



Full Length Research Paper

Gene Frequencies of ABO and Rh (D) Blood Group Alleles in Minna, North - Central Nigeria.

A. T. Anifowoshe^{1,2*}, B. F. Oyeyemi^{2,3}, O. A. Iyiola¹, I. O. Ahmed¹, K. M. Akinseye^{2,4},
A. J. Akinsowon^{2,5}.

¹Department of Zoology, University of Ilorin, Ilorin, Nigeria.

²Department of Zoology, University of Ibadan, Ibadan, Nigeria.

³Science Technology Department, Federal Polytechnic, Ado Ekiti, Ekiti, Nigeria.

⁴Biology Department, Adeyemi College of Education, Ondo, Ondo, Nigeria.

⁵Integrated Science Department, Emmanuella Alayande College of Education, Oyo, Nigeria.

*Corresponding author. Email: abassgenetics@gmail.com; anifowoshe.at@unilorin.edu.ng
Tel: +2348037302386

ABSTRACT

Due to its genetic and medical importance, information on distribution and prevalence of ABO and Rhesus blood type is germane in a society. There is dearth of information in Minna North-central Nigeria, it was thus imperative to study its prevalence and allelic frequencies of ABO and Rhesus blood types in the state. This investigation examined the prevalence and gene frequencies for the ABO and Rh (D) alleles in Minna North-central Nigeria, from January 2008 to December 2012 (5 years). Retrospective data for 13937 individuals were extracted over this period for prevalence of ABO and Rh blood groups. This was employed to evaluate the genotypic and allelic frequencies based on Hardy-Weinberg (H-W) equations. Chi-square goodness-of-fit test was also calculated to compare observed and expected frequencies. This study recorded prevalence rate of 44.457%, 25.544%, 19.294%, and 10.705% for O, A, B and AB blood group respectively while 96.721% and 3.279% were Rhesus D positive and negative respectively. Allelic frequencies of the ABO blood groups include O (0.667), A (0.170), B (0.163), and D (0.818) and d (0.182) for Rhesus D positive and Rhesus d negative respectively. On the other hand genotypic frequencies reported were 0.445, 0.029, 0.227, 0.027, 0.217 and 0.055 for OO, AA, AO, BB, BO and AB respectively. All frequencies reported in this study differ significantly from H-W equilibrium (goodness-of-fit χ^2 for ABO = 819.58, df=3, $P \leq 0.05$ and goodness-of-fit χ^2 for Rh = 0.091, df = 1, $P \leq 0.05$). This pioneering study on ABO and Rhesus blood types in Minna strengthens and corroborates the fact that there is genetic variation in ABO and Rhesus blood types. In future results from this study can act as baseline information for geneticist, clinicians and allied professional on the distribution of these germane blood types in Minna.

Keywords: Blood groups, Rhesus, alleles frequencies, gene frequencies.

INTRODUCTION

The ABO and Rhesus (Rh) blood system are the most important blood group system; they are one of the most polymorphic and immunogenic systems known in human. This makes them useful in genetics and medicine. Individuals who lack the A and/or B antigens on their red blood cells generally have naturally occurring antibodies in their plasma that are directed against the missing antigens. For this reason, ABO grouping should include both forward (cell) and reverse (plasma) procedures. Proper determination of the ABO group is necessary when selecting red blood cell-containing products for transfusion in order to prevent immediate hemolytic transfusion reactions, thus it is important in blood transfusion.

Study on blood grouping is germane because of its importance in evolutionary studies, its importance in its relationship with several diseases in gaining popularity by the day. Studies have shown and reported association between ABO blood group phenotype and relative risk of infectious and non infectious diseases which include malaria (Fry *et al.*, 2007; Panda *et al.*, 2011; Wolofsky *et al.*, 2012; Vigan-Womas *et al.*, 2012), sensitivity to *Helicobacter pylori* (Borén *et al.*, 1993) liver fibrosis (Shavakhi *et al.*, 2012), hemorrhage (Dentali *et al.*, 2013) cancer (Iodice *et al.*, 2010; Xie *et al.*, 2010), eye diseases (Khan *et al.*, 2009), skin diseases (Valikhani *et al.*, 2007), cardiovascular diseases (Skaik, 2009; Biswas *et al.*, 2013; Sode *et al.*, 2013), diabetes (Koley, 2008; Okon *et al.*, 2008), Smallpox (Krieger and Vilente, 1969), Leprosy (Urade and Chakravarty, 1999) and Cholera (Swerdlow *et al.*, 1994) though the explanation for the association between ABO blood groups and disease is still unclear. In recent times, studies have shown that there could be relationship between ABO blood group and cancer though this seems to be limited to pancreatic cancer (Woo *et al.*, 2013; Pelzer *et al.*, 2013; Greer *et al.*, 2011; Iodice *et al.*, 2010).

