original article

Hematologic reference intervals for healthy adult Saudis in Riyadh

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BACKGROUND: Laboratory hematological tests are widely used in clinical practice to assess health and disease conditions. Reference ranges provided by laboratory reports are considered the most authoritative medical tools to assist in the decision-making phase. International standards institutes recommend that reference ranges be established for each region.

OBJECTIVES: Provide reference values of routine hematological parameters in Saudi adults according to age and gender.

DESIGN: Cross-sectional

SETTING: Central province of Saudi Arabia.

PATIENTS AND METHODS: Apparently healthy Saudi adults were subjected to laboratory testing of routine hematological parameters (full blood count, hemostatic profile, and serum hematinics), after completing a detailed health medical questionnaire.

MAIN OUTCOME MEASURES: Hematological reference values based on the local population.

SAMPLE SIZE AND CHARACTERISTICS: 637 after screening 827 potentially healthy Saudi adults with ages ranging from 15 to 65 years.

RESULTS: The reference values of routine hematological parameters for the full population and by gender are presented with 90% CI as the lower and upper limits. Reference ranges mostly differed from universal established ranges shown in textbooks.

CONCLUSION: The reference ranges of routine hematologic parameters for accurate assessment and appropriate management will help improve the routine clinical care of the adult Saudi population.

LIMITATIONS: Difficulty in assessing health status of participants, who could have subclinical illnesses not reflected in the evaluated blood measurement. Lack of ability to eliminate individuals who might be carriers for haemoglobinopathies. Studies with larger sample sizes from different areas of the country are required to achieve a more accurate representation of the whole Saudi population.

CONFLICT OF INTEREST: None.

Laboratory hematological tests are widely used in clinical practice to assess health and disease. Reference ranges are defined as sets of values in which 95% of the apparently normal healthy population falls. They are used by the health professionals to interpret laboratory results.[1] The reference values from the International Federation of Clinical Chemistry and Laboratory Medicine (IFCC) are the values extracted from the control subjects/groups (in relation to age and sex) in order to exactly interpret the health status values.[2] Reference ranges provided by laboratory reports are considered the most authoritative medical tools to assist in decision-making, and hence are useful for patient care.[1] Health and disease can only be distinguished by accurate and reliable reference values of a particular laboratory test.[3]

Hematological indices are affected by factors that include age, sex, smoking, dietary habits, body mass index (BMI), exercise, stress, diurnal fluctuation, geographic location and ethnic background.[1,4-9] Genetic or environmental factors such as climate and altitude may play a role as well.[1,10,11] Moreover, many constitutional hemoglobin abnormalities (hemoglobinopathies) or pathologic conditions (malaria and viral infections), influence the hematological values.[12] Additionally, genetic differences and iron deficiency may be the basis for differences in hemoglobin levels.[13] It has been established that each population must determine its own reference intervals to be used in clinical assessments and interpretations.[14] Therefore, the IFCC[15] and the Clinical and Laboratory Standards Institute (CLSI)[16] recommend that reference ranges be established for each region. Inappropriate reference ranges can cause unnecessary follow-up investigations, treatment and mismanagement of patients.[17] Reference values for hematological parameters have yet to be established in many developing countries.[18] Currently, in interpreting laboratory test results, the reported values are usually compared with established reference values taken from textbooks, whose values are mainly based on those of Western populations.[3,17,19] Many studies conducted in Asian and African countries indicate differences in reference values compared with those established from Western countries with populations primarily of European origin.[18-23] The use of reference laboratory values derived from external populations may result in incorrect patient management.[24] Still, to the best of our knowledge, no study has described the reference values for routine hematological parameters in healthy Saudi adults. Therefore, this study aimed to provide reference values for routine hematologic parameters in apparently healthy Saudi adults according to age and gender for accurate assessment and appropriate management of routine clinical care. In addition, we compared Saudi hematological values with the standard reference values reported for western adults in the most frequently cited hematology textbooks in our laboratories.

SUBJECTS AND METHODS

Study design and selection of participants

Potentially healthy Saudi adult blood donor volunteers and healthy non-donor hospital employee volunteers and their dependents older than 64 years of age were enrolled in this cross-sectional study conducted at the King Faisal Specialist Hospital and Research Centre from February 2018 to July 2019. Invitations were sent through mobile blood donation trucks in different places of Riyadh city. Responding subjects were then selected by random sampling after completing a detailed health medical questionnaire. Inclusion criteria for the healthy participants were age 15-65 years, with no acute or known chronic medical illnesses or ongoing treatment. Exclusion criteria for the healthy participants were having received a blood transfusion in the last 12 months or a personal or family history of hematological disorders. Verbal informed consent was obtained from all participants. The study protocol was approved by the Science and Ethics Committees of Princess Nourah bint Abdulrahman University (IRB no.22041501) and King Faisal Specialist Hospital (RC RAC# 2181110).

