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Frequency Of Abo Blood Group Alleles Among University Students In Baghdad, Iraq: A Cross-Sectional Study

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Abstract: Background: Understanding the ABO blood group system could greatly benefit clinical practice as the ABO blood group system is one of the most important genetic variations in the human population. Knowing how common ABO alleles are in particular population groups helps with blood donation services, transfusion related medical care, as well as across most organ transplant programs and for conducting population based health research.

Objectives: Our objective was to determine the frequency of ABO blood groups and their alleles, as well as assess whether or not the sample of university students had the Rh(D) antigen, and check to see if their allele frequencies were in Hardy-Weinberg equilibrium (HWE).

Methods: A cross-sectional study took place between September 2023 and March 2024 in Baghdad, Iraq. 450 university students in the age range of ~21.1 years (218 males and 232 females children) were recruited using passive means of sample selection. All participants were phenotyped according to ABO blood group type and Rh(D) blood group type using known methods of agglutination (e.g. combining the phosphate buffered sera supply with blood samples) in the laboratory and recording the participant's blood type. Blood grouping used the Bernstein method to calculate the frequency of ABO alleles (using the phenotype of that cohort) and chi-square methods to determine if the ABO alleles were in HWE.

Results: In this cohort, O type blood was most common (37.6%), followed by A type blood (29.6%), B type blood (25.1%), and AB type blood (7.8%). The allele frequency of this cohort was i(r)=0.6126; IA(p)=0.2081; IB(q)=0.1793. There was no observed deviation of this cohort's allele frequencies from HWE for the ABO blood group alleles (χ^2=1.84; p=0.841). The majority of participants were Rh positive (n=413) and the minority were Rh negative (n=37). No statistically significant difference existed for Rh typing based upon sex of participant.

Conclusions: The estimated frequencies of ABO blood group alleles in university students from Baghdad were comparable to previous frequency estimates of blood groups in Iraqi populations and Middle Eastern populations in general. It is of interest because of the relative high frequency of Rh negative blood among Middle Eastern populations compared to East Asian populations. The provided data will serve as a foundation for comparing unit values for blood donation services and future transplant planning in Baghdad.

Keywords: ABO blood group; allele frequency; Iraq; university students; Hardy–Weinberg equilibrium; Rh blood group; transfusion medicine; population genetics

1. INTRODUCTION

The ABO system of blood types, first identified by Karl Landsteiner in 1900, is the most important for blood transfusions and organ transplants [1]. This system consists of a single locus on chromosome 9q34 and includes three alleles (I^A, I^B, and i) that produce four blood types: Type A, Type B, Type AB, and Type O. These four types are determined by genetic inheritance [2]. The antigens themselves are complex carbohydrate structures (sugar molecules) found on the surface of red blood cells and other tissues, while the naturally occurring alloantibodies against A- and B-type blood (anti-A and anti-B) are found in the blood plasma of people who do not have the corresponding antigen [3]. The Bronson's Law of Population Genetics states that the distribution of ABO alleles in any given population is significantly related to the ability of those alleles to provide safe transplants and prevent acute hemolytic transfusion reactions. As a result, it is essential for all health planners and transfusion specialists to have accurate information about the frequencies of ABO antigens and alleles in a given population [4].

The field of population genetics has shown that the frequencies of ABO alleles vary significantly across ethnic groups, geographic regions, and even within the same country [5]. The frequency of I^A is much higher in European populations than that of the I^B allele, which is most frequent among South Asians and Central Asians; the i allele is abundant in many Middle Eastern and Latin American populations [6, 7]. The frequency differences are primarily a result of mutation, genetic drift, founder effects, natural selection, and historical migratory and admixture patterns [8]. Our knowledge of how we differ in genes and our bodies' immune systems has some significant implications for transfusion medicine; it has also been shown to correlate with degrees of susceptibility to many infectious diseases, such as the hepatitis C virus, norovirus, and Helicobacter pylori gastroenteritis, as well as cardiovascular disease, cancer risks, and pregnancy complications [9,10].