ABO and Rh blood groups are valuable tools in contemporary medicine (blood transfusion, relationship with some diseases, organ transplantation and genetic polymorphism). This make them important during population genetics and anthropological studies (Sigmon, 1992) due to the fact that they have ability to serve as genetic marker. 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 (Bakare *et al.*, 2006; Hanania *et al.*, 2007; Iyiola *et al.*, 2012; Rajshree and Raj, 2013.).

Several studies have been carried out on allelic frequency and distribution of ABO and Rh blood group in Nigeria (Bakare *et al.*, 2006; Iyiola *et al.*, 2012; Chima *et al.*, 2012) but there is dearth of information on allelic frequency and distribution of ABO and Rh blood groups in Minna Niger state, North-central Nigeria. The present study was therefore planned to investigate allelic frequency and distribution of ABO and Rh blood group in Minna. This will serve as source of information to Health care centers and blood banks in this area.

MATERIAL AND METHODS

Medical record from three Health centers namely General Hospital (GHP), Bay Specialist hospital (BSH), and Top Medical Hospital (TMH) in Minna over a period of five years (January, 2008 to December, 2012) was used in this study. Blood specimens were collected from patients and others who came for blood test.

Estimation of blood type (ABO and Rhesus factor) phenotypes and gene (Allele) frequency To estimate phenotypes and gene (alleles) frequencies for ABO blood type; p, q and r was assigned to allele A, B, and O respectively. Their frequencies were calculated according to Hardy-Weinberg (H-W) Law $\{p^2 (I^A I^A) + 2pr (I^A I^O) + q^2 (I^B I^B) + 2qr (I^B I^O) + 2pq (I^A I^B) + r^2 (I^O I^O)\}$ while allele D and d in rhesus type were assigned p and q respectively and their frequencies was calculated using H-W equilibrium $p^2 + 2pq + q^2 = 1$ (Klug *et al.*, 2006).

Ethical approval was sought and collected from health institutions concerned and local government health authority. All blood samples were collected from participants by drawing peripheral venous into ethylenediaminetetraacetic (EDTA) tubes under septic conditions.

Determination of blood groups

With the assistance of chief technologist in Top Medical Hospital, Minna, a week training was undergone before the data was released. Drops of antigens for A, B, AB and O blood groups were placed separately with sterile pipette, on a clean tile with one row of four columns each marked A, B, AB and O respectively. A drop of blood was placed on the anti sera on each column. The cell and serum in each circle were then mixed with a stirrer, and the tiles were rocked for a while. After one minute, the mixture was examined for agglutination. Agglutination in a particular mixture indicated the ABO blood group. When there was no agglutination in the anti-A and B mixture, the sample was O. In the case of anti D column, agglutination means the donor is Rhesus positive while absence of agglutination signifies Rhesus negative.

Allele frequencies were calculated under the assumption of H-W equilibrium and 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 (Klug *et al.*, 2006).

RESULTS

Table 1 showed that a total of 13937 individuals were tested in this study, 6196 (44.457%), 3560 (25.544%), 2689 (19.294%), and 1492 (10.705%) were found to have blood group O, A, B, and AB respectively. A total of 13480 (96.721%) of the population was Rhesus 'D' positive while 475 (3.279%) were Rhesus 'D' negative. Distribution of blood group and Rhesus factor pattern for each hospital were also recorded in Table 1.

