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Variability of blood parameters across ABO and Rh blood groups: Insights from a master health check-up data of adult population

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Abstract

Background: The ABO and Rh blood group systems have been associated with variations in disease susceptibility. This study aimed to assess the variability in blood parameters, including red cell parameters and metabolic parameters (Renal function, hepatic function, blood glucose, lipid profile, and thyroid function), by ABO and Rh blood grouping systems.

Methods: A secondary data analysis was conducted among patients who underwent a preventive health check-up at a private tertiary care hospital in Coimbatore, India. The laboratory database contained records of 62,808 adult participants who reported for master health check-ups between January 2017 and February 2024. Among these patients, those who reported for the first time were included.

Results: Blood grouping and typing data were available for 50,368 and 56,155 participants, respectively, with a mean age range of 52.6 to 53.0 years across all blood groups. The most prevalent blood group was O, followed by B, A, and AB, with a similar distribution across genders. The mean hemoglobin level was highest in the B group (13.7 ± 13.9 g/dl). MCH and MCV values were elevated in the A and O groups, while MCHC and ESR were higher in the B and AB groups. Renal and liver parameters mostly did not vary by blood group or Rh type, except for elevated urea levels in the A group and higher ALP levels in the O and Rh-positive groups. LDL and total cholesterol were highest in the A group, while HDL was highest in the AB group.

Conclusion: The results underscore the importance of considering blood group variations when interpreting blood parameters in clinical practice.

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Introduction

Blood groups are a fundamental classification system based on the presence or absence of specific antigens on the surface of red blood cells. The ABO and Rh systems are the main determinants of blood type (A, B, AB, or O), each being either Rh-positive or Rh-negative. The ABO system is based on the presence of A and/or B antigens, while the Rh system is defined by the presence (Rh-positive) or absence (Rh-negative) of the Rh factor (1). However, genetic changes, including single-nucleotide polymorphisms, can result in changes to the antigenic profile of the ABO system, leading to the emergence of new antigens (2). Human ABO blood group antigens, which are glycoconjugates found on red blood cells, also appear on leukocytes, specific organs, plasma proteins, platelets, and various enzymes (3). Additionally, these antigens can be present in body fluids such as saliva, sweat, breast milk, urine, and gastric secretions (4). They play a significant role in cellular functions and certain disease pathologies (5,6).

The glycoconjugate structures on red blood cells serve a variety of purposes, such as transporters, channels, adhesion molecules, transporters for foreign ligands, viruses, bacteria, and parasites, as well as enzymes. ABO antigens and the associated natural isoagglutinins are crucial in blood transfusion and organ transplantation, though their physiological relevance is still poorly understood (7). Studies have demonstrated correlations between certain infectious and non-infectious disorders and ABO blood types (8). Previous research has shown associations between ABO blood type antigens and various diseases, including malaria (9), cognitive disorders (10), circulatory diseases (11), hyperlipidemia (12), diabetes mellitus (13), and thyroid disorders (14).

A preventive health check-up, or master health check-up (MHC), is a self-initiated, comprehensive medical examination chosen from customizable packages aimed at early diagnosis and assessment of overall health. In the current era of big data analytics, the healthcare system, which has always been an evidence-based management system, has adopted big data applications in various fields, including clinical decisions on safety and effectiveness, medical records management, laboratory records, epidemiology, and pharmacoeconomic benefits (15). The MHC data serve as one such source of big healthcare data. The automated analyzers currently in use accumulate an enormous volume of patient data. Hence, the present study explored the large MHC dataset for variability in blood parameters by blood groups. Specifically, the study assessed the variability in blood parameters, including red cell parameters and metabolic parameters (Renal function, hepatic function, blood glucose, lipid profile, and thyroid function), based on the ABO and Rh blood grouping systems.