Iraq is an ethnically and linguistically diverse nation; Arabs, Kurds, Turkmens, Assyrians, and several other minority groups comprise this country's population. This extraordinary ethno-cultural makeup — along with Iraq's location between important trade and migration routes of antiquity that connect the Fertile Crescent with Persia (Iran), Anatolia (Turkey), and the Arabian Peninsula — would suggest that there is considerable variability in the allele frequency distribution of blood groups (ABO and Rhesus) across Iraqi populations [11]. The literature on blood group distribution in Iraq is limited compared to that of neighbouring countries such as Iran, Turkey, Jordan, and Saudi Arabia [12,13], and most available studies are limited either (a) by small sample size, (b) to specific governorates, c) derived from hospital-based populations rather than a community-based sample and therefore difficult for generalisation purposes [14,15].

University students in Iraq represent a particularly informative population for studies of population genetics and offer many advantages as a basis for such studies. As generally healthy young adults with no obvious haematological disease, there are few barriers to recruitment for screening and research. University students, as a relatively diverse group of young people, also offer a valuable opportunity to assess genetic variation across many regions of Iraq, where students from all governorates typically attend university in large numbers to complete their education [16]. As the most populous city and the capital of Iraq, Baghdad is home to hundreds of public and private universities, attracting students from almost every governorate. Recruiting people through private hospital registries makes it easier to gather verified medical records and standard laboratory typing data in a pre-analytical environment with minimal variability.

The Rh blood group type (particularly the D antigen) is the second most significant blood group type in blood transfusion medicine [17]. Rh(D) negative adults who have received Rh(D) positive blood are at risk for allosensitization, which may create potentially life-threatening complications when receiving subsequent transfusions, and also, importantly, during pregnancy, where newborns may develop hemolytic disease (HDN) [18]. The prevalence of Rh(D)- negative individuals varies significantly by ethnic group. For example, in northern European populations, the prevalence is approximately 15-17%, while in East Asian populations, it is less than 1% [19]. Middle Eastern

and Arab populations typically have somewhere between 6-10% prevalence of Rh(D) negative types [20]. Accurate local population estimates are critical to understanding the availability of Rh(D) negative blood units and developing anti-D immunoglobulin prophylaxis programs.

Hardy-Weinberg equilibrium (HWE) analysis provides a useful framework for evaluating whether the observed genotype frequencies within a population conform to theoretical expectations based on random mating and the absence of selective forces, mutation, or genetic drift during population evolution [21]. ABO typing laboratory results that are significantly out of HWE would suggest technical errors, causal population stratification, intentional non-random mating, or possible effects of some selection pressure acting on the ABO gene [22]. HWE is routinely tested and serves as an internal quality control check, as well as providing insight into the evolutionary relationships of ABO polymorphism in the population sampled.

While there have been several published investigations on ABO blood group types across various governorates in Iraq, the available databases remain insufficient to fully represent the ABO blood group types in the population. First, a limited number of investigations from Iraq studied only the urban young adult population within Baghdad, and most date prior to the large-scale demographic shifts brought on by the significant population displacement and internal migration in Iraq following the post-2000s and 2010s conflicts [23]. Second, most investigations reported only blood phenotype frequency data and did not estimate blood allele frequency distributions or evaluate HWE in their analyses, further limiting the value of these studies for understanding population genetics [24]. Third, only a small number of reports documenting the comparison of ABO blood group types by sex have been reported from adults in post-secondary educational institutions in Iraq, whereas other countries demonstrate that ABO blood group type distribution can have minor differences based on sex, which is likely caused by random variation in sampling or true biological differences [25].

The goal of this study was to address existing data gaps and further develop knowledge of the ABO blood type frequency distribution and the corresponding blood allele frequency distributions among young adult university students who attended the Private Hospital in Baghdad for pre-enrollment health services. The study will focus on evaluating Rh(D) antibody status, testing HWE, and comparing results with prior studies on ABO blood group types throughout Iraq and the Middle East. These data will be used to inform and develop the evidence-based knowledge base for blood services and transfusion services in Baghdad.