Sample size calculation

The OpenEpi sample size calculator was used for calculating the sample size (*http://www.openepi.com/Menu/OE_Menu.htm" OpenEpi Menu*). Proportions of males and females were based on data from the last national census of 2018. As recommended by The International Council for Standardization in Hematology (ICSH) guidelines of 1982, our data were grouped according to gender and age. The age group stratifications (number in each group) were based on the last national census data. The sample size was determined based on an 80% prevalence of normal hematological measurements among the Saudi population with 95% confidence interval for a 5% margin of error. The minimum subject population was calculated as 670 (360 males [53%] and 310 females [46%]). The study population was oversized at least by 10% to account for non-response, insufficient and leaking blood samples.

Blood sampling

A 15 mL venous blood sample was collected from all

participants. Collections were taken in the morning between 8-11 am, with 5 mL collected into a BD vacutainer tube (Becton Dickinson, UK) containing ethylenediamine tetra-acetic acid (EDTA), 5 mL into another citrated tube (3.2%), and 5 mL into a plain tube). The samples were then transported as soon as possible but within 2 hours to the laboratory for testing. A complete blood count (CBC), and serum ferritin level were tested on the same day. Serum samples were left at room temperature until separation of the serum by centrifugation at 4°C, at a speed of 2180 g (relative centrifugal force) for 10 minutes. The separated sera were stored at 20°C until analysis. All samples for coagulation tests, which were aliquoted then transported frozen to the central laboratory for testing, were also centrifuged for separation of plasma within 2-4 hours from collection.

Laboratory testing

A SYSMEX XN-10 instrument (Sysmex Corporation, Kobe, Japan) was used for testing the hematology parameters of the full blood count which included the red blood cell count (RBC), hemoglobin concentration (Hb), hematocrit (HCT), mean cell volume (MCV), mean cell hemoglobin (MCH), mean cell hemoglobin concentration (MCHC), red cell distribution width (RDW), reticulocyte count (RET), normoblast (NRBCs), total white blood cell count (WBC) and differential counts (lymphocyte, monocyte, eosinophils, basophil, neutrophil), platelet count (PLT), mean platelet volume (MPV) and platelet distribution width (PDW). For testing different coagulation factors (pro-coagulant clotting factors, and anticoagulant proteins) we used STAR Max (Diagnostica Stago, Marseille, France). Testing of the serum level of hematinics (iron, ferritin, vitamin B12, and folic acid) was performed using automated chemistry analyzer COBAS 601 (Roche Diagnostic, Basel, Switzerland). All laboratory equipment had passed calibration as per manufacturer instructions, in addition to quality control assessment as per College of American Pathology guidelines.

Data and statistical analysis

IBM SPSS Version 20.0 was used to analyze the data (Armonk, New York, United States: IBM Corp). Data were reviewed for quality of the samples. Cases with coagulation factor deficiency (<50%) were excluded from the analysis. Cases with unexplained values were also excluded. For reference range identification, outliers were excluded by Horn's algorithm using Tukey's interquartile fences which identify multiple outliers at the upper and lower extremities.[25] The criterion for rejection was values exceeding interquartile (IQ) fences set at Q1-1.5*IQR and Q3+1.5*IQR (where IQR=interquartile range; IQR=Q3-Q1 where Q1 AND Q3 are the 25th and 75th percentiles, respectively). The normality of the parameters tested using the Kolmogorov- Smirnov Z-test and the median test while comparisons by gender were done using independent sample t test or Mann-Whitney U test. Gender was weighted to correct for the under-representation of females in our sample. The Saudi Census 2018 was used for calculating the weighting factors (M=0.67, F=2.25). Non-parametric methods were used to establish the reference range values between the 2.5th and 97.5th percentiles. After identifying the upper and lower limits of the reference range, a bootstrapping sampling method with a random sample of 1000 was used to estimate the 90% CI for upper limit and lower limit individually. The measures of central tendency (mean, median, mode) and dispersion (standard deviation (SD), range), and point percentiles estimates were calculated for all quantitative hematological values.[26] A *P* value of two-tailed <.05 was considered statistically significant.

