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Comparative Prevalence of Kidd Blood Group Antigen among Saudi and Non-Saudi Blood Donors in a Regional Blood Bank in Riyadh, Saudi Arabia

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Abstract

Background: Blood group antigens play a critical role in transfusion medicine, affecting the safety and effectiveness of blood transfusions. Among these blood groups, the Kidd blood group system, which includes Jka, Jkb, and Jk3 antigens, is particularly significant due to its implications in delayed hemolytic transfusion reactions and its genetic variability across different populations. ***Objectives:*** This study compared the prevalence of Kidd blood group phenotypes among Saudi and non-Saudi blood donors in the regional blood bank in Riyadh, Saudi Arabia. The goals were to understand the distribution of these antigens and assess the level of genetic integration between the two groups. ***Methods:*** A cross-sectional study was conducted with 311 blood donors, comprising 155 Saudis and 156 non-Saudis. The phenotypes analyzed included Jk(a+b+), Jk(a-b+), Jk(a+b-), and Jk(a-b-). Data were collected from the regional blood bank in Riyadh, and statistical analysis was performed using Chi-square tests to compare phenotype distributions between the groups. ***Results:*** The study found that the most prevalent phenotype was Jk(a+b-), occurring in 47.74% of Saudis and 44.23% of non-Saudis. The least common phenotype was Jk(a-b-), observed in just over 1% of non-Saudis and less than 1% of Saudis. The prevalence rates for Jk(a+b+) and Jk(a-b+) were similar between the two groups, suggesting a high level of genetic integration. No significant differences were found in the distribution of these phenotypes between Saudi and non-Saudi donors, indicating substantial genetic similarity and intermingling. ***Conclusions:*** The results suggest that the regional blood bank in Riyadh has a homogenized population concerning Kidd blood group antigens, facilitating the development of donor databases that include comprehensive antigen profiles. These databases can enhance the precision of blood matching and reduce the risk of transfusion reactions. This study highlights the importance of genetic diversity in developing personalized medicine strategies and adapting transfusion protocols to local and regional antigen profiles.

Keywords: Kidd Blood Group System, Blood Group Antigens, Prevalence, Genetic Diversity, Blood Donors.

INTRODUCTION

Blood grouping is clinically essential for safe blood transfusions and organ/tissue transplantations. Human blood is categorized based on inherited antigenic substances on red blood cells (Daniels, 2010). According to the International Society of Blood Transfusion (ISBT), there are 45 recognized blood group systems (ISBT, 2024), with ABO and Rh being the most significant in transfusion medicine (Dunbar, 2020).

Some significant blood group systems include Duffy, Kidd, Kell, Lewis, MNS, and P (Thornton & Grimsley, 2019). The Kidd blood group system, consisting of Jka, Jkb, and Jk3 antigens, is critical in transfusion medicine (Lawicki *et al.,* 2017). It was first described in 1951 when an anti-Jka antibody was identified in a woman who had delivered a child with hemolytic disease of the newborn (HDN). The Jkb antigen was discovered in 1953 (De Silvestro *et al.,* 2013).

Blood group antigens are immunogenic and can result in antibody formation if a person lacking the antigen is exposed to it through transfusion or pregnancy

(Lawicki *et al.,* 2017). This exposure puts patients at risk of transfusion reactions and hemolytic disease in fetuses and newborns if blood group antibodies are present (Daniels, 2010). Therefore, antibody screening is performed before transfusions, and maternal antibodies are monitored during pregnancy (Dean, 2005).

The Kidd blood group system is essential because anti-Jka and anti-Jkb can cause severe delayed hemolytic transfusion reactions, which are dangerous due to the difficulty in detecting these antibodies (Sanford *et al.,* 2015). Anti-Jk3, produced by those with the rare Jk(a-b-) phenotype, can also cause hemolytic reactions (Daniels, 2013). Additionally, individuals with the Jk(a–b–) phenotype have suboptimal urine concentrating ability (Hamilton, 2015).

The Jk(a+b+) phenotype has a prevalence of around 50% in Caucasians, 40% in Blacks, and 49% in Asians (Reid *et al.,* 2012). Jk(a+b-) constitutes 26% Caucasians, 51% Blacks, and 23% Asians, while Jk(a-b+) is seen in 23% Caucasians, 8% Blacks, and 27% Asians (Reid *et al.,* 2012). The Jk(a-b-) phenotype is extremely rare globally, except in Polynesians, where its prevalence is around 0.9% (Reid *et al.,* 2012). Limited data is available on Kidd blood group prevalence in the Arab population. A study in Kuwait reported phenotype frequencies of 26.2% (Jk(a+b-)), 22.3% (Jk(a-b+)), 50.3% (Jk(a+b+)), and 1.1% (Jk(a-b-)) which is fairly aligned with frequencies reported in Caucasians (Ameen *et al.,* 2003).