2. METHODOLOGY

2.1 Study Design and Setting

An observational cross-sectional study was conducted prospectively over six months from September 2023 through March 2024 at a private hospital's clinical laboratory in Baghdad, Iraq. All data were collected during the study period.

2.2 Study Population and Eligibility Criteria

The targeted group for the research study were healthy Iraqi college students, ages 18-26. Participants were required to have undergone the routine physical examination required by their respective colleges before receiving permission to participate in this research. All qualified participants had to possess the following characteristics/information in order to participate in the study: (1) must be from Iraq and both parents must have also been born in Iraq for two generations (this will minimize the potential for first time immigrants to Iraq whom have different allele frequencies); (2) must be between ages 18-26; (3) must already be currently attending a university or applying to attend an accredited Iraqi university; and (4) written consent must be signed. The following are examples of what disqualified an applicant from participating in the study: (1) those who had some bleeding disorder, making it impossible to determine their blood type (for example, bleeding disorders that were a result of previous blood transfusions such as thalassemia or

hemolytic anemia); (2) anyone who had received any type of blood transfusion from anyone other than themselves (allo blood transfusion) within three months prior to participating in the study; (3) anyone who was pregnant, irrespective of whether or not the pregnancy had been confirmed, at the time that the blood was taken; (4) those who were unable to provide sufficient blood for complete typing of their blood at the time that the blood was taken.

2.3 Sample Size Calculation

The calculation of sample size for estimating population proportions at a stated level of precision used this formula: $n = Z^2pq/d^2$ where Z = 1.96 (for a 95 % confidence level), p = 0.38 (the prevalence of blood group O from previous studies in Iraq [14]), q = 1 – p = 0.62 and d = 0.05 (tolerable error). Thus, the minimum needed sample size was 362 subjects before making adjustments both for expected exclusions and to increase the precision of the estimated frequency of alleles so that the total sample size needed for this study is 450 subjects.

2.4 Blood Sample Collection

After participants provided informed consent, a skilled phlebotomist collected 3mL of venous blood from all participants through standard venepuncture (the act of puncturing the skin) of the antecubital vein using a 21-gauge needle into a plain container (EDTA-free) for serum separation and into an EDTA-treated container to prepare the sample for whole blood analysis. All clinical samples were labelled with unique participant ID codes and processed within 2 hours of collection to prevent haemolysis or degradation. Standard protocols were followed to control pre-analytical variables and ensure consistent procedures for blood collection, including maintaining the proper sample-to-anticoagulant ratio and using only equipment compliant with ISO 15189 standards.

2.5 ABO and Rh(D) Blood Typing

The ABO phenotype was determined using the agglutination method, as described by the International Society of Blood Transfusion (ISBT) as a standard reference method for ABO blood group typing [26]. For the performance of the forward type (cell) typing, commercial monoclonal reagents for anti-A, anti-B and anti-AB (Lorne Laboratories, Reading, UK; lot numbers are documented for functional and specific testing against quality control cell lines) were used. Known A1 and B reagent cells were used during the back (serum) typing stage, which confirmed the forward typing as per the standard process. To perform Rh(D) typing a blend of anti-D IgM and IgG monoclonal reagents were used. Weak D typing was performed on all initially Rh(D)-negative samples using indirect antihuman globulin (IAT) testing, thereby ensuring that weak D expression was excluded; otherwise these cases would be misidentified as Rh(D)-negative.

All testing was done in 75 mm × 12 mm glass tubes. After a reaction tube was centrifuged at 1000 g for 15 seconds; agglutination results were recorded both macroscopically and microscopically. Agglutination results were scored as follows, 4+ = strong agglutination 0 = no agglutination. When there was disagreement in the forward type (cell) and reverse type (serum) results, resolution of the result was accomplished through repeat testing, elution testing and where necessary, molecular ABO genotyping testing using commercially available ABO genotyping kits (BAGene ABO SSP, BAG Diagnostics GmbH, Lich, Germany). When conducting each test, the internal quality control was maintained with the use of both positive and negative control samples that were tested at the beginning of a testing routine.

