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Original article

Demography and blood donation trends in Saudi Arabia: A nationwide retrospective, cross-sectional study

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ABSTRACT

Background: Blood product supply and utilization are understudied in Saudi Arabia. This study evaluates the trends in Saudi blood banks readiness, donors' demography, and blood product utilization and wastage.

Study design and methods: A retrospective, cross-sectional study of records obtained from the Ministry of Health (MOH) was initiated to report trends and statistics on annual whole blood donors and blood product utility from 2010 to 2020. Data collected in 2020 was further characterized for donors' demographics, laboratory readiness, and staffing.

Results: The average number of annual blood donors over the last decade (2010–2020) was 325,847.3 ± 43,160. The forecasted blood donation and dispatch trends suggest a significant increase in blood demand (R^2 = 0.7582) over annual donation rates (R^2 = 0.2356). In 2020, 342,460 nationwide blood donations were registered in governmental donation centers and females constituted a mere 2.5 %. Approximately 60 % of whole blood donation was voluntary, 36% was compensatory, and 4% was part of driving license renewal. The highest blood donation rate per 1,000 inhabitants was observed in Taif (69.8) and Alqonfoda (45.0). Eastern directory and Madinah had the most successful donation campaigns attracting 53% and 50% of total annual donations, respectively. Notably, Tabouk, Hai'l, and Albaha had the highest blood product wastage medians.

Conclusion: Blood donation rates and impetus, staffing ratios, and laboratory readiness and wastage varied among the various directories. Laboratory managers and medical directors need to increase efforts to refine current guidelines in order to comply with the transformation plan of the health sector.

1. Introduction

Blood donation has always been considered an integral public health priority and an act of public solidarity. Blood banking has a pivotal role in providing emergency and critical health care services. A well-structured national blood transfusion service system is thus of value in contributing towards better patient care. The Kingdom of Saudi Arabia (KSA) is divided into 13 provinces, officially known as Emirates, and represents the first-level administrative division. The provinces are further divided into governorates based on geographical, demographics, and other factors (Walston et al., 2008). With a population estimated to be 33.4 million (of whom 25 million are Saudi nationals) where 50% of its inhabitants being under 25 years old, Saudi Arabia is considered one of the youngest populations in the world (GAF, 2022). The Centers for Disease Control and Prevention (CDC) reported that ischemic heart disease and road injuries due to conflict and terror are among the top ten causes of death in the country. Additionally, prevalence of hereditary blood diseases such as β-thalassemia (0.05%) and sickle cell disease

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(4.5%) are the highest in comparison to neighboring Middle Eastern countries (Alsaeed et al., 2018).

The Kingdom's blood transfusion services underwent several national initiatives which had the collective effect of refining blood transfusion management. The Ministry of Health (MOH) takes the biggest share of blood transfusion services in the country via the regional Directorates of Laboratories and Blood Banks (DLBBs), and all governmental blood banks must report blood donations, screening for transfusion-transmissible infections, blood products utilization and wastage annually to the Center of Laboratories and Blood Transfusion Services.

For decades, MOH has been providing 62% of inpatients' care free-of-charge through governmental health facilities (Al-Ahmadi and Roland, 2005). The system was long known to be successful at controlling endemic disease, immunization, and maternal health issues; however, it has been recently challenged by the rapid population growth, escalating costs, and deteriorating quality (e.g., long waiting times) of governmental hospitals (NTP, 2020). In 2018, healthcare expenditure in Saudi Arabia was estimated to represent 6.36% of the gross domestic product (GDP) (World Bank, 2022). Blood donation screening, processing, and labor also exert a considerable economic burden and adds to the cost pressures which can be otherwise controlled. Thus, reaching a considerable balance between supply and demand while reducing wastage must be a priority. In this study, we characterize nationwide blood banks' readiness, blood donors' demography, donation impetus, and rates of utilization and wastage. Such knowledge is invaluable in the assessment of current strategies and to formulate priorities for future quality performance indicators.

2. Methods

2.1. Ethical approval

This retrospective, cross-sectional study was approved by the Ethical Committee of MOH (21–71 E) dated August 2021. Blood Transfusion Services data files were retrieved and analyzed for blood banks' readiness, donors' demographics, and donation and utilization patterns.

2.2. Statistics

Descriptive statistics of hospitals readiness, donors' demographic characteristics, and blood usage rates were stratified against major Saudi cities based on population size. The performance indicator, wastage as a percentage of issues (WAPI), is a metric of different types of wastage (expiration, temperature control error, and miscellaneous) and solely accounts for issued products and not the size of blood bank's inventory (Baig et al., 2020). WAPI was calculated as follows:

$$WAPI\ (\%) = \frac{wasted\ blood\ units\ per.\ unit\ time}{issued\ blood\ units\ per.\ unit\ time} \times 100$$

A linear regression equation was fitted to blood donation and dispatch trends over the years 2010–2020, slope values, R^2, and 10-year forecast were generated using the FORECAST.ETS.STAT function and Exponential Smoothing algorithm (ETS) and error metrics (MASE. SMAPE, MAE, RMSE) on Microsoft Excel version 16.95 (Microsoft Corporation, Redmond, WA, USA). The average rate of blood donation was displayed as the average number of donors ± standard deviation. In all cases, a P value < 0.05 was considered statistically significant and GraphPad Prism version 9.2.0 (GraphPad Software, Inc., San Diego, CA, USA) was used for analysis.