Table 1: Phenotypic distribution of ABO and Rhesus blood group system from 2008 to 2012 in Minna, North-Central Nigeria

Study site	ABO system	Rh system					
		A	B	AB	Total	Sex	Rh + Rh - Total
TOP MED	O	496(40.194)	365(29.579)	240(19.449)	133(10.778)	1234	Male 578(46.840) 5(0.405) 583(47.245)
						Female	644(52.188) 7(0.567) 651(52.755)
						Total	1222(99.028) 12(0.972) 1234
BAY		929(53.146)	344(19.680)	276(15.789)	199(11.384)	1748	Male 454(25.973) 18(1.030) 472(27.002)
						Female	1249(71.453) 27(1.545) 1276(72.998)
						Total	1703(97.426) 45(2.574) 1748
GENERAL		477(43.551)	285(26.025)	2173(19.836)	1160(10.589)	10955	Male 3667(33.473) 188(1.716) 3855(35.189)
						Female	6888(62.875) 212(1.935) 7100(64.811)
						Total	10555(96.349) 400(3.651) 10955
GROSS							
TOTAL		6196(44.457)	3560(25.544)	2689(19.294)	1492(10.705)	13937	13480(96.721) 475(3.279) 13937

Values in parenthesis represent percentages of occurrence

As shown in Table 2, frequency of allele O, A and B were 0.667, 0.170 and 0.163 respectively. While D and d were 0.818 and 0.182. Also genotypic frequencies of OO, AA, AO, BB, BO and AB were 0.445, 0.029, 0.227, 0.027, 0.217 and 0.055 respectively. We recorded a genotypic frequency of 0.667, 0.300 and 0.033 for DD, Dd and dd respectively. Genotypic and allelic frequencies of each study site were also recorded in Table 2.

The observed and expected number of ABO and Rh blood group among individuals sampled were recorded in Table 3. As shown in Table 3; using chi square analysis we found out that the distribution and proportion of ABO blood antigens in Minna North-central Nigeria differ significantly from those expected under Hardy–Weinberg equilibrium (goodness-of-fit χ^2 for ABO =819.58, df=3, $P \leq 0.05$). Also, proportion and incidence of Rh blood antigens was not significantly differ from those expected under Hardy–Weinberg equilibrium (goodness-of-fit χ^2 for Rh= 0.091, df=1, $P \leq 0.05$).

Table 2: Gene and allele frequency of ABO and Rh blood type in Minna, North-Central Nigeria

Study site	Gene (allele)	Frequency	Genotype	Frequency	Phenotype	Frequency (%)
TOP MED	O	0.634	OO	0.402	O	40.2
	A	0.296	AA	0.088	A	
	B	0.07	AO	0.375	A	46.3
			BB	0.005	B	
			BO	0.089	B	9.4
			AB	0.041	AB	4.1
	D	0.901	DD	0.812	Rh (D)+ve	
			Dd	0.178	Rh (D)+ve	99
	d	0.099	Dd	0.01	Rh (d)-ve	1
	BAY	O	0.729	OO	0.531	O
A		0.233	AA	0.054	A	
B		0.038	AO	0.34	A	39.4
			BB	0.002	B	
			BO	0.055	B	5.7
			AB	0.018	AB	1.8
D		0.839	DD	0.704	Rh (D)+ve	
			Dd	0.27	Rh (D)+ve	97.4
d		0.161	Dd	0.026	Rh (d)-ve	2.6
GENERAL		O	0.66	OO	0.436	O
	A	0.174	AA	0.03	A	
	B	0.166	AO	0.23	A	26
			BB	0.028	B	
			BO	0.219	B	24.7
			AB	0.058	AB	5.8
	D	0.808	DD	0.653	Rh (D)+ve	
			Dd	0.31	Rh (D)+ve	96.3
	d	0.192	Dd	0.037	Rh (d)-ve	3.7
	GRAND TOTAL	O	0.667	OO	0.445	O
A		0.17	AA	0.029	A	
B		0.163	AO	0.227	A	25.6
			BB	0.027	B	
			BO	0.217	B	24.4
			AB	0.055	AB	5.5
D		0.818	DD	0.667	Rh (D)+ve	
			Dd	0.3	Rh (D)+ve	96.7
d		0.182	Dd	0.033	Rh (d)-ve	3.3

Table 3: Observed and expected number of ABO and Rh blood group among individuals sampled in Minna Nigeria

ABO blood group			Rh system		
Blood group	Observed	Expected	Blood group	Observed	Expected
O	6196	6201	Rh(D)+ve	13480	13474
A	3560	3563			
B	2689	3401	Rh(d)-ve	457	463
AB	1492	772			
Total	13937	13937	Total	13937	13937
goodness of fit $X^2 = 819.58$, df= 3 and $p < 0.05$			goodness of fit $X^2 = 0.091$, df= 1 and $p \leq 0.05$		