Methods

A secondary data analysis was conducted among patients who came for a preventive health check-up at a private tertiary care hospital in Coimbatore, India. The laboratory database contained records of 62,808 adult participants who reported for an MHC between January 2017 and February 2024. From this database, we included patients who reported for an MHC for the first time. The number of first-time patients was 52,400. Among them, data for blood grouping and typing were available for 50,368 and 56,155 patients, respectively (Figure. 1). Complete data on red cell parameters, renal function, hepatic function, blood glucose, lipid profile, and thyroid function were available for all these participants. The Cobas 6000 analyzer (Roche Diagnostics, Switzerland) was employed for conducting liver function tests (LFT), renal function tests (RFT), lipid profile assessments, and thyroid profile, including thyroid-stimulating hormone (TSH), while the Integra 400 Plus system (Roche Diagnostics, Switzerland) was utilized for measuring HbA1c. The Beckman Coulter analyzer (Beckman Coulter, Inc., United States) was used to measure red blood cell parameters in this study. Laboratory data were available in Microsoft Excel and analyzed using SPSS v26. Categorical variables were expressed as percentages, and continuous variables as mean and standard deviation. An independent t-test was used to find the association between blood groups and laboratory blood parameters. The present study was approved by the Institutional Human Ethics Committee (EC/AP/1100/12/2023).

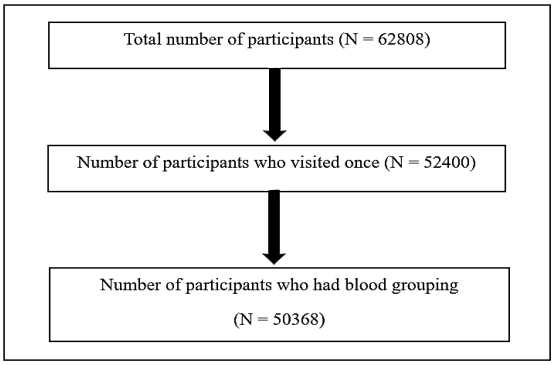

Figure 1. Workflow for the enumeration of participants

Results

The data for blood grouping was available for 50,368 participants and blood typing for 56,155 participants. The mean age ranged between 52.6 and 53.0 years across all blood groups. Among the data available for blood grouping and Rh typing, 37.8% (19,088/50,368) and 36.1% (20,309/56,155) were females, respectively. Blood group distribution was similar for both genders, with the most prevalent being O (41.2% among females and 41.5% among males), followed by B (31.1% among females and 30.8% among males), A (21.3% among females and 21.5% among males), and AB (6.2% among females and 6.1% among males). The baseline demographic characteristics, including age and gender, were statistically comparable across the various blood groups and both Rh types (Table 1).

The mean hemoglobin value was statistically higher among those in the B group (13.7 ± 13.9 g/dl). The MCH and MCV values were statistically higher in the A blood group (28.6 ± 2.9 pg/cell and 85 ± 6.9 mm³, respectively) and the O group (28.6 ± 2.9 pg/cell and 84.9 ± 7.1 mm³, respectively). Conversely, the MCHC and ESR were statistically higher in the B blood group (33.7 ± 1.2 g/dl and 16.1 ± 13.7 mm/hr, respectively) and the AB group (33.7 ± 1.2 g/dl and 15.9 ± 13.6 mm/hr, respectively). The PCV was highest in the B blood group (40.6 ± 5 cells/µl) and lower in the O (40.5 ± 4.9 cells/µl), followed by the AB (40.4 ± 4.9 cells/µl) and A (40.3 ± 4.9 cells/µl) blood groups. PCV and ESR were higher among patients with a Rh-positive blood group (40.8 ± 5 cells/µl and 15.5 ± 13.5 mm/hr, respectively) in comparison with the Rh-negative blood group (40.5 ± 5.2 cells/µl and 12.6 ± 12 mm/hr, respectively) (Table 2).

Most of the renal and liver parameters did not differ based on the blood group or Rh type, except for the urea and ALP levels. Urea was higher in the A group (21.2 g/dl), followed by O, AB, and B. ALP was higher in the O group (80.3 ± 25.9 U/L), followed by B, AB, and A. ALP was also higher in the Rh-positive group (78 ± 26.3 U/L) than in the Rh-negative group (Table 3). LDL and total cholesterol were highest in the A group at 130.1 ± 37.4 mg/dl and 189.4 ± 40.3 mg/dl, respectively. HDL was highest in the AB group at 41.9 ± 10.5 mg/dl (Table 4).