While the molecular genetics and clinical significance of the Kidd blood group system are well-established, ethnic variations in its prevalence globally necessitate periodic epidemiological studies (Thakral *et al.,* 2010). With increasing molecular diagnostic capabilities, precision data on allele frequency can also be obtained (Olives *et al.,* 1997). This literature review aims to update the Kidd blood group system and determine the need for prevalence data specific to the population of Saudi Arabia. Updated epidemiological data will help create a donor database for reference in transfusion medicine and aid in the effective inventory management of rare Kidd null donor units (Daniels, 2013).

Expanding on the significance of the Kidd blood group system in transfusion medicine and beyond, it's imperative to delve deeper into its clinical implications, especially concerning hemoglobinopathies prevalent in certain regions, including the Middle East. The Eastern region of Saudi Arabia exhibits a high prevalence of hemoglobinopathies, with significant incidences of Sickle Cell Disease (SCD) and Thalassemia, necessitating multiple transfusions for affected patients (Owaidah *et al.,* 2020). This underscores the importance of comprehensive blood group antigen profiling, including the Kidd blood group, to ensure the provision of phenotypically matched blood, minimizing the risk of alloimmunization and transfusion-related complications.

The discovery of the Kidd blood group system and its antigens underscores human blood groups' complexity and clinical significance. The system's contribution to our understanding of transfusion medicine, particularly the risks associated with alloimmunization and delayed hemolytic transfusion reactions, cannot be overstated (Daniels, 2013; Sanford *et al.,* 2015). Moreover, the physiological role of the Kidd glycoprotein as a urea transporter highlights the interconnectedness of blood group antigens with other bodily functions, offering insights into renal physiology and potentially influencing the clinical management of conditions related to urine concentration (Halawani *et al.,* 2022).

Given the clinical challenges associated with the Kidd blood group antigens, such as the detection of anti-Jka and anti-Jkb antibodies and the management of patients with the rare Jk(a-b-) phenotype, there's a clear need for ongoing research and education in this area (Daniels, 2013; Sanford *et al.,* 2015). The rarity of the Jk(a-b-) phenotype and its associated health implications, albeit minor in urine concentration ability, represent the nuanced understanding required in transfusion medicine and genetics (Sands *et al.,* 1992).

The variation in the prevalence of Kidd blood group phenotypes among different ethnic and racial groups raises important considerations for blood transfusion practices worldwide. The development of a comprehensive donor database, particularly one that includes rare phenotypes like Jk(a-b-), is crucial for enhancing transfusion safety and ensuring that patients receive the most compatible blood possible. This is particularly relevant in regions with diverse populations, where the prevalence of specific blood group antigens and antibodies may significantly differ from global averages (Reid *et al.,* 2012; Ameen *et al.,* 2003; Owaidah *et al.,* 2022).

1.2 Aim and Objectives:

The primary aim of this study is to accurately determine the prevalence of Kidd blood group antigens among Saudi blood donors within the regional blood bank in Riyadh, Saudi Arabia. This analysis will illuminate the distribution of these important blood group antigens and provide insights into the genetic diversity within the Saudi population.

Objectives:

1. Identify the prevalence of Kidd blood group phenotypes among non-Saudi donors.
2. Compare the prevalence of Kidd phenotypes between Saudi and non-Saudi donor groups.

These objectives aim to fill a critical gap in the current understanding of the Kidd blood group system's

epidemiology in the Middle East, particularly within Saudi Arabia. The findings will significantly enhance regional blood transfusion services by enabling more precise and improving patient outcomes and safety during blood transfusion procedures.

Study Importance:

The Kidd blood group system, with its significant antigens Jka, Jkb, and Jk3, plays a crucial role in transfusion medicine, mainly due to the potential for antibodies against these antigens. These antibodies may cause delayed hemolytic transfusion reactions (DHTRs), which are hazardous because of their late onset and difficulty detecting the causative antibodies (Daniels, 2013).

The Jk(a-b-) phenotype is considered rare, even globally. However, it is notable in certain ethnic groups, such as Polynesians. This underscores the necessity for updated and region-specific prevalence data to enhance the management of blood bank inventories, particularly for the rare Jk(a-b-) units, and to ensure the safety of transfusions (Halawani *et al.,* 2022).