3. Results

3.1. Readiness of blood banks

Nationwide, there are 25 central blood banks, 103 secondary blood banks, and 107 blood transfusion centers that are distributed among the main cities (Table 1). Central blood banks perform blood collection, processing, and distribution. As central laboratories, central blood banks also carry out serological and nucleic acid screening tests for transfusion-transmitted infections (TTIs) on blood units collected within the same geographical region. Secondary blood banks perform all services provided by central blood banks, except for TTI screening, including blood transfusion. Transfusion centers are solely responsible for cross-matching and blood transfusion services. All blood banks are equipped with standard manual and automated blood processing and apheresis facilities with considerable variation in readiness among cities given their different demography (Tables 2 and 3). Blood banks are staffed with varying numbers of physicians (specialists and consultants), nurses, phlebotomists, and laboratory personnel (technicians and specialists). The presence of physicians is mandatory for the management of donation complications. The total number of blood bank personnel in 2018 was 2,469 which underwent a steep decline by 29.44% and reached 1,742 employees in 2020. Phlebotomists and general physicians were the most affected, decreasing in numbers by 56.3% and 47.3%, respectively (Fig. 1). To determine whether blood donation centers are sufficiently staffed, the exact number of employees per center and the output per full-time equivalent (FTE) must be available. Due to the unavailability of this information, the ratio of annual donors to operational and bench staff members (i.e., directly involved with donors' preparation and blood products processing) was determined instead (Table 4). Donor to staff ratio varied widely among the different cities with Alqonfoda (5.2) and Ha'il (2.4) demonstrating the highest donor to staff ratio, while Taif stood out as having the least (0.4). This method however does not take into consideration institution volume, daily donor numbers, or demographic variabilities; thus, productivity evaluation may have produced different results by alternative measures.

3.2. Demographic data

Trends of blood donations and dispatches from 2010 to 2020 are illustrated in Fig. 2A. The average number of blood donors did not fluctuate much in the past 10 years with an average of 325,847.3 ± 43,160 donors annually. However, the steady blood supply trend did not keep pace with the significant emerging increase in demand for blood products. Interestingly, blood donation rates were not significantly affected by the drastic reduction in phlebotomists or with COVID-19 pandemic (i.e. years 2019 and 2020) (Fig. 2B).

To evaluate donors' retention and recruiting strategies, the 2020 cohort of donors was further characterized. The number of total blood donors in 2020 was 342,460, of which 82.5% were frequent donors while 17.5% were first-time donors (Table 5 and Table 6). Female donors constituted 2.51% of total donations. The distribution of donors' blood groups was similar to what was reported previously in regional studies (Alsuhaibani et al., 2015; Bashwari et al., 2001).

The median blood donation rate among the twenty main cities is equivalent to 15 donations per 1000 people, which is equivalent to that of upper-middle-income countries (Table 5) (WHO, 2020). The highest blood donation rate per 1000 people was observed in Taif (69.8), Alqonfoda (45.0), and Alqurayat (28.0). Interestingly, provincial capitals and most populous cities of Riyadh (6.4), Mecca

Table 1
Governmental blood donation centers and staffing in Saudi Arabia.

Directory	MOH Blood Banks				Job category							
	Central	Secondary	Transfusion centers	Total	Consultant	Specialist	General Physician	Lab Specialist	Lab Technician	Nurse	Phlebotomist	Total
Riyadh	4	9	23	**36**	3	9	2	40	61	29	0	**144**
Makkah	1	6	3	**10**	5	6	4	62	75	3	8	**163**
Jeddah	2	6	2	**10**	2	3	1	42	64	2	10	**124**
Taif	1	2	12	**15**	3	10	0	53	54	0	1	**121**
Alqonfoda	1	4	0	**5**	1	1	0	3	4	1	0	**10**
Madinah	1	5	11	**17**	2	9	5	44	148	21	1	**230**
Qassim	2	6	8	**16**	4	4	1	41	48	13	3	**114**
Eastern	1	5	11	**17**	2	12	0	57	84	11	0	**166**
Alehsa	1	1	3	**5**	3	3	5	19	39	0	5	**74**
Hafr ALbatin	1	3	2	**6**	1	3	1	16	14	0	0	**35**
Aseer	1	14	5	**20**	1	4	1	16	36	2	1	**61**
Beesha	1	2	1	**5**	0	2	1	11	12	0	0	**26**
Tabouk	1	8	0	**9**	3	11	2	35	43	9	5	**108**
Ha'il	1	4	8	**13**	0	3	1	14	0	0	0	**18**
Northern borders	1	3	4	**8**	0	1	1	6	11	0	1	**20**
Jizan	1	13	3	**17**	0	5	2	53	73	2	3	**138**
Najran	1	5	4	**10**	0	12	1	40	47	0	0	**100**
Albaha	1	3	4	**8**	1	3	1	10	9	0	0	**24**
Aljawf	1	4	1	**6**	1	3	0	11	29	5	0	**49**
Alqurayat	1	0	2	**3**	0	1	1	4	7	4	0	**17**
Total	**25**	**103**	**107**	**235**	**32**	**105**	**30**	**577**	**858**	**102**	**38**	**1742**

Table 2
Instruments available in governmental donation rooms and blood bank laboratories.