DISCUSSION

It is a known fact that there is considerable variation in distribution of ABO blood groups from race to race, Nigeria is no exception (Iyiola *et al.*, 2012) this study reported that (44.457%) of our subjects were group O, (25.544%) were group A, (19.294%) were group B while (10.705%) were group AB implying that prevalence of $O > A > B > AB$. This in tandem with results from other parts of Nigeria; Lagos, Ilorin, Nasarawa, Niger-Delta, Benin, Uyo, Port-Harcourt, Ogbomoso, all six geopolitical zones in Nigeria and Ibadan as reported by Iyiola *et al.* (2012); (2011); Pennap *et al.* (2011); Erhabor *et al.* (2010); Egesie *et al.* (2008); Enosolease and Bazuaye (2008); Ekanem, (2006); Jeremiah, (2006); Bakare *et al.* (2006), Falusi *et al.* (2000) and Omotade *et al.* (1999) respectively but slightly different from the trend ($O > B > A > AB$) reported in Northern parts of the country like Gusau, Abuja, Kano and Adamawa as presented by Erhabor *et al.* (2013); Olaniyan *et al.* (2013); Chima *et al.* (2012) and Abdulazeez *et al.* (2008) respectively.

Although occurrence of blood type O is the highest from all Nigerian study, type A is greater than B in our study, this is not in tandem with other results from Northern Nigeria; this might be due to the fact that there could have been inter regional marriage in our study site because Minna North central Nigeria is proximate (gateway) to other parts of the country. Our result is thus in congruent in previous reports from all Nigerian studies accessed and confirm that group O is the most common among ABO blood group. It is evident that individuals with blood group O had a lower incidence of pancreatic cancer, compared to those with non-O blood groups (Woo *et al.*, 2013; Pelzer *et al.*, 2013). Thus higher incidence of blood type O in our study might be of evolutionary advantage against pancreatic cancer aside from its importance in blood transfusion and improved malaria outcomes in blood group O individuals, this might be due to absence of A or B antigens (Wolofsky *et al.*, 2012).

A similar result ($O > A > B > AB$) was obtained from a study by Hamed *et al.* (2012) during a nationwide study in Mauritania, different ethnic/racial groups in the United State (Garratty *et al.*, 2004), Saudi Arabia (Sarhan *et al.*, 2009) and Iraq (Jaff, 2010). But there was a slight discrepancy ($O > B > A > AB$) from studies conducted in Antananrivo (Madagascar) (Randriamanantany *et al.*, 2012) and Guinea (Loua *et al.*, 2007). Results from Turkey and Jordan by Kuku *et al.* (2004) and Hanania *et al.* (2007) reported a different distribution ($A > O > B > AB$) of ABO blood group. Lastly, our results is also different from prevalence ($B > O > A > AB$) reported from Western Rajasthan (India), Northern India, Utter Pradesh (India), Punjab (Pakistan) and Azad Jammu and Kashmir (Pakistan) by Rajshee and Raj, (2013); Chandra and Gupta, (2012); Rai and Kumar, (2011); Anees and Jawad, (2011) and ($B = O > A > AB$) Khan *et al.* (2009) respectively.

With respect to Rhesus D antigen, the frequency of 96.721% was recorded for Rh positive which consist of DD (66.7%), Dd (30%) while the remaining (3.279%) accounted for Rh negative (dd). Outcome of our study is in congruent with 95.7% positive rate reported in Abuja (Olaniyan *et al.*, 2013), 98.8% in Gusau (Erhabor *et al.*, 2013), 97.0% in Lagos (Iyiola *et al.*, 2012), 95.5% among women in Enugu (Okeke *et al.*, 2012), 94.8% in Kano (Chima *et al.*, 2012), 94.0% in Nassarawa (Pennap *et al.*, 2011), 95.5% in Ilorin (Iyiola *et al.*, 2011), 93.0% in Niger-Delta (Erhabor *et al.*, 2010), 98.0% in Niger-Delta (Egesie *et al.*, 2008), 93.88% in Benin (Enosolease and Bazuaye, 2008), 97.4% in Adamawa (Abdulazeez *et al.*, 2008), 96.68% in Uyo (Ekanem, 2006), 96.7% in Ogbomoso (Bakare *et al.*, 2006), 96.77% in Port-Harcourt (Jeremiah, 2006), 94.30% in six different geopolitical zones in Nigeria (Falusi *et al.*, 2000) and 95.0% reported in Ibadan (Omotade *et al.*, 1999). Similar results was obtained from other parts of the world; Antananarivo (Madagascar) 98.90% (Randriamanantany *et al.*, 2012), Mauritania 94.23% (Hamed *et al.*, 2012), Guinea 95.94% (Loua *et al.*, 2007), Western Rajasthan (India) 91.75% (Rajshee and Raj 2013), Northern India 95.45% (Chandra and Gupta 2012), Utter Pradesh (India) 95.59% (Rai and Kumar, 2011), Punjab (Pakistan) 87.1% (Anees and Jawad, 2011), United State Black non-Hispanic 92.9% (Garratty *et al.*, 2004), Saudi Arabia 92.8% (Sarhan *et al.*, 2009) Iraq 91.73% (Jaff, 2010), Turkey 89.3% (Kuku *et al.*, 2004)