Study Hypotheses

This research involves comparing the prevalence of Kidd blood group antigens among Saudi and non-Saudi blood donors in the regional blood bank in Riyadh, Saudi Arabia; the corresponding null and alternative hypotheses are:

Null Hypotheses (H_0): There is no difference in the Jka and Jkb phenotype frequency between Saudi and non-Saudi donors.

Alternative Hypotheses (H_a): There is a difference in the Jka and Jkb phenotype frequency between Saudi and non-Saudi donors.

These hypotheses are formulated to statistically analyze whether there are significant differences in the distribution of Kidd blood group antigens between the two groups, potentially reflecting genetic diversity and influencing transfusion practices.

This study outlines the comparative prevalence of Kidd blood group antigens among Saudi and non-Saudi blood donors in a regional blood bank in Riyadh, Saudi Arabia. Understanding the distribution of Kidd phenotypes is crucial for preventing delayed hemolytic transfusion reactions and managing rare blood unit inventories, highlighting a critical aspect of transfusion safety.

From a global perspective, Hamilton (2015) provided a comprehensive review of the Kidd blood group system, discussing its historical discovery, antigenic characteristics, and the polymorphisms responsible for the Jka and Jkb antigens. Null phenotypes identified in various populations underscore the global relevance and complexity of the Kidd blood group system.

Holt *et al.,* (2020) explored the potential role of antibodies against minor blood group antigens, including those from the Kidd system, in renal transplantation. Their study reviewed the immunogenic potential of minor blood group antigens and their expression in renal tissue, which could lead to cross-reactivity in a transplanted kidney. This research emphasized the need for attention to non-ABO system antibodies in transplant immunology.

From a regional perspective, studies also shed light on the prevalence of Kidd blood group phenotypes. A study in the Jazan Province of Saudi Arabia found the prevalence of Jka and Jkb antigens to be 90.64% and 69.40%, respectively. This indicates that the Jk(a+b+) phenotype is the most common among the study population, underscoring the importance of identifying the frequency of JK antigens and phenotypes in various provinces of Saudi Arabia for transfusion safety and inventory management (Halawani *et al.,* 2022).

Another study in the Eastern region of Saudi Arabia aimed to determine the frequency of major blood group phenotypes, including Kidd. The study found variations in blood group phenotypes compared to other populations due to the diverse ethnic backgrounds in the area. This suggests regional differences in the prevalence of blood group systems, including Kidd, within Saudi Arabia, highlighting the need for localized blood group databases to support transfusion services (Owaidah *et al.,* 2020).

A study by Alsuhaibani *et al.,* (2019) examines red cell antigen prevalence among Sickle Cell Disease (SCD) patients in Riyadh, Saudi Arabia, comparing these frequencies with Caucasian and African American populations. It highlights the challenges in managing transfusions for SCD patients due to alloimmunization risks, noting that the Jk(a-) phenotype is 10% less common in Saudis compared to Caucasians. The study emphasizes the difficulty of providing extended phenotype-matched RBCs for SCD patients and recommends assessing alloimmunization rates to determine the necessity of generalizing extended phenotype matching.

In conclusion, while direct data on the Kidd blood group prevalence, specifically in the Middle East and Saudi Arabia, are limited, the importance of the Kidd blood group system in transfusion medicine and its potential variations across different populations underscore the need for further research in these regions. The existing literature on related genetic and hematological conditions suggests a rich context for exploring the Kidd blood group system's implications for transfusion safety and inventory management of rare blood units within these diverse populations.

METHODOLOGY

This chapter outlines the methodology used to investigate the prevalence of Kidd blood group antigens

among Saudi and non-Saudi blood donors within the regional blood bank in Riyadh, Saudi Arabia. This approach involves designing a prospective, cross-sectional study to capture an overview of the antigen distribution across diverse demographic segments, enabling a comparison of phenotype between Saudis and non-Saudis.

Research Design:

This prospective study employs a cross-sectional design to analyze Kidd blood group antigen prevalence among Saudi and non-Saudi blood donors in regional lab. This design allows for data collection at a single point in time, facilitating the comparison of Kidd phenotypes between the two groups.

Research Approach:

The research employs quantitative methods to gather numerical data on the frequency of Jk(a+b-), Jk(a-b+), Jk(a+b+), and Jk(a-b-) phenotypes among the blood donors, enabling objective measurement and statistical analysis of prevalence rates.

3.3 Research Settings:

The study was conducted at the regional blood bank in Riyadh, and it included mobile donation units visiting high-traffic areas like universities and shopping malls. This diversity ensures comprehensive coverage and access to a broad demographic, enhancing the study's reliability.