Directory	Fridges/ Freezer			Donation room equipment					Centrifuges		Manual plasma separation	Apheresis machine
	2–6 °C	−40 °C	−86 °C	Blood bags shaker	Platelets shaker	Tube sealer	Couches	Hb measurement	Regular	Refrigerated		
Riyadh	38	30	15	40	20	19	39	23	15	17	32	6
Makkah	49	25	11	33	14	24	32	15	13	17	26	9
Jeddah	29	18	3	30	17	25	29	18	19	10	20	4
Taif	14	7	4	20	10	5	20	5	6	5	6	3
Alqonfoda	9	9	3	9	3	9	12	6	3	1	9	1
Madinah	39	29	3	33	14	17	29	17	22	20	37	4
Qassim	27	16	5	30	13	12	27	11	12	1	15	2
Eastern region	36	15	5	25	11	36	25	16	20	13	26	3
Alehsa	15	4	5	16	6	10	15	14	4	2	14	4
Hafr ALbatin	11	8	6	13	8	5	13	4	5	2	8	2
Aseer	30	20	5	26	14	30	36	19	16	11	14	6
Beesha	11	9	3	15	7	12	10	5	6	4	10	1
Tabouk	29	21	2	30	13	16	25	14	11	15	16	3
Ha'il	22	18	8	6	8	15	20	11	10	10	10	1
Northern borders	20	15	–	10	9	6	10	6	10	7	9	1
Jizan	53	31	7	41	23	29	38	22	22	15	32	3
Najran	35	21	5	40	19	17	40	33	16	15	2	4
Albaha	21	9	5	12	6	7	10	9	4	6	13	0
Aljawf	20	15	1	17	8	6	16	10	8	8	9	1
Alqurayat	7	2	2	5	2	1	3	4	3	3	3	1
Total	**488**	**305**	**96**	**429**	**214**	**301**	**430**	**262**	**214**	**182**	**311**	**59**

(7.0), and Jeddah (9.6) recorded the least donated blood units in 2020. To encourage voluntary donation, government hospitals arranged 1,137 blood donation campaigns in 2020 (Table 5). Such campaigns expanded the total annual blood donation by 24%. Donation campaigns were most successful at increasing donation rates in the Eastern directory (53%) and Madinah (50%). The campaigns have also increased voluntary blood donation rates in Riyadh (21%) and Makkah (14%). Donation campaigns had little impact on the total blood donation rate in Alqurayat (2%), Jeddah (6%), and the Northern borders (6%) directories. In addition to blood donation campaigns, blood is also donated voluntarily (i.e., nonremunerated) and represented 59.98% of nationwide blood donations, or as a replacement donation by family and friends of someone who needs blood (36%), or during driver's license renewal (4.02%) (Table 5). Voluntary donation exceeded 69% in nine directories namely, the Eastern directory, Qassim, Hail, Najran, Northern borders, Hafr Albatin, Taif, Alqurayat, and Alehsa. Thus, MOH has noted these directories as the first candidates for eliminating replacement donation in order to reach 100% voluntary non-remunerated blood donation and to comply with the Global Framework for Action established by WHO (WHO, 2010). Donations by non-Saudi citizens represented 27.19% of whole donations (Table 6). Nationwide, the most common blood groups are O+ (45.18%), A+ (23.52%), B+ (16.53%), O- (5.14), AB+ (4.61%), A- (2.53%), B- (1.71%) and AB- (0.73%), respectively (Fig. 3).

3.3. Blood utilization and wastage

Whole blood units collected in 2020 were processed into different blood components with a total of 797,184 units being issued (Fig. 4). Packed red blood cells (pRBC) represented 41.6% of all issued blood components followed by fresh frozen plasma (FFP),

Table 3
Cross matching and standard laboratory assessment techniques in governmental blood bank laboratories.