Frequencies of alleles O (0.667), A (0.170) and B (0.163) recorded in this study is in tandem with others from Nigeria (Omotade *et al.*, 1999; Falusi *et al.*, 2000; Iyiola *et al.*, 2011; 2012) in which prevalence of allele $O > A > B$ but slightly different from results from Ogbomoso, Nigeria ($O > A = B$) obtained by Bakare *et al.* (2006). Similarly, our result is also in congruent with results from Mauritania (Hamed *et al.*, 2012), Tunisia (Said *et al.*, 2003), Germany (Wagner *et al.*, 1995), Jordan (Hanania *et al.*, 2007) but dissimilar occurrence ($O > B > A$) was observed in Guinea (Loua *et al.*, 2007), Madagascar (Randriamanantany *et al.*, 2012) and Punjab (Pakistan) (Anees and Jawad, 2011). In all population prevalence of allele O was highest.

Prevalence of ABO in this study differ significantly from those expected under Hardy-Weinberg equilibrium, this is similar to results from Ilorin and Lagos as reported by Iyiola *et al.* (2011; 2012). This might be due to the fact that Minna, Ilorin and Lagos comprised of mixed-populations because people settle in those places easily (high incidence of migration).

CONCLUSION

This study has provided pioneer report on prevalence and allelic frequencies of ABO and rhesus blood type in Minna North-central Nigeria. Genetic diversity in blood types among individuals in Minna has been established and supported by this study. We hope this will serve as a baseline reference material for clinical, genetics and allied studies in Minna, North-central Nigeria.

ACKNOWLEDGEMENT

The authors wish to show appreciation to the authorities and Chief Technologists of Top medical Hospital, Bay Hospital and General Hospital all in Minna, Nigeria for their technical assistance and available records. We also thank the authorities of these hospitals for granting access to these records.

REFERENCES

- Abdulazeez, A.A., Alo, E.B. and Rebecca, S.N. (2008). Carriage rate of Human Immunodeficiency Virus (HIV) infection among different ABO and Rhesus blood groups in Adamawa state. *Nigeria Biomed Res*, 19(1):41–4.
- Anees, M. and Jawad, A. (2007). Distribution of ABO and Rh Blood Group Alleles in Sahiwal district of the Punjab, Pakistan. *Proceedings of the Pakistan Academy of Sciences*, 48 (1): 39–43.
- Bakare, A.A., Azeez, M.A. and Agbolade, J.O. (2006). Gene frequencies of ABO and rhesus blood groups and haemoglobin variants in Ogbomosho, South-West Nigeria. *Afr J Biotechnol.*, 5:224–9.
- Biswas, S., Ghoshal, P.K., Halder, B. and Mandal, N. (2013). Distribution of ABO Blood Group and Major Cardiovascular Risk Factors with Coronary Heart Disease *BioMed Research International*, doi.org/10.1155/2013/782941
- Borén, T., Falk, P., Roth, K.A., Larson, G. and Normark, S. (1993). Attachment of *Helicobacter pylori* to human gastric epithelium mediated by blood group antigens. *Science*, 262(5141):1892-1895.