Data Sample:

The study targeted blood donors aged 18 to 65 in Riyadh between 2023 and 2024. This age range ensures reliable samples for statistically significant prevalence assessment. Nationality records were used to classify different ethnicities, aiding in the analysis of phenotype frequencies. This enhances the validity of the results and supports tailored transfusion practices for diverse populations.

Inclusion Criteria:

The study specifically included Saudi and non-Saudi donors to understand blood group distributions across different genetic backgrounds, providing a robust data set for comparative analysis.

Sampling Method:

A convenience sampling method was employed to recruit donors who met the inclusion criteria during the study period. Using the Raosoft online sample size calculator, a sample size of 4,204 donors was estimated based on blood bank data records. This estimation was made with a confidence level of 95% and a margin of error of 5.4%.

Data Collection:

Data were collected from blood bank records and donor databases. Anti-sera were used from Bio-Rad Medical Diagnostics GmbH reagents to determine Kidd antigen presence via the tube method.

The tube test involves the agglutination method in which the monoclonal antibodies Anti-Jka and Anti-Jkb.

Test steps based on manufacture instructions:

1. Preparation: A 3-5% suspension of red blood cells is prepared in an isotonic saline solution.
2. Reagent addition: A drop of Anti-Jka or Anti-Jkb reagent is placed in a labeled tube.
3. Mixing and incubation: A drop of red blood cell suspension is added, mixed, and incubated at room temperature for 15-30 minutes.
4. Centrifugation: The mixture is centrifuged at 800-1000 x g for 60 seconds.
5. The reactivity of each batch of reagents is confirmed against known antigen-positive and negative samples, ensuring specificity and reliability.
6. Reagents are stored at a temperature of 2 to 8 degrees Celsius and may not be used after the expiration date or if they appear cloudy.

Data Analysis

Statistical analysis quantified and compared Kidd antigen prevalence among Saudi and non-Saudi donors using Excel. Additionally, the results were confirmed using SPSS version 26 for enhanced reliability. Methods included:

1. **Descriptive Statistics:** Calculating frequencies and percentages of Kidd phenotypes and demographic analysis to identify patterns.
2. **Inferential Statistics:** Chi-square tests were used to compare Kidd antigen prevalence and test for statistical significance. The choice of chi-square tests is appropriate for categorical data and helps determine if there is a significant association between nationality and Kidd phenotype distribution.

Ethical considerations

Ethical considerations will be addressed throughout the study to protect participants' rights and confidentiality. The research protocol will be reviewed and approved by the institutional review board of KSMC (IRB-H0RI-30-Jan-24-01). Informed consent will be obtained from all participants before their inclusion in the study, and measures will be implemented to safeguard their privacy and anonymity. Any potential conflicts of interest will be disclosed and handled appropriately.

RESULTS

This chapter presents the statistical analysis results of Kidd blood group antigen prevalence among Saudi and non-Saudi blood donors in the Regional Blood Bank of Riyadh, focusing on Jk(a+b+), Jk(a-b+), Jk(a+b-), and Jk(a-b-) phenotypes.

Sample Description

A total of 311 blood donors participated, consisting of 155 Saudis and 156 non-Saudis. This balanced cross-section of the regional blood bank in Riyadh's diverse population provides sufficient statistical power to detect differences in blood group phenotype prevalence.

Participants

The participants were adult blood donors aged 18-65, sampled from the main donation center in the regional lab and mobile units. Inclusion criteria required healthy donors with no recent transfusions or bone marrow transplants. The study focused on the following Kidd phenotypes:

1. **Jk(a+b+):** Presence of both Jka and Jkb antigens.
2. **Jk(a-b+):** Presence of Jkb and absence of Jka antigens.
3. **Jk(a+b-):** Presence of Jka and absence of Jkb antigens.
4. **Jk(a-b-):** Absence of both Jka and Jkb antigens.

Analyzing these phenotypes aims to improve blood transfusion protocols, donor-recipient matching, and patient safety.

Descriptive Statistics

This section presents a descriptive analysis of the 311 donors. Table 1 shows the distribution of participants by blood phenotype and nationality.