Table 1. Demographic patterns of the study subjects

Demography	Blood grouping (N = 50368)					Rh typing (N = 56155)		
	A	B	AB	O	P-value	Rh +	Rh –	P-value
Age (Years) Mean (SD)	53.0 (12.2)	52.9 (12.1)	52.6 (12.0)	52.9 (12.2)	0.28#	53.2 (12.2)	53.3 (12.0)	0.69 #
Female N. (%)	4068 (37.7)	5955 (38.2)	1198 (38.4)	7867 (37.7)	0.71$	19121 (36.1)	1188 (37.2)	0.21$

#Independent test, $Chi-square test

Table 2. Differences in CBC across various blood groups and Rh types

Blood parameters	A	B	AB	O	P-value£	Rh +	Rh –	P value#
	Mean (SD), N = 50368					Mean (SD), N = 56155		
Haemoglobin (g/dl)	13.6 (1.8)	13.7 (1.9)	13.6 (1.8)	13.6 (1.8)	**< 0.001***	13.7 (1.8)	13.6 (1.9)	0.06
RBC (million/microlitre)	4.8 (0.5)	4.8 (0.5)	4.8 (0.5)	4.8 (0.5)	**< 0.001***	4.8 (0.5)	4.8 (0.6)	**0.017***
WBC (cells/cumm)	7575.5 (2917.6)	7644.8 (2800.9)	7678.3 (5412.2)	7654.4 (1995.1)	0.08	7672.9 (2762.5)	7579.3 (1935.8)	**0.010***
MCH (pg/cell)	28.6 (2.9)	28.5 (2.9)	28.5 (2.8)	28.6 (2.9)	**< 0.001***	28.6 (2.8)	28.6 (2.9)	0.88
MCHC (g/dl)	33.6 (1.2)	33.7 (1.2)	33.7 (1.2)	33.6 (1.2)	**< 0.001***	33.6 (1.2)	33.6 (1.2)	**0.008***
MCV (µm3)	85.0 (6.9)	84.4 (7.0)	84.7 (6.9)	84.9 (7.1)	**< 0.001***	85.0 (7.0)	84.8 (7.0)	0.18
Platelets (cells/µl)	2.9 (0.4)	2.2 (0.5)	4.1 (0.0)	2.7 (0.7)	0.11	2.6 (0.7)	2.7 (0.7)	0.09
PCV (cells/µl)	40.3 (4.9)	40.6 (5.0)	40.4 (4.9)	40.5 (4.9)	**< 0.001***	40.8 (5.0)	40.5 (5.2)	**0.006***
ESR (mm/hr)	15.6 (13.4)	16.1 (13.7)	15.9 (13.6)	15.1 (13.2)	**< 0.001***	15.5 (13.5)	12.6 (12.0)	**< 0.001***

£One-way ANOVA, #Independent test, *Statistically significant at p<0.05

Table 3. Renal and liver function variables across various blood groups and Rh types