- Chandra, T. and Gupta, A. (2012). Prevalence of ABO and Rhesus Blood Groups in Northern India. *Journal of Blood Disorders and Transfusion*, 3:132. doi:10.4172/2155-9864.1000132.
- Chima, O.K., Mohammed, T.B., Aisha, K., Alhaji, S.A., Muhammad, B.M. and Kwaru, A.H. (2012). ABO and rhesus blood groups among blood donors in Kano, North-Western Nigeria. *Nigerian Journal of Basic and Clinical Sciences*, 9(1): 11-13.
- Dentali, F., Sironi, A.P., Ageno, W., Bonfanti, C., Crestani, S., Frattini, F., Steidl, L. and Franchini, M. (2013). Relationship between ABO Blood Group and Hemorrhage: A Systematic Literature Review and Meta-Analysis. *Semin Thromb Hemost*, 39:72–82.
- Egesie, U.G., Egesie, O.J., Usar, I. and Johnbull, T. O. (2008). Distribution of ABO, Rhesus blood groups and Haemoglobin electrophoresis among the Undergraduate students of Niger Delta University Nigeria. *Nigerian Journal of Physiological Sciences*, 23 (1-2):5-8.
- Ekanem, M.B. (2006). The distribution of ABO and Rhesus blood groups in University of Uyo Teaching Hospital (UUTH), Uyo, Nigeria. *Ibom Medical Journal*, 1(1):18-20.
- Enosolease, M.E. and Bazuaye, G.N. (2008). Distribution of ABO and Rh-D blood groups in the Benin area of Niger-Delta: implication for regional blood transfusion. *Asian J Transfus Sci.*, 2(1):3–5.
- Erhabor, O., Adias, T.C., Jeremiah, Z.A. and Hart, M.L. (2010). Abnormal hemoglobin variants, ABO, and Rhesus blood group distribution among students in the Niger Delta of Nigeria. *Pathology and Laboratory Medicine International* 2:41–46.
- Erhabor, O., Isaac, I.Z., Saidu, A., Ahmed, H.M., Abdulrahman, Y., Festus, A., Ikhuenbor, D.B., Iwueke, I.P., and Adias, T.C. (2013). The Distribution of ABO and Rhesus Blood Groups among Residents of Gusau, Zamfara State, North Western Nigeria. *Research and Reviews: Journal of Medical and Health Sciences*, 2(4):58-63.
- Falusi, A.G., Ademowo, O.G., Latunji, C.A., Okeke, A.C., Olatunji, P.O., Onyekwere, T.O., Jimmy, E.O., Raji, Y., Hedo, C.C., Otukonyong, E.E. and Itata, E.O. (2000). Distribution of ABO and RH genes in Nigeria. *Afr J Med Med Sci.*, 29(1):23-6.
- Fry, A.E., Griffiths, M.J., Auburn, S., Diakite, M., Forton, J.T., Green, A., Richarson, A., Wilson, J., Jallow, M., Sisay-Joff, F., Pinder, M., Peshu, N., Williams, T.N., Marsh, K., Molyneux, M.E., Taylor, T.E., Rockett, K.A. and Kwiatkowski, D.P. (2007). Common variation in the ABO glycosyltransferase is associated with susceptibility to severe *Plasmodium falciparum* malaria. *Hum Mol Genet.*, 17(4):567-576.

- Garratty, G., Glynn, S.A., McEntire, R. and Retrovirus Epidemiology Donor Study (2004). ABO and Rh(D) phenotype frequencies of different racial /ethnic groups in the United States. *Transfusion*, 44(5):703-6.
- Greer, J. B., LaRusch, J., Brand, R.E., O'Connell, M.R., Yadav, D. and Whitcom for the NAPS2 Study Group (2011). ABO blood group and chronic pancreatitis risk in the NAPS2 cohort. *Pancreas*, 40(8): 1188–1194.
- Hamed, C. T., Bollahi, M. A., Abdelhamid, I., Mahmoud, M.A., Ba, B., Ghaber, S. Habti, N. and Houmeida, A. (2012). Frequencies and ethnic distribution of ABO and Rh(D) blood groups in Mauritania: results of first nationwide study. *International Journal of Immunogenetics*, 39(2):151–154.
- Hanania, S.S., Hassawi, D.S. and Irshaid, N.M. (2007). Allele Frequency and Molecular genotypes of ABO blood group system in a Jordanian Population. *J. Med. Sci.*, 7(1):51-58.
- Iodice, S., Maisonneuve, P., Botteri, E., Sandri, M.T. and Lowenfels, A.B. (2010). ABO blood group and cancer. *European Journal of Cancer*, 46:3345 –3350.
- Iyiola, O.A., Igunnugbemi, O.O. and Bello, O.G. (2012). Gene frequencies of ABO and Rh(D) blood group alleles in Lagos, South-West Nigeria. *The Egyptian Journal of Medical Human Genetics*, 13:147–153.
- Iyiola, O.A., Igunnugbemi, O.O., Anifowoshe, A.T. and Raheem, U.A. (2011). Gene frequencies of ABO and Rh(D) blood group alleles in Ilorin, North-Central Nigeria. *World J Biol Res.*, 4(1):6–14.
- Jaff, M.S. (2010). ABO and rhesus blood group distribution in Kurds. *Journal of Blood Medicine*, 1: 143–146.
- Jeremiah, Z.A. (2006). Abnormal haemoglobin variants, ABO and Rh blood groups among students of African descent in Port-Harcourt, Nigeria. *African Health Sciences*, 6(3):177–81.
- Khan, M.I., Micheal, S., Akhtar, F., Naveed, A., Ahmed, A. and Qamar, R. (2009). Association of ABO blood groups with glaucoma in the Pakistani population. *Can J Ophthalmol.*, 44:582-586.
- Khan, M.N., Khaliq, I., Bakhsh, A., Akhtar, M.S. and Amin-ud-Din, M. (2009). Distribution of ABO and Rh D blood groups in the population of Poonch district, Azad Jammu and Kashmir. *Eastern Mediterranean Health Journal.*, 15(3):717-721.