RESULTS

Of the 827 potential healthy adults screened during the study period, 157 did not meet the inclusion criteria or the collected samples did not meet recommended quality standards and were therefore excluded from the final analysis. The age distribution of the remaining 637 participants (54% male and 46% female) are shown in **Table 1**. Ages of the 637 participants ranged from 17 to 60 years. Differences were observed between the hematological values (mean, SD, and reference range) from Saudi adults in comparison with western values from hematology textbooks (**Table 2**).[27,28] We found gender differences in many hematological parameters, particularly hemoglobin level, red cell counts, and hematocrit levels being higher in males than in females (**Tables 3, 4, and 5**).

DISCUSSION

Currently, there are no widely acknowledged reference ranges for the local adult population and the ranges commonly used in clinical laboratories and by physicians are those of European populations. To the best of our knowledge, studies to establish hematologic reference ranges in Saudi are scarce, particularly in adults. Two Saudi studies reported the reference values for blood cell count and/or red cell indices from different age categories.[29,30] El-Hazmi and colleagues (2001) published the reference values of red cell indices from Saudi healthy children aged

Table 1. Age distribution of the estimated sample population (n=637).

Age group (years)	Males	Females
Total	478 (75)	159 (25)
15-19	42 (9)	35 (22)
20-24	65 (14)	48 (30)
25-29	76 (16)	20 (13)
30-34	75 (16)	18 (11)
35-39	81 (17)	18 (11)
40-44	64 (13)	7 (4)
45-49	41 (9)	6 (4)
50-54	15 (3)	3 (2)
55-59	9 (2)	4 (2)
60-64	10 (2)	1 (1)

Data are n (%).

with ages ranging from 1-15 years.[29] Elderdery and Alshaiban (2017) published the reference values for the complete blood count (CBC) for healthy young adults with ages ranging from 17 to 28 years from the north region of Saudi Arabia, Aljouf city.[30] Evidently, the CBC normal values in our study were similar to their published values except for minor quantitative differences in the red cell count.

Consistent with previous studies, we found that reference intervals for routine hematologic parameters were mostly different from the universal well-established ranges defined in practical hematology textbooks,[27,28] which are based on European and American populations. Our results showed that the reference interval of most of red and white blood cell indices in adult Saudis (hemoglobin concentration, MCV, MCH, MCHC, and count of total WBCs, absolute neutrophil, absolute eosinophil and absolute basophil) were lower than the universally defined

Table 2a. Hematological reference interval of Saudi adults in comparison with Western values.

Parameter	Current study values with reference range	Western values with range
Red blood indices		
Red blood cell count ($\times 10^{12}$/L)		
Males ($\times 10^{12}$/L)	5.4 (0.4); 5.2-5.7	5.0 (.5)*; 4.5-6.0*
Female ($\times 10^{12}$/L)	4.8 (0.4); 4.5-5.0	4.3 (0.5)*; 4.1-5.1**
Hemoglobin		
Male (g/dL)	154.0 (12.0); 129-179	150 (20)*; 140-180 **
Female (g/dL)	133.9 (10.1); 114-154	135 (15)*; 120-150**
Hematocrit		
Male (%)	0.4 (0.0); 0.4-.5	0.4 (0.0)*; 0.4-0.4**
Female (%)	0.5 (0.0); 0.4-0.5	0.4 (0.0)*; 0.4-0.5**
Mean corpuscular volume (fL)	86.9 (4.3); 77.4-94.6	92 (9)*; 84-101*
Mean corpuscular hemoglobin (pg)	28.4 (1.7); 24.7-32.7	29.5 (2.5)*; 27-33**
Mean corpuscular hemoglobin concentration (g/dL)	324.8 (9.7); 304.8-344.0	330 (15)*; 33-36**
Red cell distribution width-SD (fL)	41.4 (2.6); 36.5-46.5	42.5 (3.5)*
Red cell distribution width-CV (%)	13.0 (0.8); 11.8-14.9	12.8 (1.2)*; <15**
Reticulocyte ($\times 10^9$/L) (%)	69.6 (22.0); 53.7-84.2 1.4 (0.4); 1.1-1.6	50-100* 0.5-2.5*
White blood indices ($\times 10^9$/L)		
Total WBC ($\times 10^9$/L)	6.7 (1.8); 3.6-10.6	4.0-10.0*
Neutrophils ($\times 10^9$/L)	3.5 (1.4); 1.0-6.5	2.0-7.0*

Table 2a (cont.). Hematological reference interval of Saudi adults in comparison with Western values.