Table 1: Donor and Prevalence Rates of Kidd Blood Group Phenotypes

Phenotype	Group	Donor	Prevalence (%)
Jk(a+b+)	Saudi	58	37.42
Jk(a+b+)	Non-Saudi	59	37.82
Jk(a-b+)	Saudi	22	14.19
Jk(a-b+)	Non-Saudi	26	16.67
Jk(a+b-)	Saudi	74	47.74
Jk(a+b-)	Non-Saudi	69	44.23
Jk(a-b-)	Saudi	1	0.65
Jk(a-b-)	Non-Saudi	2	1.28
Total	Saudi	155	100
Total	Non-Saudi	156	100

The following Figure 1 presents these statistics to visually illustrate the differences in the distribution of phenotypes among various nationalities:

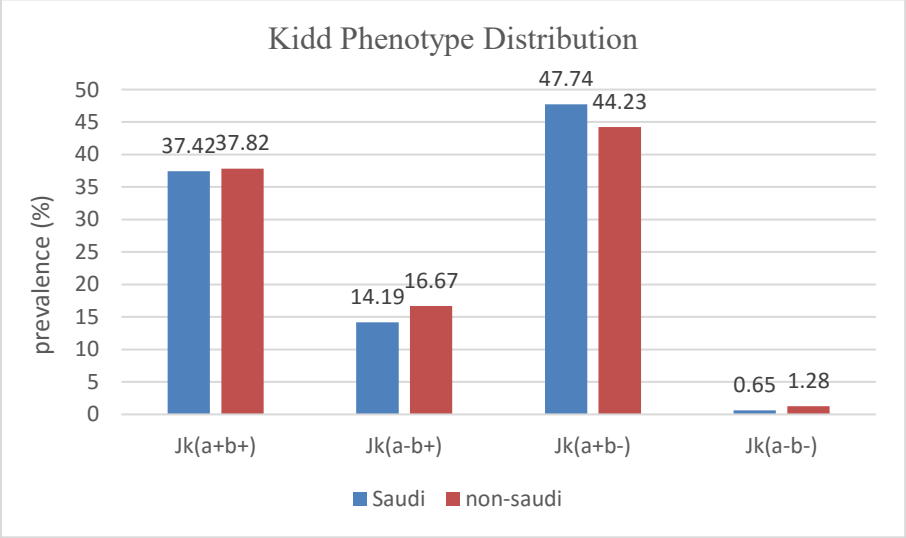

Figure 1: Kidd phenotype distribution

As Table 1 and Figure 1 indicate, the most common phenotype among both groups is Jk(a+b-), with a slightly higher prevalence in Saudis (47.74%) compared to non-Saudis (44.23%). This phenotype, indicating the presence of Jka and the absence of Jkb antigens, suggests a higher adaptability or historical prevalence of the Jka antigen in the population's genetic makeup. Conversely, the least common phenotype observed is Jk(a-b-), with an incidence of 0.65% in Saudis and 1.28% in non-Saudis. The rarity of this phenotype highlights its limited expression in the general population. The analysis reveals minor differences in the prevalence rates of Kidd blood group phenotypes between Saudi and non-Saudi donors. Both groups show

similar patterns in the distribution of these antigens: Jk(a+b+) at 37.42% in Saudis and 37.82% in non-Saudis, and Jk(a-b+) at 14.19% in Saudis and 16.67% in non-Saudis.

Inferential Statistics:

Chi-Square Tests

Implement a Chi-square test in Excel to determine whether there are statistically significant differences between observed and expected frequencies for each category (Saudi and non-Saudi) and then calculate the expected frequencies for each category. The results were confirmed using SPSS version 26 for enhanced reliability. Methods included:

Steps in Chi-square Test Implementation:

1. **Prepare Data**: Arrange the observed values (O) in a table format. The following table shows the observed values for each group:

Phenotype	Saudi	non-saudi
Jk(a+b+)	58	59
Jk(a-b+)	22	26
Jk(a+b-)	74	69
Jk(a-b+)	1	2

Figure 2: The observed Values calculation in the Chi-square test implementation

2- The second step is the expected value (E) calculation step, which uses the following formula:

$$E = \frac{(crospond\ row\ total\ *\ crospond\ column\ total)}{total}$$

The following Table shows the calculated Expected values (E) Table:

expected (E)

group	Jk(a+b+)	Jk(a-b+)	Jk(a+b-)	Jk(a-b-)
Saudi	58.311897	23.92283	71.270096	1.495177
Non-Saudi	58.688103	24.07717	71.729904	1.504823

Figure 3: The Expected Values calculation in the Chi-square test implementation

1- In the third step, after the expected values table is read, the chi-square statistic will be calculated using the following formula:

$$X^2 = Sum\ [\frac{(O-E)^2}{E}]$$

Where O is the observed frequency, and E is the expected frequency. Calculate this for each category and have them in a separate row or column. The ratio represents the difference between the frequencies observed in the experiment (O) and the theoretically expected frequencies based on specific theories (E). It can also be found by dividing the difference between the observed and expected frequencies by the expected frequencies. The following table shows the calculated values:

(O-E)^2/E

group	Jk(a+b+)	Jk(a-b+)	Jk(a+b-)	Jk(a-b-)
Saudi	0.00167	0.15455	0.10457	0.16399
Non-Saudi	0.00166	0.15356	0.10389	0.16294
x^2	0.84683			

Figure 4: Step 4 calculations in Chi-square test implementation

2- The fourth step is the determination of the Degrees of Freedom (DoF) value. It can be calculated for a Chi-square test by computing n−1, where n is the number of categories in the analyzed data.

$$DOF = (No.of\ Columns\ - 1) * (No.of\ rows - 1)$$

To calculate DoF in this study, the value is DoF after variables substituting:

$$DOF = (4\ - 1) * (2 - 1) = 3$$

3- The final step includes using the function (p_value = chi2.sf (chi_square_statistic, DOF)). Its results are the output of the Chi-square statistic test implementation of the study's data set. By implementing all these steps in this study data, the p-value of the test =0.83824.

By comparing the p-value of the Chi-square test to the significance level of 0.05, we find that the p-value is greater than 0.05. This means that we fail to reject the null hypothesis, indicating no significant difference between the observed and expected frequencies. Thus, the Chi-square test results do not indicate significant differences in the distribution of Kidd blood group phenotypes between Saudi and non-Saudi donors, suggesting that donor nationality does not significantly influence the prevalence of these phenotypes within the studied population.

DISCUSSION

This study examines the prevalence of Kidd blood group antigens among 311 participants, divided between Saudis and non-Saudis at the regional blood bank in Riyadh. The most common phenotype was Jk(a+b-), slightly more prevalent in Saudis, while the rarest was Jk(a-b-), observed at a minimal frequency (less than 1% in Saudis and slightly above 1% in non-Saudis).

The findings effectively answer the research questions and the hypotheses posed. The null hypothesis, which states that there is no difference in Jka and Jkb phenotype frequency between Saudi and non-Saudi donors, is supported by the data. This suggests that donor nationality does not significantly influence the prevalence of these phenotypes within the studied population.

This higher prevalence rate and similar distribution patterns suggest a significant genetic mixing and similarity. One reason may be that the majority of the non-Saudis are also from Arab ethnicities, such as Yemen, Jordan, and Egypt. The absence of significant differences in Kidd blood group antigen prevalence between Saudi and non-Saudi donors supports the development of donor databases that include comprehensive antigen profiles. This simplifies the process of finding phenotype matching and eliminates the need for ethnicity-based differentiation. This can enhance the efficiency of blood transfusions and reduce the risk of alloimmunization. Keller *et al.,* (2023) highlight the importance of genetic typing and personalized transfusion strategies, which align with these findings by demonstrating how detailed genetic and antigen profiling can improve transfusion safety and efficacy.

Personalized medicine strategies in transfusion practices involve customizing treatments based on individual characteristics, which means creating comprehensive donor databases with detailed antigen profiles. This will significantly reduce the risk of alloimmunization, especially for patients with hemoglobinopathies like sickle cell disease and thalassemia, who require frequent transfusions and are at a higher risk of adverse reactions (Reid *et al.,* 2012; Halawani *et al.,* 2022). Implementing personalized protocols based on these antigen profiles can improve clinical outcomes and minimize adverse reactions. These databases should be regularly updated and carefully maintained with robust data management systems to ensure accuracy and accessibility. Additionally, connecting these databases with other healthcare providers will ensure comprehensive and coordinated care, enabling informed decision-making and better patient outcomes (Keller *et al.,* 2023).

In populations where Jk(a+b-) is prevalent, as indicated by this study, the risk of alloimmunization against Jkb could be increased, especially for those who receive multiple transfusions, such as patients with sickle cell disease and thalassemia. This necessitates a more careful approach in blood transfusion practices. To minimize this risk, it is advisable to extend phenotype matching for transfusions beyond the Kidd blood group

system to include other clinically significant antigens such as Rh, Kell, and Duffy systems. Extended phenotype matching can help in reducing alloimmunization and prevent severe hemolytic transfusion reactions, as observed when the recipient is exposed again to an antigen to which they have previously developed antibodies (Reid *et al.,* 2012).