- Klug, W.S., Cummings, M.R. and Spencer, C.A. (2006). Concept of Genetics 8th Edition. Published by Pearson Education Inc.
- Koley, S. (2008). The distribution of the ABO blood types in patients with diabetes mellitus. *Anthropol.*, 10:129-132.
- Krieger, H. and Vilente, A.J. (1969). Smallpox and the ABO system in Southern Brazil. *Hum Heredity.*, 19:654-657.
- Kuku, I., Kaya, E., Erkurt, M.A., Dikilitaş, M., Yıldız, R., Orhan, M., Görgel, A. and Aydoğdu, I. (2004). Malatya ve Çevresi ABO ve Rh Kan Grubu Dağılımı. *İnönü Üniversitesi Tıp Fakültesi Dergisi.*, 11(4):213-215.
- Loua, A., Lamah, M.R., Haba, N.Y. and Camara, M. (2007). Frequency of ABO blood group and rhesus D in the Guinean population. *Transfus Clin Biol.*, 14(5):435-9.
- Okeke, T.C., Ocheni, S., Nwagha, U.I. and Ibegbulam, O.G. (2012). The prevalence of Rhesus negativity among pregnant women in Enugu, Southeast Nigeria. *Nigerian Journal of Clinical Practice*, 15(4):400-402.
- Okon, U.A., Antai, A.B., Osim, E.E. and Ita, S.O. (2008). The Relative Incidence of Diabetes Mellitus In ABO/Rhesus Blood Groups In South-Eastern Nigeria. *Nig J Physiol Sc.*, 23(1- 2):1-3.
- Olaniyan, T.O., Ajibola, B.M., Rasong, H., Dare, B.J. and Shafe, M.O. (2013). Blood Group and Rhesus Factor Pattern among Indigenes of FCT, Abuja, Nigeria. *J Community Med Health Educ.*, 3(3): 208.
- Omotade, O.O., Adeyemo, A.A., Kayode, C.M., Falade, S.L. and Ikpeme, S. (1999). Gene frequencies of ABO and Rh (D) blood group alleles in a healthy infant population in Ibadan, Nigeria. *West Afr J Med.*, 18(4):294-7.
- Panda, A.K., Panda, S.K., Sahu, A.N., Tripathy, R., Ravindran, B. and Das, B.K. (2011). Association of ABO blood group with severe falciparum malaria in adults: case control study and meta-analysis. *Malaria Journal*, 10:309.
- Pelzer, U., Klein, F., Bahra, M., Sinn, M., Dörken, B., Neuhaus, P., Meyer, O. and Riess, H. (2013). Blood group determinates incidence for pancreatic cancer in Germany. *Frontiers in Physiology*, 4(118):1-4.