Directory	Cross matching			BacT. Detection		ARCHITIC	NAT	TTI Inst.	Pathogen inactivation
	Serum		ABO						
	Manual	Semi-automated	Automated	Alert	eBDS				
		automated							
Riyadh	11	7	8	9	0	6	6	5	0
Makkah	7	7	15	0	5	2	2	–	0
Jeddah	10	8	11	3	4	5	6	4	4
Taif	0	5	9	1	2	2	2	2	0
Alqonfoda	3	6	9	0	1	2	1	2	0
Madinah	10	8	10	2	2	2	3	5	1
Qassim	0	0	2	0	0	0	2	–	0
Eastern	7	1	8	1	3	2	3	4	0
Alehsa	8	3	6	3	2	2	2	–	0
Hafr ALbatin	0	6	4	2	0	2	2	–	0
Aseer	8	11	9	6	6	4	4	10	0
Beesha	4	0	2	1	1	2	1	1	0
Tabouk	7	4	9	4	1	2	2	4	0
Ha'il	2	13	5	3	1	2	2	1	0
Northern borders	8	8	2	3	0	2	2	–	0
Jizan	16	11	9	0	4	2	2	6	2
Najran	11	3	6	8	8	2	2	9	0
Albaha	2	0	3	0	2	2	2	–	0
Aljawf	1	5	5	0	1	1	2	1	0
Alqurayat	0	2	2	1	0	2	2	–	0
Total	**115**	**108**	**134**	**47**	**43**	**46**	**50**	**54**	**7**

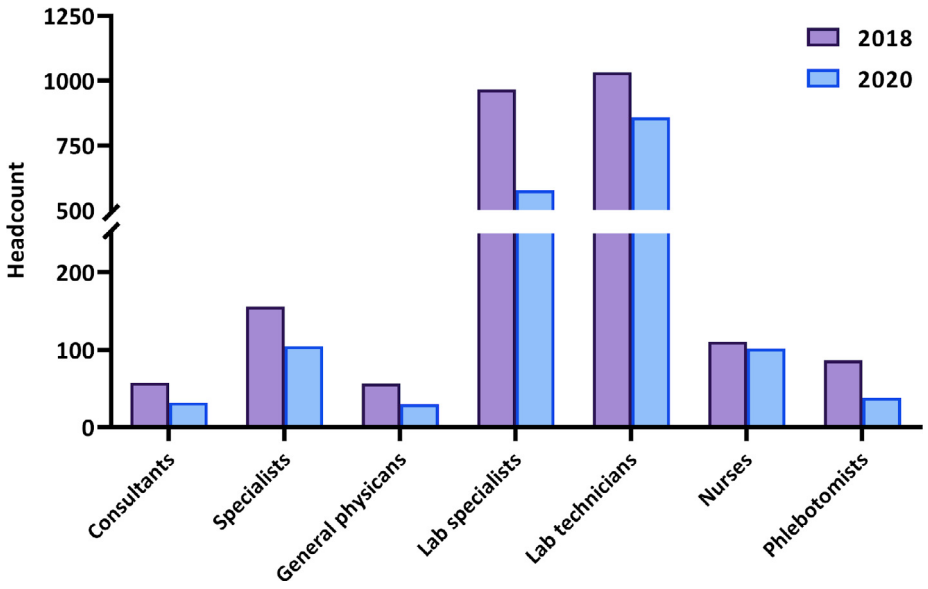

Fig. 1. Headcount of healthcare professionals in Saudi governmental blood banks in the years 2018 and 2020.

platelets, and cryoprecipitates (30.98%, 26.19%, 1.18%, respectively). Ideal blood inventory management requires a trade-off between shortage and wastage. WAPI was thus utilized to compare and rank wastage in blood products among the different cities, where the lower the percentage, the better the performance independently of the hospital type and size (Chapman and MacPherson, 2007; Stanger et al., 2012; Yazer et al., 2016). The median WAPI in all cities was 12 for pRBCs, 49 for platelets, 50.69 for plasma, and 24.38 for cryoprecipitate. PRBCs wastage was the highest in Alqurayat (WAPI = 42.75%), Tabouk (26.57%), and Hafr Albatin (25.78%) directories. The highest wastage in plasma was recorded in three directories: Alqonfoda (89.27%), Hafr Albatin (68.28%), and Jizan (61.46). Wastage percentage of platelets was relatively high considering its short half-life which ranged from 12% to 95% (Fig. 4). Conversely, wastage of blood products collected by apheresis was considerably low with 98% of collected RBC units were dispatched. Similarly, 78% of plasma units and 93.6% of collected platelets units were dispatched (Fig. 5). A total of 6,914 pre-processed whole blood units were discarded either due to heavy bag weight (14.70%), clot formation (24.87%), or quantity insufficiency (60.41%) (Fig. 6).

4. Discussion

Blood bank management in Saudi Arabia is underrepresented in the scientific literature. The current study reports blood banks' readiness, donation patterns, and emerging challenges. Based on the retrieved Blood Transfusion Services annual reports, governmental blood banks are sufficiently equipped with standard equip-

Table 4
Regional variations in blood donation rates and donor to staff ratio in 2020.