The rarity of the Jk(a-b-) phenotype, which lacks both Jka and Jkb antigens, presents a unique challenge and opportunity in transfusion medicine. Individuals with this phenotype can serve as universal donors for patients with antibodies against Jka and Jkb, making them invaluable in specific transfusion scenarios. However, their extreme rarity necessitates careful management and strategic planning within blood banks. This study found that the least common phenotype was Jk(a-b-), observed in just over 1% of non-Saudis and less than 1% of Saudis, underscoring its limited expression in the general population (Halawani *et al.,* 2022; Owaidah *et al.,* 2020).

A comparison in negative frequencies between the current study at the regional blood bank in Riyadh and AlSuhaibani *et al.,* (2019) is shown in Figure 5:

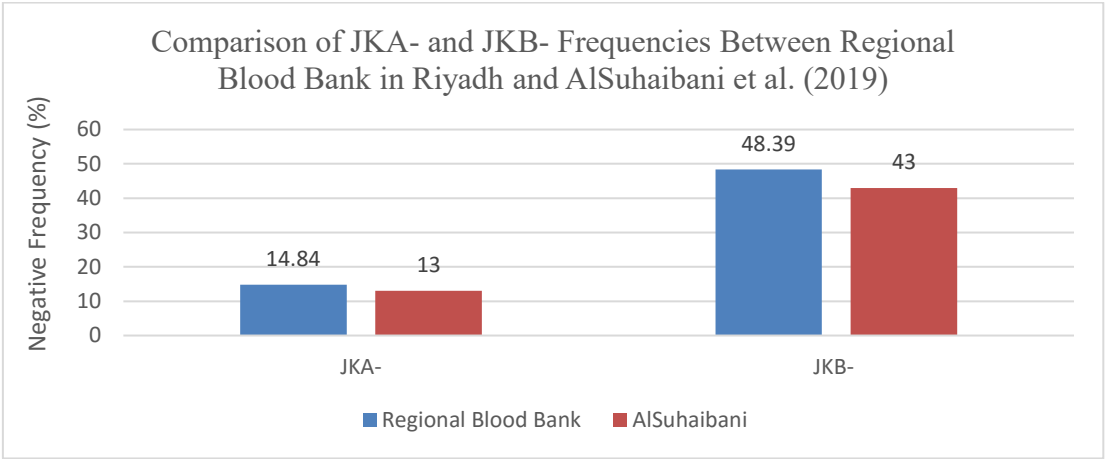

Figure 5: Comparison of JKA- and JKB- Frequencies Between Regional Blood Bank in Riyadh and AlSuhaibani *et al.,* (2019)

Figure 5 illustrates the frequencies of the JKA- and JKB- blood group antigens. At the Regional Blood Bank in Riyadh, the JKA- frequency is 14.84%, slightly higher than the 13% reported by AlSuhaibani *et al.,* (2019) at Prince Sultan Military Medical City in Riyadh. Similarly, the JKB- frequency is 48.39%, compared to 43% in AlSuhaibani *et al.*'s study. This close similarity in frequency percentages underscores the reliability of the data. It highlights the necessity for ongoing monitoring and updates of blood group antigen prevalence to enhance transfusion safety and the effectiveness of donor matching.

Regional Diversity of Kidd Phenotypes Distribution

The comparative analysis of Kidd blood group antigens between the Riyadh region and other geographical areas, as highlighted in the studies by Halawani *et al.,* (2022) and Owaidah *et al.,* (2020), examined the prevalence of Kidd blood group antigens in the Jazan Province of Saudi Arabia, found significantly different distributions when compared to other ethnicities, including the Eastern Province as reported by Owaidah *et al.,* (2020).