- Pennap, G.R., Envoh, E. and Igbawua, I. (2011). Frequency Distribution of Hemoglobin Variants, ABO and Rhesus Blood Groups among Students of African Descent. *British Microbiology Research Journal*, 1(2): 33-40.
- Rai, V. and Kumar, P. (2011). Genetic Analysis of ABO and Rh Blood Groups in Backward Caste Population of Uttar Pradesh, India. *Notulae Scientia Biologicae*, 3(3):7-14.
- Rajshree, B. and Raj, J.Y. (2013). Distribution of ABO blood group and Rh(D) factor in western rajasthan. *National Journal of Medical Research*, 3(1):73-75.
- Randriamanantany, Z.A., Rajaonatahina, D.H., Razafimanantsoa, F.E., Rasamindrakotroka, M.T., Andriamahenina, R., Rasoarilalamanarivo, F.B., Hanitriniala, S.P., Herisoa, F.R., Rasamindrakotroka, A. and Alson, O.A.R. (2012). Phenotypic and allelic profile of ABO and Rhesus D blood group system among blood donor in Antananarivo. *International Journal of Immunogenetics*, 39(6):477–479.
- Said, N., Ben Ahmed, F., Doghri, A., Ghazouani, E., Layouni, S., Gritli, N. and Nsiri, B. (2003) The ABO system polymorphism in Tunisian blood donors. *Transfus Clin Biol*, 10(5):331-4.
- Sarhan, M.A., Saleh, K.A. and Bin-Dajem, S.M. (2009). Distribution of ABO blood groups and rhesus factor in Southwest Saudi Arabia. *Saudi Med J*, 30(1):116-119.
- Shavakhi, A., Hajalikhani, M., Minakari, M., Norian, A., Riahi, R., Azarnia, M. and Liaghat, L. (2012). The association of non-O blood group and severity of liver fibrosis in patients with chronic hepatitis C infection. *Journal of Research in Medical Sciences*, 17(5): 466–469.
- Sigmon, J.M. (1992). Basic principles of the ABO and Rh blood group systems for hemapheresis practitioners. *Journal of Clinical Aphaeresis*, 7(3):158–162.
- Skaik, Y.A. (2009). ABO blood groups and myocardial infarction among Palestinians. *Ann Card Anaesth*, 12:173-174.
- Sode, B.F., Allin, K.H., Dahl, M., Gyntelberg, F. and Nordestgaa, B.G. (2013). Risk of venous thromboembolism and myocardial infarction associated with factor V Leiden and prothrombin mutations and blood type. *Canadian Medical Association Journal*, 185(5):E229-E237.
- Swerdlow, D.L., Mintz, E.D., Rodriguez, M., Tejada, E., Ocampo, C., Espejo, L., Barrett, T.J., Petzelt, J., Bean, N.H. and Seminario, L. (1994). Severe life-threatening cholera associated with blood group O in Peru: implications for the Latin American epidemic. *J Infect Dis*, 170(2):468-472.

- Urade, B.P. and Chakravarty, M. (1999). Association of ABO and Rh blood groups with Leprosy. *J Hum Ecol*, 10(4):297-299.
- Valikhani, M., Kavand, S., Toosi, S., Kavand, G. and Ghiasi, M. (2007). ABO blood groups, Rhesus factor and pemphigus. *Indian J Dermatol*, 52:176-178.
- Vigan-Womas, I., Guillotte, M., Juillerat, A., Hessel, A., Raynal, B., English, P., Cohen, J.H., Bertrand, O. and Peyrard, T. (2012). Structural Basis for the ABO Blood-Grouping Dependence of *Plasmodium falciparum* Rosetting. *PLoS Pathogens*, 8(7): e1002781.
- Wagner, F.F., Kasulke, D., Kerowgan, M. and Flegel W. A. (1995). Frequencies of the Blood Groups ABO, Rhesus, D Category VI, Kell, and of Clinically Relevant High-Frequency Antigens in South-Western Germany. *Infusionsther Transfusionsmed*, 22(5):285–290.
- Wolofsky, K.T., Ayi, K., Branch, D.R., Hult, A.K., Olsson, M.L., Conrad Liles, W., Cserti-Gazdewich, C.M. and Kain, K.C. (2012). ABO Blood Groups Influence Macrophage-mediated Phagocytosis of *Plasmodium falciparum*-infected Erythrocytes. *PLoS Pathogens*, 8(10): e1002942.
- Woo, S.M., Joo, J., Lee, W.J., Park, S., Han, S., Kim, T.H., Koh, Y.H., Kim, H.B. and Hong, E.K. (2013). Risk of Pancreatic Cancer in Relation to ABO Blood Group and Hepatitis C Virus Infection in Korea: A Case-Control Study. *J Korean Med Sci.*, 28: 247-251.
- Xie, J., Qureshi, A.A., Li, Y. and Han, J. (2010). ABO Blood Group and Incidence of Skin Cancer. *Plos One*, 5(8):119-172.