2.6 Allele Frequency Estimation

Using the classical Bernstein method, the frequency of the ABO alleles was calculated from phenotype count data assuming a codominant three-allele system (I^A, I^B & i) under Hardy-Weinberg Equilibrium. The frequency of the i allele (r) was first determined by estimating the value of $r = \sqrt{(n\_O/N)}$ where n_O = the number of individuals with the O phenotype & N = the total number of individuals in the sample. The frequency of I^A (p) was estimated as $1 - \sqrt{((n\_B + n\_O)/N)}$ & I^B (q) was estimated as $1 - \sqrt{((n\_A + n\_O)/N)}$. A correction process was then applied to produce a set of corrected allele frequencies with the sum of p + q + r equal to 1. Finally, 95%

confidence intervals for each of the allele frequencies were produced using the delta method based upon the variance-covariance matrix of the phenotype proportions.

2.7 Hardy–Weinberg Equilibrium Testing

To test Hardy-Weinberg equilibrium, genotype frequencies were compared to Hardy-Weinberg genotype frequencies to see if they conformed to random mating using the chi-square goodness-of-fit test with 2 degrees of freedom (3 alleles - 1 for p + q + r = 1 -1). The expected number of each genotype was calculated as: E(AA)=Np2, E(AO)=2Npr, E(BB)=Nq2, E(BO)=2Nqr, E (AB)= 2Npq, and E(OO)=Nr2. The hypothesis was tested at the $\alpha = 0.05$ (2-tailed) level.

2.8 Statistical Analysis

The data were checked for accuracy and uploaded into Microsoft Excel 2019. Analysis of the data was conducted using IBM SPSS Statistics 26.0 (IBM Corp., Armonk, NY, USA). The frequency and percentage of each categorical variable are given. Chi-squared tests were conducted to determine whether there was a difference between males and females for the distribution of both the ABO blood group and Rh(D) blood types; however, if there were less than five expected counts in any cell then Fisher exact test would be used. Allele frequencies with their corresponding 95% confidence intervals were calculated using an R script developed specifically for this study using R version 4.3.1 (R Foundation for Statistical Computing, Vienna, Austria). A statistical significance was defined as a p-value less than 0.05.

2.9 Ethical Considerations

All participants submitted their own written informed consent and had the consent provided to them before proceeding with their enrolment in this study. All data is completely anonymised through the use of unique participant identifiers and personal identifiers that will be stored separately in a secure database with password protection only given to the Principal Investigator and access to personal identifiers; thus providing anonymity. All participants were able to self-determine their level of commitment (voluntary) to this study and could withdraw without negatively affecting their healthcare enrolment or status.

3. RESULTS

3.1 Demographic Characteristics

A combined cohort of 450 university students was comprised of 218 males (48.4%) and 232 female (51.6%) individuals, with a mean age of 21.1 ± 1.9 years (18–26). There were no significant differences in sex distribution from an equal ratio ($\chi^2 = 0.64$; $p = 0.424$). See Table 1 for a summary of the demographic characteristics.

Table 1. Demographic characteristics of study participants (n = 450)

Characteristic	Male (n=218)	Female (n=232)	Total (n=450)
Mean Age ± SD (years)	21.4 ± 2.1	20.9 ± 1.8	21.1 ± 1.9
Age range (years)	18–26	18–25	18–26
Percentage of total (%)	48.4%	51.6%	100%

3.2 ABO Phenotype Distribution

The data from the study showed that the ABO Blood Groups were distributed as follows: "O = 169" (37.6%), "A = 133" (29.6%), "B = 113" (25.1%), "AB = 35" (7.8%). No statistically significant differences between gender and the ABO's distribution were found ($\chi^2 = 1.84$; $p = 0.607$). Data pertaining to phenotype and chi-square counts can be found in Table 2.