Directory	Population*	Annual blood donors	Total blood donation centers	Staff†	donors/day	Donor:staff$
Riyadh	8,002,100	51,716	38	101	192	1.9
Makkah	4,474,045	31,391	10	145	116	0.8
Jeddah	3,456,259	33,467	9	116	124	1
Taif	175,000	12,223	15	108	45	0.4
Alqonfoda	220,000	9,906	5	7	36	5.2
Madinah	2,080,436	29,835	18	193	110	0.5
Qassim	1,387,996	19,051	15	92	70	0.7
Eastern	3,348,474	19,412	16	141	72	0.5
Alehsa	1,041,863	14,838	7	63	55	0.8
Hafr Albatin	390,282	6,536	6	30	24	0.8
Aseer	1,959,681	21,129	19	53	78	1.4
Beesha	204,491	5,409	5	23	20	0.8
Tabouk	890,922	12,236	9	80	45	0.5
Ha'il	684,619	9,041	13	14	33	2.4
Northern borders	359,235	5,701	8	18	21	1.1
Jizan	1,533,680	29,840	17	129	110	0.8
Najran	569,332	13,576	10	87	50	0.5
Albaha	466,384	7,316	8	19	27	1.4
Aljawf	349,959	5,717	7	40	21	0.5
Alqurayat	147,550	4,120	2	11	15	1.3
Total	**31,742,308**	**342,460**	**237**	**1,470**	**1,264**	

* Based on population statistics of 2020 (GAS, 2022).
† Healthcare professionals who are directly involved in donors' preparation and blood products processing.

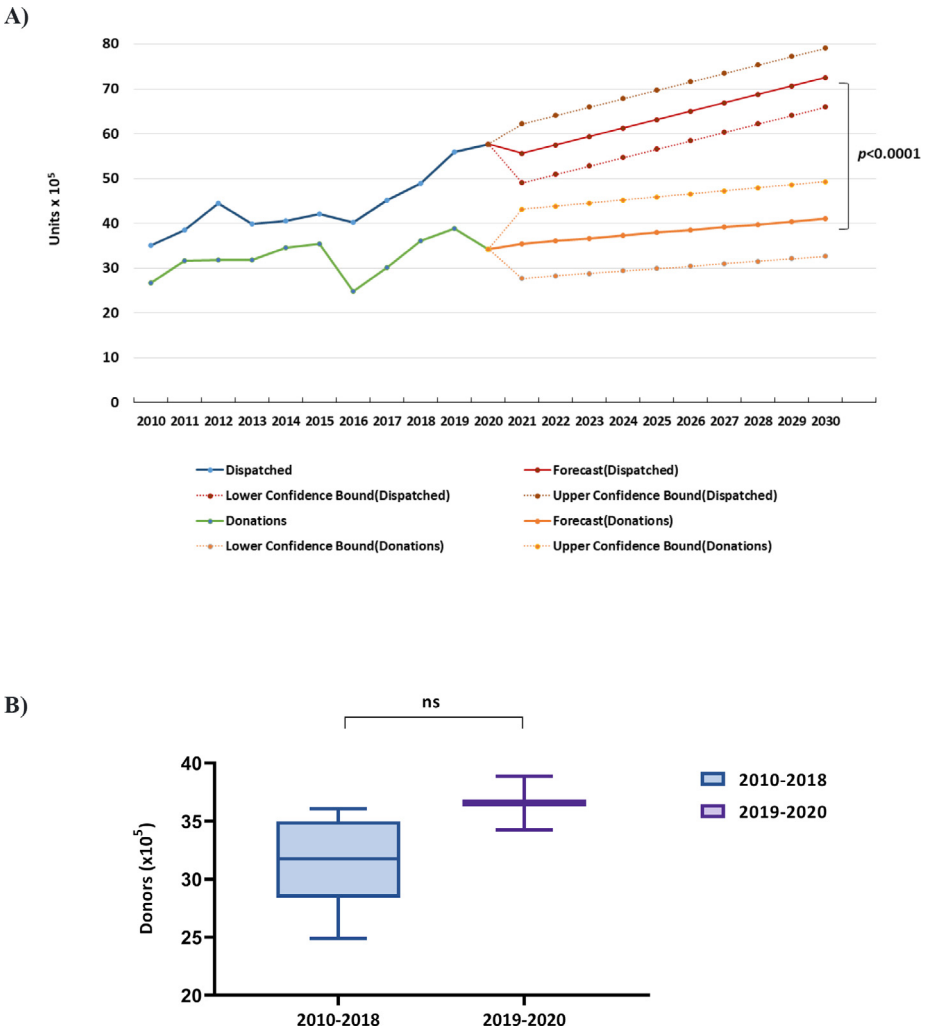

Fig. 2. Trends of whole blood donations (WB). A) Trends of WB donation (R^2 = 0.2356) and PRBCs dispatches (R^2 = 0.7582) during the years 2010 – 2020, and forecasted supply and demand (2021–2030) ($p < 0.0001$). **B)** Average of annual donors during the COVID-19 pandemic (2019–2020) was not statistically significant (ns) from the years (2010–2018) ($p = 0.113$, 95% Confidence Interval: −11.71, 1.47).

Table 5
Donors' distribution among Saudi directories.