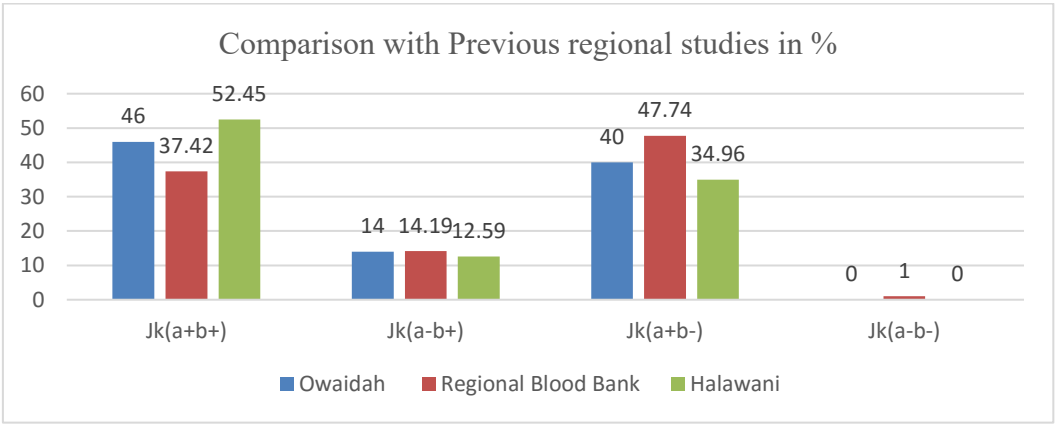

Figure 6: Comparison with Previous regional studies in %

As shown in Figure 6. By comparing these findings with the study conducted by Owaidah *et al.,* in the Eastern region of Saudi Arabia and Halawani *et al.,* in Jazan, the Jk(a+b-) phenotype is observed in 40% of donors in the Eastern region, which is lower than the 47.74% at the Regional Blood Bank in Riyadh but higher than the 34.96% in Jazan. The Jk(a-b+) phenotype in the Eastern region is 14%, similar to the 14.19% at the Regional Blood Bank in Riyadh and slightly higher than Jazan's 12.59%. The Jk(a+b+) phenotype is present in 46% of donors in the Eastern region, which is higher than the 37.42% at the Regional Blood Bank in Riyadh but lower than Jazan's 52.45%. Interestingly, The Jk(a-b-) phenotype is absent in the Eastern region, similar to Jazan, while at the Regional Blood Bank in Riyadh, it is 0.65%)

These regional variations in Kidd blood group antigen prevalence within Saudi Arabia, as highlighted by the contrasting findings in Jazan and the Eastern Provinces, underscore the need for localized blood transfusion protocols that consider these genetic diversities. For example, the Jazan Province showed a different distribution of Kidd antigens compared to Riyadh, necessitating specific donor databases for that region. Similarly, the Eastern Province displayed unique antigen prevalence patterns, indicating the need for region-specific donor-recipient matching databases. Adapting transfusion practices to regional genetic characteristics and connecting the database with other healthcare providers in those regions is crucial for minimizing risks such as alloimmunization and transfusion-related complications.

Furthermore, the international literature, including work by Hamilton (2015), links the prevalence and distribution of blood group antigens to broader immunological responses. Hamilton (2015) elaborates on the clinical implications of the Kidd blood group system in red blood cell serology, providing a global overview of how these antigens can impact patient care.

CONCLUSIONS

This study revealed no significant differences in the prevalence of Kidd blood group antigens between Saudi and non-Saudi blood donors at the regional blood bank in Riyadh, indicating high genetic integration. These findings support the development of donor databases that include comprehensive antigen profiles, which can enhance the precision of blood matching and reduce the risk of transfusion reactions. This approach can lead to improved transfusion safety and efficiency by allowing for better prediction and management of transfusion-related complications across diverse populations.

This comprehensive study has provided critical insights into the distribution of these antigens and their implications for transfusion medicine. The findings suggest a high level of genetic integration, likely due to extensive intermingling and long-term residence of diverse populations in the region. This homogenization of certain genetic traits can greatly influence transfusion strategies and the overall approach to blood donor matching in the region. The study underscores the necessity of developing personalized medicine strategies that consider the antigen profiles of all patients with hemoglobinopathies. By tailoring blood transfusion practices to these antigen profiles, healthcare providers can enhance the safety and efficacy of transfusions, reducing the risk of adverse reactions and improving clinical outcomes.

To implement personalized medicine strategies in practice, comprehensive donor databases should be developed that include detailed antigen profiles for both local and resident populations. These databases will facilitate precise matching of donors and recipients, significantly reducing the risk of adverse transfusion reactions. Additionally, healthcare providers should receive training and education on the importance of antigen profiling in transfusion medicine to ensure they are equipped to make informed decisions based on updated and accurate information.

In conclusion, this study's findings advocate for the continued development of personalized medicine strategies and comprehensive donor databases. These measures will enhance transfusion practices, improve patient outcomes, and contribute to the broader understanding of genetic diversity's impact on transfusion medicine.

Limitations and Recommendations for Future Research

This study had several limitations. The small sample size may not represent the entire population, and the focus was exclusively on Kidd blood group antigens. Geographic limitation was also present as the study was conducted at a regional blood bank in Riyadh, which may not be generalizable to regions. Additionally, resource limitations, such as the lack of gel cards for the automated machine, restricted the ability to increase the number of samples for research purposes.

Future research should include diverse ethnic groups and regions for a comprehensive view of Kidd antigen prevalence. Investigating the impact of personalized medicine strategies on patient outcomes and studying alloimmunization risk factors in patients with frequent transfusions is essential.

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