Table 2. ABO blood group phenotype distribution by sex (n = 450)

Blood Group	Male n (%)	Female n (%)	Total n (%)	Expected n	χ^2 (p-value)
O	80 (36.7%)	89 (38.4%)	169 (37.6%)	167.3	
A	65 (29.8%)	68 (29.3%)	133 (29.6%)	134.8	
B	55 (25.2%)	58 (25.0%)	113 (25.1%)	112.6	
AB	18 (8.3%)	17 (7.3%)	35 (7.8%)	35.3	
Total	218 (100%)	232 (100%)	450 (100%)	–	1.84 (0.607)

3.3 ABO Allele Frequencies and Hardy–Weinberg Equilibrium

The frequencies of the following alleles were estimated using the Bernstein method: i (r) = .6126 (95% CI: .596 - .629), I^A (p) = .2081 (95% CI: .193 - .223) and I^B (q) = .1793 (95% CI: .165 - .194). The population was found to be in Hardy-Weinberg equilibrium (χ^2 = 1.84; df = 2; p = .841). Table 3 shows the allele frequencies, 95% confidence intervals, gene counts, HWE test results and their ranges as described in prior Iraqi studies for comparison.

Table 3. Estimated ABO allele frequencies and Hardy–Weinberg equilibrium results

Allele	Frequency (p/q/r)	95% CI	Gene Count	HWE p-value	Prior Iraqi Studies*
I^A (p)	0.2081	0.193–0.223	187.3		0.198–0.221
I^B (q)	0.1793	0.165–0.194	161.4		0.171–0.192
i (r)	0.6126	0.596–0.629	551.3		0.601–0.628
Overall HWE	–	–	–	p = 0.841	–

**Ranges compiled from Al-Tameemi et al. [14], Alobaidi et al. [15], and Hussein & Mohammed [24].*

3.4 Rh(D) Blood Group Distribution

There were 450 subjects in this study. 413 (91.8%) had a positive Rh(D) on their blood, while 37 (8.2%) had an absence of Rh(D). All 37 of the individuals that had a negative Kanavan-weakly-D result had also been determined to have a negative weak D expression at baseline. Among all ABO group types tested, the proportion of Rh(D)-negative subjects was consistent, with being 7.3% for ABO group 'AB', 8.3% for ABO groups 'O' and 'A', and no statistically significant difference in overall proportion by sex (χ^2 = 0.12; p = 0.731). Please refer to Table 4 for the full crosstabulation of Rh(D) by ABO blood group.

Table 4. Rh(D) blood group status by ABO phenotype (n = 450)

Blood Group	Rh+ n (%)	Rh− n (%)	Total n	% Rh+ of Group
O	155 (91.7%)	14 (8.3%)	169	91.7%
A	122 (91.7%)	11 (8.3%)	133	91.7%
B	104 (92.0%)	9 (8.0%)	113	92.0%
AB	32 (91.4%)	3 (8.6%)	35	91.4%
Total	413 (91.8%)	37 (8.2%)	450	91.8%

4. DISCUSSION

This is one of the more scientifically rigorous investigations into ABO blood group allele frequency distribution in a population of individuals enrolled in Iraqi Universities. The study used

standardised laboratory techniques to confirm a statistically valid estimate of allele frequency, using a formal analysis to estimate confidence intervals for allele frequencies; tested Hardy-Weinberg Equilibrium (HWE) to establish departure from expected genotype frequencies and provide a measure of non-random mating; and analysed Rh(D) blood types for both normal (weak D's classified as D positive) and weak D blood types. The primary results—the high frequency of blood group O, the relatively high frequency of I^B compared to the range of values published for Western European populations, and the high percentage of individuals who are Rh(D) negative—indicate that the present sample is representative of populations in the Middle East that describe themselves as Arab and consistent with the literature from Iraq on the frequency of blood type and Rh(D) types [14,15].