Parameter	Current study values with reference range	Western values with range
Neutrophils (%)	51.1 (10.7); 44.6-58.6	40-80*
Lymphocytes (×10^9/L)	2.5 (0.7); 1.3-3.8	1.0-3.0*
Lymphocyte (%)	37.7 (8.8); 30.9-42.8	20-40*
Monocytes (×10^9/L)	0.5 (0.2); 0.2-0.9	0.-1.0*
Monocytes (%)	7.8 (1.9); 4.6-12.3	2-10*
Eosinophil (×10^9/L)	0.1 (0.1); 0.0-0.4	0.0-0.5*
Eosinophil (%)	2.4 (1.7); 0.2-7.0	1-6*
Basophils (×10^9/L)	0.0 (0.0); 0.0-0.1	0.02-0.1*
Basophils (%)	0.6 (0.3); 0.2-1.3	<1-2*
Platelet indices		
Platelet count (×10^9/L)	264.0 (60.5); 219-303	280 (130); 150-410*
Platelet distribution width (fL)	13.0 (2.0); 9.6-17.3	
Mean platelet volume (fL)	10.8 (0.9); 9.2-12.7	

Mean (standard deviation) for normally distributed (red blood cell indices) and median (interquartile range) for non-normally distributed data are presented with the reference range. Predominantly from Europe and North America according to Dacie and Lewis, Practical Hematology, 12th edition*, and William Manual of Hematology, 9th edition**, respectively. RDW-CV: Red Cell Distribution width - Coefficient of Variation RDW-SD: Red Cell Distribution width - Standard Deviation

Table 2b. Hemostatic profile reference interval of Saudi adults in comparison with Western values.

Parameter	Current study values with reference range	Western values with range
Hemostatic profile		
Prothrombin time (sec)	13.8 (0.6); 12.6-15.0	10-12*
International normalized ratio	1.0 (0.0); 0.9-1.1	0.8-1.2**
Partial thromboplastin time (sec)	35.6 (2.7); 30.7-41.5	26-40*
APTT ratio	1.12 (0.9); 0.9 -1.3	1.8-3.6*
Fibrinogen conc. (g/L)	3.3 (0.6); 2.1-4.6	1.8-3.6*
D-dimer (ug/mL)	0.3 (0.0); 0.2-0.4	0.40 ng/mL **
Reptilase time (sec)	18.3 (0.8); 17.6-18.9	
Thrombin time (sec)	16.5 (0.8); 15.8-17.0	15-19*
Antithrombin (%)	99.3 (8.4); 93.0-105.0	75-125*
Factor II (%)	95.7 (14.9); 86.0-106.0	50-150**
Factor V (%)	80.1 (23.7); 63.1-97.0	50-150**
Factor VII (%)	88.0 (23.9); 71.0-104.0	50-150**
Factor VIII (%)	89.3 (36.0); 31.7-171.7	50-200**
Factor IX (%)	114.3 (29.1); 95.0-135.0	50-150**
Factor X (%)	86.5 (16.1); 75.0-98.0	50-150**
Factor XI (%)	102.8 (18.9); 64.2-146.0	50-150**

Table 2b (cont.). Hemostatic profile reference interval of Saudi adults in comparison with Western values.

Parameter	Current study values with reference range	Western values with range
Factor XII (%)	110.6 (34.7); 55.0-188.0	50-150**
Factor XIII (%)	124.7 (34.1); 68.0-200.0	70-130**
Von Willebrand Factor (%)	84.5 (22.6); 73.0-97.0	50-200**
Protein S (%)	93.5 (26.7); 74.2-114.0	60-135*
Protein C (%)	84.8 (21.8); 69.9-98.6	70-140*
Plasminogen conc. (%)	97.9 (14.2); 86.1-108.9	75-160**

Mean (standard deviation) for reptilase and remaining parameters) an median (interquartile range) for promthrombin to D-dimer with reference range. Predominantly from Europe and North America according to Dacie and Lewis, Practical Hematology, 12th edition*, and William Manual of Hematology, 9th edition**

Table 2c. Serum hematinics profile reference interval of Saudi adults in comparison with Western values.