Directory	Total donors (% female)	Voluntary donations (%)	Compensatory donation (%)	Driving license renewal donation (%)	Donation per 1000 people	Donation campaigns (% of voluntary donations)	Number of voluntary societies	Number of mobile donation units
Riyadh	51,716 (2.0%)	43%	55.10%	2.10%	6.4	173 (21%)	14	6
Makkah	31,391 (3.9%)	34%	64%	2%	7	26 (14%)	0	2
Jeddah	33,467 (1.7%)	59.50%	40.50%	0%	9.6	18 (6.5%)	3	2
Taif	12,223 (4.8%)	75%	15%	10%	69.8	21 (10%)	1	1
Alqonfoda	9,906 (0.7%)	68%	5%	27%	45	83 (28)	3	1
Madinah	29,835 (1.1%)	47%	52%	1%	14.3	47 (50%)	6	2
Qassim	19,051 (7.9%)	70%	30%	0	13.7	163 (14%)	3	1
Eastern	19,412 (1.8%)	94%	6%	0	5.7	98 (53%)	3	1
Alehsa	14,838 (2.1%)	69%	31%	0	14.2	24 (27%)	0	1
Hafr ALbatin	6,536 (0.5%)	89%	10%	1%	16.7	18 (8%)	0	1
Aseer	21,129 (2.0%)	57%	41%	1%	10.7	24 (18%)	0	2
Beesha	5,409 (2.1%)	68%	24%	8%	26.5	9 (13%)	1	1
Tabouk	12,236 (1.4%)	56%	16%	28%	13.7	23 (16%)	9	5
Ha'il	9,041 (1.6%)	74%	26%	0	13.2	26 (13%)	0	3
Northern borders	5,701 (0.7%)	73%	26%	15	15.8	14 (6%)	0	2
Jizan	29,840 (1.5%)	56%	36%	8%	19.4	178 (39%)	22	3
Najran	13,576 (1.7%)	95%	3%	2%	23.8	85 (19%)	5	1
Albaha	7,316 (3.5%)	67%	25%	8%	15.6	62 (30%)	2	1
Aljawf	5,717 (0.5%)	67%	31%	2%	16.3	41 (22%)	2	1
Alqurayat	4,120 (0.6%)	79%	21%	0	28	4 (2%)	0	1
Total	**342,460 (2.51%)**	**59.98%**	**36.00%**	**4.02%**	**Median = 15**	**1,137 (24%*)**	**74**	**38**

* Of nationwide voluntary donations.

Table 6
Percentages of donors based on motivation.

Gender	Citizenship	Voluntary	Compensatory	Driving license renewal	Total
Male	Saudi	46.38%	22.55%	1.84%	70.70%
	Non-Saudi	11.70%	12.85%	2.15%	26.70%
	Total male donations	58.08%	35.41%	3.99%	97.49%
Female	Saudi	1.60%	0.40%	0.03%	2.03%
	Non-Saudi	0.29%	0.19%	0.01%	0.49%
	Total female donations	1.89%	0.59%	0.03%	2.51%
Total		**59.98%**	**36.00%**	**4.02%**	**100%**

ment and instrumentation to facilitate the process of blood collection, processing, and storage. The 2018 reduction in staff numbers was an act supporting the second strategic objective of the health sector's National Transformation Plan (NTP) which entails increasing the efficient utilization of available resources. Interestingly, the average annual blood donation was not significantly affected by blood banks' staff reduction or the COVID-19 pandemic. Because staff performance details were not available, we determined the daily donors to staff ratio to roughly estimate the efficacy of the blood donation process. Ratios varied considerably among the investigated cities which probably reflects demographic variability (Novis et al., 2022). For this data to be useful for decision makers, the actual staffing level must be compared with FTE in each center and must take into consideration the governorates' population size to identify where shortages are most significant. In addition, staffing ratios and productivity must be investigated in future studies as labor costs represent 50% to 70% of direct laboratory expenditures (Valenstein et al., 2005).

A consistent growing gap between whole blood supply and demand over the past decade was observed in this study. Such a gap needs to be addressed by policy makers to identify determinants of blood utilization and wastage to monitor and improve the efficiency and quality of blood transfusion practices. A well-managed blood bank should have a cost-efficient operational strategy for balancing supply with forecasted demand. The clinical demand for pRBCs was particularly severe where the number of transfused pRBCs accounted for 82.8% of all blood donations in 2020. Median WAPI values in Saudi governmental blood banks are higher than those reported by American and European countries (Yazer et al., 2016) and thus, urging the need to formulate strategies to minimize blood products wastage. Given that platelets have a short shelf-life of five days, wastage is generally expected to be higher than that of other blood components. To reduce blood wastage and enhance stock management, a number of low-cost policies can be implemented. These include improved communication between blood banks and providers (Levin et al.,

