhamid I, Mahmoud M, Ba B, Ghaber S, et al. Frequencies and ethnic distribution of ABO and Rh (D) blood groups in Mauritania: results of first nationwide study. Int J Immunogenet 2012;39 (2):151–4.
[18] Torabizade maatoghi J, Paridar M, Mahmodian Shoushtari M, Kiani B, Nori B, Shahjahani M, et al. Distribution of ABO blood groups and rhesus factor in a Large Scale Study of different cities and ethnicities in Khuzestan province, Iran. Egypt J Med Hum Genet 2016;17(1):105–9.
[19] Tesfaye K, Petros Y, Andargie M. Frequency distribution of ABO and Rh (D) blood group alleles in Silte Zone, Ethiopia. Egypt J Med Hum Genet 2015;16 (1):71–6.
[20] Causil-Vargas L, Gómez-Mercado L, Otero-Díaz D, Moscote-Blanco L, Monterrosa-Mestra L, Burgos-Flórez D, et al. Frecuencia de grupos sanguíneos (sistema ABO) entre estudiantes de la universidad de córdoba sede berástegui. Ciencia e Investigación Medico Estudiantil Latinoamericana 2016;21(1):24–6.
[21] Ndoula ST, Noubiap JJN, Nansseu JRN, Wonkam A. Phenotypic and allelic distribution of the ABO and Rhesus (D) blood groups in the Cameroonian population. Int J Immunogenet 2014;41(3):206–10.
[22] Dewan G. Comparative frequency and allelic distribution of ABO and Rh (D) blood groups of major tribal communities of southern Bangladesh with general population and their determinants. Egypt J Med Hum Genet 2015;16 (2):141–7.
[23] Randriamanantany ZA, Rajaonatahina DH, Razafimanantsoa FE, Rasamindrakotroka MT, Andriamahenina R, Rasoarilalamanarivo FB, et al. Phenotypic and allelic profile of ABO and Rhésus D blood group system among blood donor in Antananarivo. Int J Immunogenet 2012;39(6):477–9.
[24] Benahadi A, Alami R, Boulahdid S, Adouani B, Laouina A, Mokhtari A, et al. Distribution of ABO and Rhesus D blood antigens in Morocco. Int J Biol Anthropol 2013;6(1).
[25] Loua A, Lamah MR, Haba NY, Camara M. Frequency of blood groups ABO and Rhesus D in the Guinean population. Transfus Clin Biol 2007;14:435.
[26] Chandra T, Gupta A. Frequency of ABO and rhesus blood groups in blood donors. Asian J Trans Sci 2012;6(1):52–3.
[27] Omotade OO, Adeyemo AA, Kayode CM, Falade SL, Ikpeme S. Gene frequencies of ABO and Rh (D) blood group alleles in a healthy infant population in Ibadan, Nigeria. West Afr J Med 1991;18(4):294–7.
[28] Falusi AG, Ademowo OG, Latunji C. Okeke AC, Olatunji PO, Onyekwere TO, et al. Distribution of ABO and Rh genes in Nigeria. Afr J Med Sci 2000;29:23–6.
[29] Hassan A, Babadoko AA, Ahmed AJ, Isa HA, Suleiman AM. The pattern of distribution of ABO blood groups in North Western Nigeria. Ann Niger Med 2005;1(2):17–8.
[30] Bakare AA, Azeez MA, Agbolade JO. Gene frequencies of ABO and rhesus blood groups and haemoglobin variants in Ogbomosho, South-West Nigeria. Afr J Biotechnol 2006;5:224–9.
[31] Enosolease ME. Distribution of ABO and Rh_D blood groups in the Benin area of implication for regional blood transfusion. Asian J Trans Sci 2008;2(1):3–5.
[32] Iyiola OA, Igunnugbemi OO, Raheem UA, Anifowoshe AT. Gene frequencies of ABO and Rh(D) blood group alleles in Ilorin, North-Central Nigeria. World J Biol Res 2011;4(1):6–14.