Renal and liver function tests	A	B	AB	O	P-value £	Rh +	Rh –	P-value#
	Mean (SD), N = 50368					Mean (SD), N = 56155		
Renal Function Test								
Urea (mg/dl)	21.2 (8.6)	20.8 (8.3)	20.9 (8.5)	21.0 (8.4)	**0.01***	21.0 (8.5)	20.9 (7.8)	0.41
Uric acid (mg/dl)	5.2 (1.4)	5.2 (1.4)	5.1 (1.4)	5.2 (1.4)	0.19	5.2 (1.5)	5.2 (1.4)	0.16
Creatinine (mg/dl)	0.8 (0.4)	0.8 (0.3)	0.8 (0.4)	0.8 (0.4)	0.89	0.8 (0.4)	0.8 (0.3)	0.44
Liver Function Test								
Direct Bilirubin (mg/dl)	0.2 (0.2)	0.2 (0.2)	0.2 (0.1)	0.2 (0.2)	0.13	0.2 (0.2)	0.2 (0.1)	0.65
Indirect Bilirubin (mg/dl)	0.4 (0.3)	0.4 (0.5)	0.4 (0.3)	0.4 (0.3)	0.21	0.4 (0.4)	0.4 (0.3)	0.73
Total Bilirubin (mg/dl)	0.6 (0.4)	0.6 (0.4)	0.6 (0.4)	0.6 (0.4)	0.18	0.6 (0.4)	0.6 (0.4)	0.74
SGOT (U/L)	24.5 (21.2)	24.4 (17.2)	24.2 (16.5)	24.9 (31.2)	0.24	24.7 (24.4)	24.5 (18.2)	0.59
SGPT (U/L)	27.8 (24.4)	27.8 (24.2)	27.6 (20.3)	27.7 (47.5)	0.99	28.0 (35.4)	27.3 (20.9)	0.30
ALP (U/L)	72.8 (24.7)	79.3 (27.9)	73.8 (25.2)	80.3 (25.9)	**< 0.001***	78.0 (26.3)	76.8 (25.8)	**0.011***
Albumin (g/dL)	4.4 (0.3)	4.4 (0.3)	4.4 (0.3)	4.4 (0.3)	0.77	4.4 (0.3)	4.4 (0.3)	0.13
Total Protein (g/dL)	7.3 (0.4)	7.3 (0.4)	7.3 (0.4)	7.3 (0.4)	**0.041***	7.3 (0.4)	7.3 (0.4)	0.86

£One-way ANOVA, #Independent test, *Statistically significant at p<0.05

Table 4. Lipid, thyroid, and glucose profiles across different blood groups and Rh types

Metabolic profile	A	B	AB	O	P-value£	Rh +	Rh –	P-value#
	Mean (SD), N = 50368					Mean (SD), N = 56155		
Lipid profile								
VLDL (mg/dl)	29.9 (20.8)	30.0 (28.8)	30. 2 (22.0)	30.3 (20.8)	0.78	30.3 (24.6)	29.4 (18.2)	0.11
LDL (mg/dl)	130.1 (37.4)	126.8 (36.9)	129.5 (37.7)	127.8 (36.7)	**< 0.001***	129.6 (37.4)	130.0 (36.4)	0.64
HDL (mg/dl)	41.5 (10.1)	41.3 (9.9)	41.9 (10.5)	41.2 (9.9)	**0.02***	41.3 (10.1)	41.3 (10.0)	0.92
Total Cholesterol (mg/dl)	189.4 (40.3)	185.4 (40.4)	188.1 (39.8)	186.0 (39.9)	**< 0.001***	186.8 (40.3)	186.7 (38.5)	0.82
Thyroid profile								
TSH (µU/mL)	3.6 (7.0)	3.5 (6.6)	3.6 (6.4)	3.5 (7.0)	0.792	3.6 (6.9)	3.4 (5.3)	0.11
Blood glucose								
FBS (mg/dl)	117.7 (50.7)	117.7 (50.8)	118.2 (51.7)	116.6 (49.3)	0.07	117.0 (49.7)	115.8 (48.3)	0.204
HbA1c (%)	6.8 (2.1)	6.7 (1.9)	6.8 (1.9)	6.7 (1.9)	**0.021***	6.7 (2.0)	6.7 (1.9)	0.633

£One-way ANOVA, #Independent test, *Statistically significant at p<0.05

Discussion

The distribution of the ABO system showed that O was the most frequent type, accounting for more than two-fifths of the population, followed by B and A. AB was present in only about 6.0%. A similar pattern of distribution, with nearly the same prevalence, was observed in both national and regional (Tamil Nadu) data (16). The order of prevalence, O > B > A > AB, was also reported in studies from other countries, including Australia (17), Britain (18), and the USA (19). Saudi Arabia also had a high prevalence of O and the lowest prevalence of AB (20). However, Europe and Africa had a higher prevalence of A and B groups. The majority (94.3%) of the participants overall, including 94.1% of the females, were Rh positive. This high Rh positivity rate is consistent with the findings of a systematic review from India, which reported a rate of 94.1% both nationally and in Tamil Nadu (16).