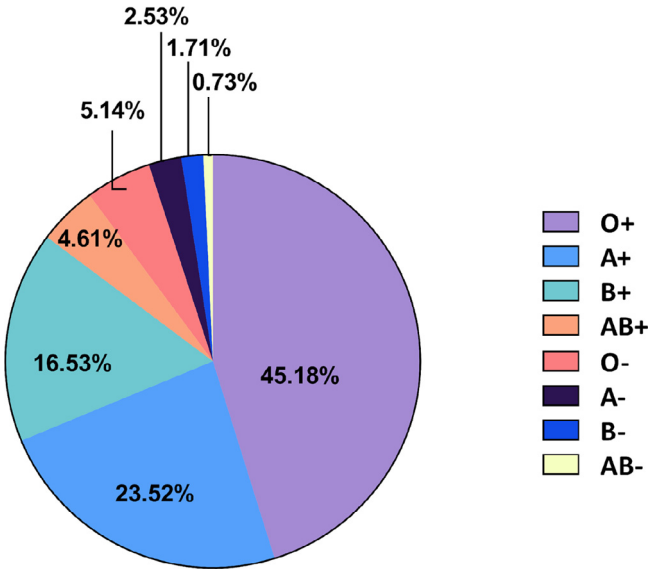

Fig. 3. Frequencies of nationwide blood groups.

2019; Mishra et al., 2021), staff continual education (Burk et al., 2021), improved transport Kron et al., 2021), and updating transfusion protocols (Bawazir and Dakkam, 2020; Gholami et al., 2021) which all have been proven to have a cumulative effect in reducing blood wastage.

It is estimated that in a high-income country such as Saudi Arabia, the median blood donation rate would be 31.5 per 1000 people (WHO, 2020). However, the median donation rate in 2020 was far below the recommended rate with only three cities meeting the recommended median (i.e., Taif, Alqonfoda, and Alqurayat). Surprisingly, the provincial capitals of Riyadh and Mecca recorded the least median donation rates.

Although blood banks in Saudi Arabia abide by the standards and regulations of MOH, they do not operate under a centralized management system. Such a fragmented system yielded several shortcomings and limitations to this study, most notably the lack of demographic details of blood donors (age, marital status, socioeconomic status, donation frequency, and impetus of frequent donors); hence, limiting our ability to characterize the donor's cohort. In addition, the decentralized system resulted in the inadequate reporting of blood banks' shortage or overload status and did not identify which departments (e.g., surgery, obstetrics/gyne-

	PRBCs					Platelets					FFP					Cryoprecipitate				
	Prepared*	Issued†	Expired		WAR	Prepared	Issued	Expired		WAR	Prepared	Issued	Expired		WAR	Prepared	Issued	Expired	WAR	
	(units)	(units)	(units)	(%)$	(%)	(units)	(units)	(units)	(%)	(%)	(units)	(units)	(units)	(%)	(%)	(units)	(units)	(units)	(%)	(%)
Riyadh	49,162	42,849	1,020	2	12.84	18,968	14,114	5,105	27	26	32,019	13,127	1,759	5	59.00	2,596	2,265	0	0	12.75
Makkah	29,762	29,632	1,320	4	0.44	23,887	11,497	8,729	37	52	21,407	12,428	989	5	41.94	1,177	841	46	3.9	28.55
Jeddah	33,009	25,897	623	2	21.55	22,071	15,102	4,038	18	32	30,046	21,688	611	2	27.82	812	614	19	2.3	24.38
Taif	13,325	12,211	327	3	8.36	10,868	4,405	4,688	43	59	5,926	4,847	245	4	18.21	93	51	0	0	45.16
Alqonfoda	9,906	6,768	378	4	31.68	9,906	498	150	2	95	9,906	1,062	150	2	89.28	150	150	0	0	0.00
Madinah	29,205	24,721	2,345	8	15.35	29,205	24,681	3,150	11	15	29,205	25,296	-	-	13.38	1,139	706	0	0	38.02
Qassim	19,051	18,414	636	3	3.34	16,000	13,764	2,238	14	14	14,681	13,509	1,171	8	7.98	440	425	15	3.4	3.41
Eastern	18,485	16,358	2,127	12	11.51	4,528	3,664	864	19	19	7,563	5,098	227	3	32.66	1,206	1,206	0	0	0.00
Alehsa	19,540	16,052	257	1	17.85	2,788	2,589	-	-	5	5,331	4,612	43	1	13.49	581	554	0	0	4.65
Hafr Albatin	6,536	4,851	1,187	18	25.78	4,108	2,474	1,146	28	40	6,536	2,073	-	-	68.28	-	-	-	-	-
Aseer	15,224	13,510	2,078	14	11.26	12,080	5,378	3,297	27	55	14,116	11,644	610	4	17.51	151	111	0	0	26.49
Beesha	5,558	4,079	432	8	26.61	3,149	805	1,224	39	74	4,562	1,871	241	5	59.99	105	20	0	0	89.19
Tabouk	11,621	8,533	2,114	18	26.57	8,775	2,932	4,929	56	67	10,480	4,520	1,681	16	56.87	171	152	19	11	11.11
Ha'il	9,044	8,502	554	6	5.99	6,192	3,099	2,502	40	50	6,153	2,824	632	10	54.10	123	90	26	21	26.83
Northern borders	5,517	4,921	265	5	10.80	5,443	2,803	601	11	49	5,484	2,457	425	8	55.20	-	-	-	-	-
Jizan	28,171	25,388	1,192	4	9.88	9,799	4,146	1,557	16	58	19,460	7,498	1,131	6	61.47	485	105	30	6	78.35
Najran	13,476	13,286	497	4	1.41	13,579	11,899	543	4	12	13,476	12,162	180	1	9.75	130	126	4	3	3.08
Albaha	7,482	7,098	288	4	4.49	3,413	1,768	835	24	48	6,574	2,691	1,184	18	59.07	511	410	46	11	19.77
Aljawf	5,810	4,972	1,123	19	14.42	4,225	629	2,906	69	85	3,373	1,512	552	16	55.17	-	-	-	-	-
Alqurayat	3,207	1,836	972	30	42.75	-	-	-	-	-	719	379	64	9	47.29	39	19	4	10.26	51.28
Total	331,927	290,992	19,735	5.94	Median = 12.17	208,785	126,396	51,293	25	Median = 49	247,017	151,293	11,895	5	Median = 50.69	9,455	8,379	209	11	Median= 24.38