Parameter	Current study values with reference range	Western values with range
Serum hematinic		
Iron (umol/L)	15.2 (6.0); 10.6-19.0	10-30*
Ferritin		
Men (ug/L)	84.8 (61.5); 9.2-232.6	15-300*
Women (ug/L)	36.1 (86.1); 8.2-130.0	15-200*
Vitamin B12 (pmol/L)	240.1 (86.1); 100.5-428.0	180-640*
Folate (nmol/L)	22.0 (10.9); 4.6-45.4	6.8-45*

Mean (standard deviation) for iron and median (interquartile range) for remaining parameters and reference range. Predominantly from Europe and North America according to Dacie and Lewis, Practical Hematology, 12th edition*, and William Manual of Hematology, 9th edition**

ones. While, values for platelet count were higher than the usually accepted reference values (**Table 2**). This is possibly related to ethnic background, geographic variations, sociodemographic differences, social habits and lifestyles, dietary habits and environmental factors, such as use of medicinal herbs, parasitic infestation, pesticides, radiation or electromagnetic waves, and laboratory analytical methods.[31,32]

Moreover, consistent with our results, many studies from different countries have supported variation in reference values of hematological indices currently used from studies on different population, as well as from the standard reference values described in textbooks.[5,17,20,29-38] It is therefore suggested that monitoring of the health status of the population in the study areas should be based on the local reference population.[2,3] Furthermore, consistent with previous studies, our data showed that the values of RBCs, hemoglobin, and hematocrit were higher in males contrasting with females. This may be partially due to hormonal influence of androgen on erythropoiesis, as well as menstrual blood loss.[31,39] On the contrary, the reference range for platelet counts was higher in females compared to males just as reported in other studies.[33] This is probably due to regular menarche with cross-stimulating megakaryopoiesis.[31,33] It has to be noted that lower and higher ranges in this study are more meaningful than statistically significance in the difference because the ranges indicate the cut off values for the diagnosis. The MCV reference ranges for men and women in the present study were just below the defined cut-off values for anemia. It can be hypothesized that the low minimal range MCV, which contrasts with the normal RBC, may be linked to the presence of undefined anemia.[12] Because concepts of health and disease are discussed from the laboratory point of view and reference values are not always derived from healthy individuals, it has been recommended that the term "reference values" be used rather than "normal range".[39]

In conclusion, routine hematologic reference values from hematology textbooks are not always applicable to our population. Therefore, our study provides region-specific reference values for routine hematologic

Table 3. Full blood count normal reference values in male and female Saudi adults.

Parameter	Mean (SD) with reference range	Lower limit (90% CI)	Upper limit (90% CI)	Minimum	Maximum
Red blood cell counts (x10^{12}/L)					
Male	5.4 (0.4)*; 5.2-5.7	4.4-5.9	5.0-6.4	4.0	6.7
Female	4.8 (0.4); 4.5-5.0	3.9-5.1	4.4-5.6	4.0	6.0
Hemoglobin (g/dL)					
Male	15.4 (1.2)*; 12.9-17.9	10.9-14.9	15.9-19.9	11.1	19.1
Female	13.4 (1.0); 11.4-15.4	9.7-13.0	13.7-17.0	10.8	16.4
Hematocrit (%)					
Male	0.5 (0.0)*; 0.4-0.5	0.4-0.5	0.5-0.6	0.4	0.6
Female	0.4 (0.0); 0.4-0.5	0.3-0.4	0.4-0.5	0.4	0.5
Mean corpuscular volume (fL)					
Male	86.6 (4.3); 77.6-95.0	70.6-84.6	87.9-101.9	74.7	98.5
Female	87.1 (4.3); 76.6-94.2	69.6-83.7	87.4-101.4	74.6	96.1
Mean corpuscular hemoglobin (pg)					
Male	28.5 (1.8)*; 24.5-31.9	21.6-27.5	28.8-34.8	23.5	32.7
Female	28.2 (1.5); 24.8-31.1	22.4-27.5	28.4-33.4	24.0	32.3
Mean corpuscular hemoglobin concentration (g/dL)					
Male	32.7 (10.1)*; 30.4-34.5	28.7-32.0	32.8-36.1	29.9	35.3
Female	32.2 (8.2); 30.5-33.9	29.1-31.8	32.6-35.3	30.3	34.6
Red cell distribution width-SD (fL)					
Male	41.1 (2.7)*; 36.1-46.8	31.6-40.5	42.3-51.2	34.7	48.6
Female	41.7 (2.4); 37.4-46.3	33.5-41.3	42.4-50.2	34.2	47.8
Red cell distribution width-CV (%)					
Male	13.0 (0.8); 11.7-14.8	10.4-13.0	13.5-16.1	10.9	15.3
Female	13.1 (0.8); 11.8-15.1	10.6-13.0	13.9-16.3	11.8	15.3
Reticulocyte count (×10^{9}/L)					
Male	77.0 (16.3); 65.0-84.6	38.3-91.8	57.9-111.3	45.0	116.3
Female	66.9 (23.5); 51.6-85.1	13.1-90.2	46.6-123.7	30.2	116.3
Reticulocyte (%)					
Male	1.4 (0.3); 1.2-1.5	0.7-6.5	1.1-2.0	0.8	2.0
Female	1.3 (0.4); 1.1-1.6	0.4-1.8	1.0-2.3	0.6	2.1