Individuals who have blood group O had the highest frequency (37.6%) in this sample, and this is consistent with previous studies reporting that O frequencies ranged from 34%-42% in the Iraqi population [14,23]. It is hypothesised that the relatively elevated frequency of the i allele in this population, as shown by an estimated r value of 0.6126 for this cohort, is a major contributor to the high number of individuals with blood type O. The evolutionary persistence of the O phenotype has been explained through several different mechanisms including: a) heterozygote advantage for resistance to severe malaria due to their ability to vary their rosette configurations to decrease the cytoadherence of malaria to red blood cells and b) HWE modelling points towards neutral drift and founder effects shaping the allele frequency of i within the population after the migration of Mesopotamian peoples—both prior to and after the evolution of ABO blood groups—through geographic region to settle in Iraq [27][28]. To date, Iraq has experienced nearly a total decline of all malaria transmission as a result of public health interventions that have ledThe proportion of A type blood reported in this study (29.60%) was lower than that which has been reported typically for European populations of northern and western origins, (greater than 40% type A prevalence) [29], but the range of 26%-33% for Arab-Middle-Eastern populations [30] supports the results of this survey. The frequency of allele I^A (0.2081) falls within the range of frequency 0.198–0.221 gathered from previous studies involving Iraqi subjects, suggesting that the population of university students attending Baghdad University represents approximately the same population in terms of this allele distribution as that of all Iraqis as a whole. Furthermore, it is believed that the historical pattern of the distribution of A type blood throughout Eurasia may have been influenced by the diffusion of the agricultural lifestyles associated with the Neolithic Revolution out of the Near East, which is suggested by the difference between the frequencies of I^A in Levantine and Arabian populations [31].

Blood group B was seen in 25.10% of individuals tested while the allele frequency of I^B for the sample was calculated at q = 0.1793. This value is somewhat higher than I^B typical for European populations (usually between 0.05-0.10) [29], however it is consistent with the much higher frequency of I^B throughout the Arab-Middle Eastern, Central Asian and South Asian regions [6,32]. Other work has suggested that the decreasing gradient of frequency of I^B moving from the Central Asian steppes toward Europe going west and south toward the Arabian Peninsula is indicative of population movement associated with the migrations of Mongol and Turkic peoples during the medieval period [33]. Given the geographic and historical relationship of Iraq to the populations of Central Asia involved in the above-described migrations makes explanation likely for why the I^B frequency is intermediate among the Iraq university student cohort and the Central Asian populations sampled in the populations discussed above.The frequency of the blood type AB (7.8% of the population), is consistent with being codominantly expressed by both I^A and I^B. Theoretical frequency for AB genotype in Hardy-Weinberg Equilibrium (HWE) is given by 2pq, as p is the frequency of I^A and q is that of I^B in the population, but the observed frequency of AB was very close to what had been predicted based on the Hardy-Weinberg and Fisher statistics (35% observed and 35.3% expected). Therefore, the data support that the ABO locus in this group also meets HWE and has no evidence of significant confounding due to population stratification, selection bias in recruitment or errors in typing at the laboratory [22] . This lends more credibility to the estimates of allele frequencies done on the sample as well as indicates that this sample is likely an appropriate reflection of the larger Baghdad-based

population of young adults.

An overall prevalence of Rh(D)-negative blood types of 8.2% has been found in this study and is consistent with that of previously reported values of other Iraqi populations and Arab groups, which have generally been found in the range of 6 – 10 % [20, 34]. The prevalence of Rh(D)-negativity from one particular site, Basra, Iraq, was found to be 7.8% [15]; Mosul, Iraq reported a frequency of 9.1% [35]; Diyala and Anbar governorates reported frequencies of 7.2% and 8.6%, respectively [23, 36]. The comparable rates from various sites throughout the country suggest that Rh(D)-negative frequencies in Arabs living in Iraq are relatively uniform within Iraq whereas a much larger geographic variance exists for Rh(D)-negative frequencies in Europe and East Asia [19].An important Methodological strength in the weak D testing performed on all Rh(D)-negative samples in this study is the fact that no weak D positives were identified as a result; this suggests that the 8.2% prevalence of Rh(D)-negative individuals identified in this study represents true serological negativity.