[33] Iyiola OA, Igunnugbemi OO, Bello OG. Gene frequencies of ABO and Rh(D) blood group alleles in Lagos, South-West Nigeria. Egypt J Med Hum Genet 2012;13:147–53.
[34] Anifowoshe AT, Oyeyemi BF, Iyiola OA, Ahmed IO, Akinseye KM. Gene Frequencies of ABO and Rh (D) Blood Group Alleles in Minna, North-Central, Nigeria. Niger J Pure Appl Sci 2015;28:2644–57.

[35] Klug WS, Cummings MR, Spencer CA, Palladino MA. Concept of Genetics. 10th ed. Pearson Education Inc; 2012.
[36] Said N, BenAhmed F, Doghri A, Ghazouani E, Layouni S, Gritli N, et al. The ABO system polymorphism in Tunisian blood. Transfus Clin Biol 2003;10:331.
[37] Holmner A, Mackenzie A, Krengel U. Molecular basis of cholera blood-group dependence and implications for a world characterized by climate change. FEBS Lett 2010;584(12):2548–55.
[38] Harris JB, Khan AI, LaRocque RC, Dorer DJ, Chowdhury F, Faruque AS, et al. Blood group, immunity, and risk of infection with *Vibrio cholerae* in an area of endemicity. Infect Immun 2005;73(11):7422–7.
[39] Glass RI, Holmgren J, Haley CE, Khan MR, Svennerholm AM, Stoll BJ, et al. Predisposition for cholera of individuals with O blood group. Possible evolutionary significance. Am J Epidemiol 1985;121(6):791–6.
[40] Rowe JA, Opia DH, Williams TN. Blood groups and malaria: fresh insights into pathogenesis and identification of targets for intervention. Curr Opin Hematol 2009;16:480–7.
[41] Tekeste Z, Petros B. The ABO blood group and Plasmodium falciparum malaria in Awash, Metehara and Ziway areas. Ethiopia Malaria J 2010;9:280.
[42] Cserti CM, Dzik WH. The ABO blood group system and Plasmodium falciparum malaria. Blood 2007;110:2250–8.
[43] Panda AK, Panda SK, Sahu AN, Tripathy R, Ravindran B, Das BK. Association of ABO blood group with severe falciparum malaria in adults: case control study and meta-analysis. Malaria J 2011;10:309.
[44] Olaniyan TO, Ajibola BM, Rasong H, Dare BJ, Shafe MO. Blood Group and Rhesus Factor Pattern among Indigenes of FCT, Abuja, Nigeria. J Commun Med Health Educ 2013;3(3):208.
[45] Adeyemo OA, Soboyejo OB. Frequency distribution of ABO, RH blood groups and blood genotypes among the cell biology and genetics students of University of Lagos, Nigeria. Afr J Biotechnol 2006;5(22):2062–5.
[46] Alimba CG, Adekoya KO, Oboh BO. Prevalence and gene frequencies of phenylthiocarbamide (PTC) taste sensitivity, ABO and Rhesus factor (Rh) blood groups, and haemoglobin variants among a Nigerian Population. Egypt J Med Hum Genet 2010;11(2):153–8.
[47] Oluwadare I, Shonekan S. ABO and Rhesus 'D' blood type distribution in students admitted into MoshoodAbiola Polytechnic, Abeokuta, Nigeria in 2006. Afr J Biotechnol 2008;7(11):1641–3.
[48] Temitayo OI, Timothy SO. Frequency distribution of hemoglobin variants and Rhesus blood groups among pregnant. Women Am Med J 2013;4(1):78–81.
[49] Muhibi MA, Hassan RO, Zakariyahu TO, Tijani BA, Hassan WO, Muhibi MO. Frequencies of ABO blood groups and haemolysins in osogbo, south-western Nigeria. Int J Biol Med Res 2012;3(1):1248–50.