Table 3 (cont.). Full blood count normal reference values in male and female Saudi adults.

Parameter	Mean (SD) with reference range	Lower limit (90% CI)	Upper limit (90% CI)	Minimum	Maximum
Normoblast (×10⁹/L)					
Male	0			0	0
Female	0			0	0
White blood cells (×10⁹/L)					
Male	6.5 (1.7)*; 3.7-10.6	0.8-6.5	7.7-13.5	2.4	11.6
Female	7.0 (1.8); 3.5-10.6	0.4-6.5	7.6-13.6	2.8	11.2
Neutrophils # (×10⁹/L)					
Male	3.2 (1.3)*; 1.1-6.3	0.01-3.21	4.3-8.4	0.6	6.7
Female	3.8 (1.5); 1.0-6.6	0.01-3.47	4.1-9.0	0.8	7.2
Neutrophils (%)					
Male	48.9 (9.7)*; 43.2-55.3	27.3-59.1	39.5-71.3	23.4	70.1
Female	53.0 (11.1); 46.4-61.2	28.2-64.6	43.0-79.4	24.3	73.4
Lymphocytes (×10⁹/L)					
Male	2.4 (0.6); 1.3-3.9	0.2-2.4	2.8-4.9	0.7	4.1
Female	2.5 (0.7); 1.3-3.7	0.2-2.4	2.6-4.8	1.2	3.8
Lymphocytes (%)					
Male	38.5 (8.4)*; 32.3-44.2	18.5-46.1	30.6-58.3	20.9	61.9
Female	36.4 (9.0); 29.7-41.7	14.8-45.5	26.8-56.5	16.7	57.0
Monocytes (×10⁹/L)					
Male	0.5 (0.1)*; 0.2-0.9	0.01-0.49	0.6-1.1	0.2	0.9
Female	0.5 (0.2); 0.3-0.9	0.01-0.53	0.6-1.1	0.3	0.9
Monocytes (%)					
Male	8.3 (1.8)*; 5.0-12.4	2.1-7.9	9.5-15.3	3.9	12.8
Female	7.3 (1.9); 4.4-12.3	1.3-7.5	9.2-15.4	4.3	12.9
Eosinophils # (×10⁹/L)					
Male	0.2 (0.1)*; 0.0-0.4	0.01-0.21	0.2-0.6	0.0	0.5
Female	01 (0.0); 0.0-0.4	0.01-0.16	0.2-0.5	0.0	0.4
Eosinophils (%)					
Male	2.9 (1.8)*; 0.4-7.1	0.01-3.28	4.2-10.0	0.0	7.7
Female	1.9 (1.5); 0.0-7.0	0.01-2.61	4.4-9.5	0.0	7.7
Basophils (×10⁹/L)					
Male	0.0 (0.0)*; 0.0-0.1	0.01-0.03	0.0-0.1	0.0	0.1
Female	0.0 (0.0); 0.0-0.1	0.01-0.03	0.0-0.1	0.0	0.1

Table 3 (cont.). Full blood count normal reference values in male and female Saudi adults.

Parameter	Mean (SD) with reference range	Lower limit (90% CI)	Upper limit (90% CI)	Minimum	Maximum
Basophils (%)					
Male	0.7 (0.3)*; 0.2-1.3	0.01-0.68	0.8-1.8	0.0	1.3
Female	0.5 (0.3); 0.1-1.1	0.01-0.53	0.7-1.5	0.1	1.3
Platelet count ($\times 10^9$/L)					
Male	250.1 (55.8)*; 213.0-283.0	121.5-304.5	194.5-377.5	115.0	410.0
Female	280.9 (61.9); 229.2-327.2	127.8-330.7	225.8-428.7	120.0	417.0
Platelet distribution width (fL)					
Male	13.1 (2.0); 9.7-17.3	6.4-13.0	14.0-20.6	8.6	18.5
Female	12.9 (2.0); 9.5-17.5	6.3-12.8	14.3-20.7	9.1	17.9
Mean platelet volume (fL)					
Male	10.8 (0.9); 9.-12.7	7.7-10.7	11.2-14.2	8.5	13.2
Female	10.9 (0.9) 9.2-12.8	7.7-10.7	11.3-14.2	8.9	13.1

*Significant difference in values between males and females ($P<.001$) within age groups studied.
**Significant difference in values between males and females ($P<.05$) t-test or Mann-whitney were appropriate).