*Stocked units.
†Dispatched units.
$Horizontal data bars are normalized to the highest value.

Fig. 4. Numbers of issued blood products and wastage of issue in 2020.

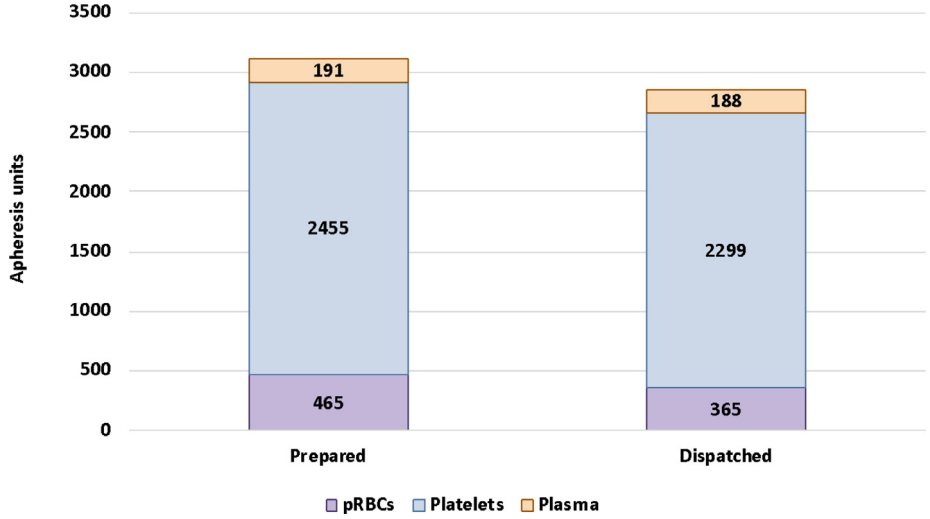

Fig. 5. Number of nationwide prepared and dispatched apheresis units in 2020.

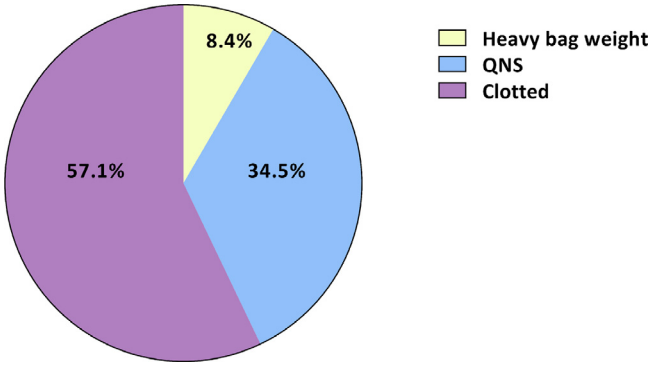

Fig. 6. Percentages of nationwide rejected whole blood units before processing, 2020. A total of 6,914 whole blood units were rejected to heavy blood bag weight, quantity insufficiency (QNS), or due to clotting.

cology, hematological conditions, accidents and emergency . . . etc.) are associated with the most utilization or wastage where such information would have added valuable insights. Advancements in information technology solutions can be utilized to improve the current blood bank management system, where transfusion services can be managed under a centralized e-management system (Alharbi, 2020; NHS Blood & Transplant, 2020). The establishment of a nationwide interconnected system is anticipated to improve the quality of the transfusion chain management including statistical reporting, risk assessment, policy execution, and surveillance. In fact, reforming the blood banking system to meet the growing population demand for safe transfusions in a cost-effective manner has been addressed by the health sector's NTP as one of the main challenges (NTP, 2020). International benchmarking should be taken into consideration to establish a centralized management system with improved logistics and accurate documentation to refine the current blood inventory management and initiate the establishment of a hemovigilance system (Marchildon et al., 2020; O'Brien et al., 2022).

To conclude, the study is the first to report blood donation trends in Saudi Arabia on a nationwide level. The establishment of a centralized blood bank management model with interconnected systems may address the administrative challenges and economic burden faced by the current blood bank management system and might provide better surveillance to identify areas of improvement in the blood transfusion chain.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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