[50] Olubayode B, Dennis SA, Abiola OA. Distribution of ABO and rhesus blood groups among medical students in Bowen University, Iwo, Nigeria. Ann Biol Res 2013;4(11):1–6.
[51] Akhigbe RE, Ige SF, Adegunlola GJ, Adewumi MO, Azeez MO. Malaria, haemoglobin genotypes abd ABO blood group genotypes in Ogbomoso, Nigeria. Int J Trop Med 2011;6(4):73–6.
[52] Famoni PO, Adekoya-Benson T, Ajala O, Agbaje A, Olatimehin O, Adeosun OC, et al. Frequencies of ABO blood groups among blood donors in Ado-Ekiti and its metropolis, South-West, Nigeria. Int J Healthcare Sci 2015;2(2):126–9.
[53] Akpan EB, Iwah-udo IS. Studies of the distribution of ABO blood groups and Rhesus factors in Uyo, Akwa Ibom State, Nigeria. Afr J Appl Zool Environ Biol 2006;8:159–61.
[54] Egesie UG, Egesie OJ, Usar I, Johnbull TO. Distribution of ABO, Rhesus blood groups and Haemoglobin electrophoresis among the Undergraduate students of Niger Delta University Nigeria, Niger. J Physiol Sci 2008;23(1–2):5–8.
[55] Odokuma EI, Okolo AC, Aloamaka PC. Distribution of Abo and Rhesus blood groups in Abraka, Delta State, Niger. J Physiol Sci 2007;22(1–2):89–91.
[56] Jeremiah ZA. Abnormal haemoglobin variants, ABO and Rh blood groups among students of African descent in Port-Harcourt, Nigeria. Afr Health Sci 2006;6(3):177–81.
[57] Erhabor O, Adias TC, Jeremiah ZA, Hart ML. Abnormal hemoglobin variants, ABO, and Rhesus blood group distribution among students in the Niger Delta of Nigeria. Pathol Lab Med Int 2010;2:41–6.
[58] Akinnuga AM, Bamidele O, Amosu AM, Ugwah GU. Distribution of ABO and Rh blood groups among major ethnic groups of medical students of Madonna University Teaching Hospital, Elele, Nigeria. Asian J Med Sci 2011;3(3):106–9.
[59] Chima OK, Mohammed TB, Aisha K, Alhaji SA, Muhammad BM, Kwaru AH. ABO and rhesus blood groups among blood donors in Kano, North-Western Nigeria. Niger J Basic Clin Sci 2012;9(1):11–3.
[60] Erhabor O, Isaac IZ, Saidu A, Ahmed HM, Abdulrahaman Y, et al. The Distribution of ABO and Rhesus Blood Groups among Residents of Gusau, Zamfara State, North Western Nigeria. Res Rev: J Med Health Sci 2013;2 (4):58–63.
[61] Obeagu EI, Ogbodo OR, Onyenweaku F, Emelike CU, Udochukwu AI. Frequency distribution of ABO, Rh blood groups and blood genotypes among the students and staff of Michael Okpara University of Agriculture, Umudike Abia State, Nigeria. Int J Res Rev Pharm Appl Sci 2013;3(4):561–5.
[62] Ugwu ZI. Pattern of ABO and Rhesus blood group distribution among students of Ebonyi State University, Abakaliki, South Eastern Nigeria. Asian J Med Sci 2016;7(1):101–4.
[63] Abdulazeez AA, Alo EB, Rebecca SN. Carriage rate of Human Immunodeficiency Virus (HIV) infection among different ABO and Rhesus blood groups in Adamawa state, Nigeria. Biomed Res 2008;19(1):41–4.
[64] Babadoko AA, Takai IU, Kawuwa MB. Distribution of ABO, Rh d blood groups and haemoglobin phenotypes among antenatal clinic attendees in Federal Medical Centre Nguru, Nigeria. Borno Med J 2014;11(2):86–91.