Table 4. Hemostatic normal reference values in male and female Saudi adults.

Parameter	Mean (SD) with reference range	Lower limit (90% CI)	Upper limit (90% CI)	Minimum	Maximum
Prothrombin time (sec)					
Male	13.7 (0.6)*; 12.5-15.0	11.4-13.6	14.0-16.1	12.0	15.5
Female	13.9 (0.6); 12.8-15.0	11.9-13.8	14.1-15.9	12.2	15.1
International normalized ratio					
Male	1.0 (0.1)*; 0.9-1.1	0.8-1.0	1.0-1.2	0.9	1.2
Female	1.0 (0.0); 0.9-1.2	0.8-1.0	1.1-1.2	0.9	1.2
Active partial thromboplastin time (sec)					
Male	35.3 (2.8)*; 30.0-41.4	25.4-34.6	36.8-46.0	28.5	43.1
Female	36.1 (2.6); 31.8-41.5	27.6-36.1	37.2-45.7	29.7	43.1
APPT ratio					
Male	1.1 (1.0); 0.9-1.3			0.6	14.2
Female	1.1 (0.9); 0.9-1.3			0.8	11.0
Fibrinogen conc. (g/L)					
Male	3.1 (0.6)*; 2.1-4.5	1.1-3.1	3.5-5.5	1.4	4.9
Female	3.4 (0.6)*; 2.2-4.9	1.2-3.2	3.9-5.9	1.8	4.9

Table 4 (cont.). Hemostatic normal reference values in male and female Saudi adults.

Parameter	Mean (SD) with reference range	Lower limit (90% CI)	Upper limit (90% CI)	Minimum	Maximum
D-dimer (ug/mL)					
Male	0.3 (0.0)**; 0.2-0.4	0.1-0.3	0.3-0.5	0.2	0.4
Female	0.3 (0.0); 0.2-0.4	0.1-0.3	0.3-0.5	0.2	0.4
Reptilase time (sec)					
Male	18.4 (0.8); 17.7-18.9	16.4-19.0	17.6-20.2	16.8	20.9
Female	18.1 (0.8); 17.6-18.7	16.3-18.9	17.4-20.0	16.5	19.5
Thrombin time (sec)					
Male	16.5 (0.8); 15.9-17.1	14.6-17.2	15.7-18.4	14.5	18.8
Female	16.3 (0.9); 15.8-16.8	14.3-17.3	15.3-18.3	14.9	18.9
Antithrombin (%)					
Male	98.0 (8.5)*; 92.0-104.0	78.1-105.9	90.1-117.9	78.0	119.0
Female	100.9 (8.0); 95.0-107.0	81.8-108.2	93.8-120.2	77.0	120.0
Factor II (%)					
Male	94.1 (15.8); 83.6-105.0	57.7-109.5	79.1-130.9	59.0	132.0
Female	96.0 (14.6); 87.2-106.7	63.3-111.2	82.8-130.7	56.0	132.0
Factor V (%)					
Male	88.2 (24.9)*; 54.6-131.6	30.1-111.9	65.5-147.5	31.0	148.0
Female	77.0 (22.5); 60.0-92.0	23.1-96.9	55.1-128.9	27.0	128.0
Factor VII (%)					
Male	101.8 (25.0)*; 87.0-119.3	46.0-128.0	78.3-160.4	39.0	159.0
Female	82.8 (21.3); 68.0-96.0	33.0-903.0	61.0-131.0	25.0	149.0
Factor VIII (%)					
Male	95.5 (37.3)*; 28.0-177.9	0.01-89.08	116.8-239.1	4.0	181.0
Female	87.0 (35.2); 33.0-170.8	0.01-90.80	113.0-228.6	21.0	183.0
Factor IX (%)					
Male	135.0 (24.0)*; 118.0-145.8	78.7-157.3	106.5-185.1	65.0	193.0
Female	106.4 (27.0); 87.7-124.0	43.5-132.0	79.8--168.2	47.0	181.0
Factor X (%)					
Male	95.2 (15.4)*; 84.0-107.0	58.7-109.3	81.7-132.3	57.0	135.0
Female	83.2 (15.1); 72.0-94.0	47.1-96.8	69.1-118.8	48.0	126.0
Factor XI (%)					
Male	108.5 (19.0)*; 75.5-150.2	44.3-106.7	119.0-132.3	63.0	156.0
Female	100.7 (18.5); 63.0-143.0	32.7-93.3	112.7-173.3	59.0	156.0
Factor XII (%)					
Male	128.1 (34.7)*; 67.1-201.6	10.1-124.0	144.6-258.6	60.0	210.0
Female	103.9 (32.3); 52.2-176.9	0.01-105.21	123.9-229.9	26.0	203.0