The interference of ABO blood grouping in disease expression has been a subject of research since the 1900s. The ABO blood type has also been shown to significantly impact haemostasis, primarily by influencing von Willebrand factor (VWF) and factor VIII levels, which are higher in non-O blood groups due to ABH structures in VWF N-linked oligosaccharides (21-23). Regional analysis within India showed differences in the distribution of the ABO system, and these, in addition to geographical and environmental influences, were related to the occurrence of diseases like cholera and malaria (24-26). The current report is novel in its kind and explored the relation of the ABO and Rh systems with blood parameters. The mean haemoglobin level was normal (Above 13 g/dl) across all groups, likely because the data is from preventive check-ups, mostly involving apparently healthy individuals, and nearly 75% of the participants were males, among whom anemia prevalence in India is low (27). Because the AB antigens are primarily located on RBCs, conditions such as aplastic anemia have shown undetectable levels of A or B antigens (28). However, beyond that, the biological role of AB antigens in disease pathology remains questionable. The current study reported that the mean values of all red blood cell indices, including RBC count, haemoglobin, MCH, MCHC, and MCV, were within the normal range but differed significantly across the various ABO types. Despite higher mean haemoglobin levels in blood group B compared to others, it had the lowest MCH, while groups A and O, with lower haemoglobin levels, had higher MCH. This suggests that haemoglobin alone is not sufficient to diagnose anemia, as MCH varies by blood type, highlighting a potential need to redefine anemia cutoffs for each ABO group. However, the need for further research to determine the role of the ABO system in anemia pathogenesis should also be considered.

The ABO blood group system has been implicated in many solid tumors, including ovarian (29), gastric (30), pancreatic (31), and renal cell carcinomas (RCC). The relationship between ABO and kidneys has been studied extensively in terms of RCC, and one such study by Martino et al. (32) reported that the O blood type has less lymph node metastasis but did not translate into a better survival rate. This study is the first to explore the relationship between renal function markers and the ABO blood system, revealing that blood urea levels are higher in groups A and O, while creatinine levels remain consistent across all groups.

The LDL, total cholesterol, and HbA1c were lowest in the B group and highest in An antigen-containing blood groups (A, AB), indicating that the B group was less prone to cardiovascular diseases. However, because the outcome variables were not available, the need for redefining lipid profile cutoffs with respect to the ABO system might also be considered. Notably, while the mean cholesterol values across all ABO groups were within the normal range, LDL and HDL values showed deviations, which might be attributed to the higher mean age of the participants (33,34).

One of the major strengths of the study is that the participants had a similar age distribution across the various blood groups. The higher mean age of the participants, over 50, enabled a better assessment of metabolic changes, as younger individuals often show normal values, making differences harder to detect. The major limitation is that, being laboratory-based data, it lacks information on pre-existing comorbidities, thereby limiting disease-specific stratified analysis. Pathologies of the kidney or lipid metabolism required clinical correlation (Data not available) in addition to RFT and LFT values for patient diagnosis. However, for conditions such as anemia (Hb values) and diabetes (HbA1c values), where diagnosis can be made, stratified analysis was conducted to determine variability in blood parameters across ABO and Rh blood groups among anemic and diabetic patients.

Conclusion

This study provides novel insights into the variability of blood parameters across different ABO and Rh blood groups in a large cohort from a tertiary care setting in Coimbatore. The findings confirm that the prevalence patterns of ABO blood groups align with national and regional data, with the O blood group being the most common. Significant variations were observed in red blood cell indices, lipid profiles, and renal markers across different blood groups, suggesting a potential influence of ABO blood types on these parameters. Hence, further large dataset studies are to be carried out in this respect. Notably, the B blood group exhibited the lowest mean LDL, total cholesterol, and HbA1c levels, indicating a potentially lower risk for cardiovascular diseases compared to an antigen-containing groups. Further research on disease outcomes may indicate the potential protective effect of blood groups against cardiovascular diseases.

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Ethical statement

A waiver for consent was obtained from the Institutional Ethics Committee of KMCHIHSR.

Conflicts of interest

The authors declare no conflicts of interest regarding this manuscript.

Author contributions

JK, PA, and MK conceived the idea for the study. MK, SK, JS, and AP were involved in data cleaning and analysis, writing the first draft, and reviewing and editing. All authors provided technical input to the manuscript and approved the final version of the paper.

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