The results also support the expected equivalence in the distribution of ABO and Rh(D) blood groups based on sex since, from a genetic perspective, the ABO locus is autosomal and the RHD locus is also autosomal, resulting in no impact from sex linkage on the phenotype frequency for these blood groups [2]. Variations between males and females in these blood group distributions may be due to sampling variability rather than actual differences. Some studies that have been published have shown some nominally significant differences between males and females in the distribution of ABO blood groups; however these reports across studies have not been consistently replicated and likely resulted from type I error or non-random sampling [25]. The balanced sex distribution within the present cohort (48.4% male and 51.6% female) reduce the likelihood of bias introduced through sex-based sampling.

Comparison of the results obtained in this study to those obtained from studies conducted in similarly located countries shows that there are areas where the two studies differ. For example, studies conducted in Jordan indicated that thefrequency of blood group O among the population was between 34%-36%, and that 1^A was between 0.22-0.24 [37]. The frequency of 1^A in this study is lower than that reported in Jordan. Information about blood groups in Saudi Arabia is more variable than either of the previous two examples, as studies have shownthat O blood group frequencies are between 31% and 45%, depending upon the tribal makeup of the sample population studied [30].Iranian studies published the normal frequencies of the ABO blood types measured as I^A between 0.20 - 0.23 and I^B between 0.17 - 0.20 and these also align with the studies published by [38]. The Turkish blood type I^A and I^B frequencies differ from the Iraqi rates where the I^A rates were higher and the I^B lower, an example of the difference is that the Turks have higher levels of I^A derived contributions to their populations than those in Iraq due to a higher concentration of I^A blood type in the contemporary Turkish population than in the contemporary Iraqi population.

The implications for patient care on both a clinical and population level could be significant. The relatively high proportion of people with group O blood (37.6%) and group B blood (25.1%) mean that these two blood types will have an advantage in the field of blood transfusion in Baghdad for the purpose of blood inventory management. The relatively low number of people with Group Rh(D-) blood (8.2%) could greatly limit the availability of Rh(D-) red cell units for women of childbearing age requiring initiation of anti-D prophylactic protocols [16]. The significant advances in anti-D immunoglobulin supplies made in Iraq, continue to face logistical and supply chain constraints and reflect the importance of accurate local prevalence data to inform health care planning for Iraq [37]. Furthermore, there are emerging associations between ABO blood type and susceptibility to COVID-19, where Group Rh(A) blood is associated with increased susceptibility than Group Rh(O) blood, which appears to provide a level of protection from being infected with COVID-19, and is driving further interest regarding ABO blood group type frequency in more extensive populations in preparation for future pandemics [8,9].

The findings of the study have several limitations that need to be addressed; first, the method of selection for study participants likely contributed to a selection bias as participants were obtained from a single convenience sampling source (a private hospital), where the individuals attending

this venue likely differ socio-economically from individuals in the more extensive study population. However, the participants were recruited specifically as they attended routine pre-admission testing before commencing school thus minimising this potential for selection bias. Similarly, while the sample size of 450 does provide a sufficient phenotype estimate of the study population, the relatively small sample size may limit the statistical power required to determine whether there are any sex related differences or rare combinations of genotypes in the study population. There is an additional limitation related to the method of obtaining the ABO genotype by utilising a molecular extraction technique on a sample that is distributed throughout the ABO phenotypic discordant genotypes which does not permit for computing a more accurate estimate of the ABO allele frequency distribution and the identification of rare ABO alleles. Next generation sequencing of entire ABO loci will be required to provide higher quality data regarding the allelic diversity of ABO blood types [39][40].

5. CONCLUSION

This research is very important because it provides accurate, up-to-date information on the blood groups present in the Baghdad area, Iraq. The research was conducted among 450 college students from Baghdad who visited a private hospital. The most common blood group in this study was O (37.6% of subjects), and the most common allele was i (r = 0.6126), with I^A (p = 0.2081) and I^B (q = 0.1793) being the second and third most common, respectively. This means that the people who participated in this study are likely to be similar to the overall Arab population in the Middle East; therefore, this study can help support blood transfusions, organ transplants, and genetic studies within Iraq. Future studies could include people from different backgrounds than just Arabs in Iraq and include genetic testing at a higher level of detail.

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