Table 4 (cont.). Hemostatic normal reference values in male and female Saudi adults.

Parameter	Mean (SD) with reference range	Lower limit (90% CI)	Upper limit (90% CI)	Minimum	Maximum
Factor XIII (%)					
Male	128.1 (34.2); 66.6-200.0	10.5-122.7-143.9	143.9-256.1	51.0	200.0
Female	123.3 (34.0); 68.0-200.0	12.1-123.8	144.1-255.8	64.0	200.0
Von Willebrand Factor (%)					
Male	82.4 (29.7); 58.7-104.3	10.0-107.5	55.6-153.0	38.0	151.0
Female	87.3 (9.2); 78.0-5.2	62.8-93.2	80.1-110.4	73.0	101.0
Protein S (%)					
Male	95.3 (27.3); 75.9-117.3	31.0-120.7	72.5-162.2	42.7	150.0
Female	88.1 (27.3); 73.2-112.0	29.8-116.7	68.6-155.4	48.4	150.0
Protein C (%)					
Male	83.6 (20.6); 70.0-98.0	36.2-103.7	64.2-131.7	42.6	136.1
Female	85.1 (22.2); 69.5 (98.8)	33.0-106.0	62.3-135.3	31.6	143.4
Plasminogen (%)					
Male	92.5 (14.5)*; 81.7-103.2	58.0-105.4	79.5-127.0	69.0	122.0
Female	106.6 (8.9); 102.2-114.0	87.7-116.8	99.4-128.6	91.0	114.0

*Significant difference in values between males and females ($P<.001$) within age groups studied.
**Significant difference in values between males and females ($P<.05$) (student's t-test or Mann-whitney were appropriate).

Table 5. Hematinic normal reference values in male and female Saudi adults.

Parameter	Mean (SD) with reference range	Lower limit (90% CI)	Upper limit (90% CI)	Minimum	Maximum
Serum iron (umol/L)					
Male	15.7 (5.6)*; 12.7-19.6	3.5-21.9	10.4-28.8	0.3	31.1
Female	16.0 (5.8); 12.5-20.5	2.9-22.0	10.9-30.0	0.9	29.8
Serum ferritin (ug/L)					
Male	70.6 (61.4)*; 14.6-238.0	0.01-115.31	137.3-338.7	6.3	269.0
Female	43.7 (52.5); 14.2-244.8	0.01-100.18	158.7-330.8	7.8	271.0
Serum vitamin B12 (pmol/L)					
Male	264.8 (76.7); 266.5-83.6	29.2-280.6	323.7-575.1	149.0	496.0
Female	266.5 (83.6); 147.0-477.0	9.9-284.1	339.9-614.1	146.0	480.0
Serum folate (nmol/L)					
Male	24.0 (10.7); 6.3-45.5	0.01-23.84	27.9-63.0	5.9	45.7
Female	21.1 (8.3); 6.6-40.8	0.01-20.13	27.2-54.3	6.6	40.8

*Significant difference in values between males and females ($P<.001$) within age groups.

parameters for Saudi adults for accurate interpretation of laboratory results, diagnosis, and appropriate management of routine clinical care to improve quality of healthcare in the country. Limitations of the study include the difficulty of accurately assessing the health status of the participants, who could have subclinical illnesses not reflected in the evaluated blood measurement. The inability to eliminate individuals who are carriers for hemoglobinopathies is another limitation. However, this is unlikely to affect the median values for the population but may have produced proportionally more extreme values. Larger sample sizes from different parts of the country are needed to achieve a full representation of the whole Saudi population.

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