Hematological indices reference intervals for a healthy Arab population in Qatar
Effect of age, gender, and geographic location

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Abstract
Hematologic reference intervals vary with gender, age, ethnicity, and geographic area. Therefore, local or national laboratory reference ranges are essential to enhance the accuracy when diagnosing health conditions. Still, no comprehensive list of reference ranges tailored to the Arab population living in Qatar. Accordingly, this study aims at establishing a hematology reference guide for Arabs in Qatar.

This is a retrospective study where 750 healthy volunteers (18–69 years) from 2015 to 2019 were included, analyzed by an automated hematology analyzer. Arab adults were divided into African (Egypt, Libya, Tunisia, Morocco) and Asian (Syria, Lebanon, Jordan, Palestine, Qatar). The Cell-Dyn and Sysmex were used for measuring hematological parameters.

The mean +/- 2SD were established for all the study groups. Arab males had significantly higher Hb, Hct, red cell distribution width, absolute neutrophil count, lymphocytes, and monocyte counts than females. Asian-Arab males had significantly higher Hb concentration and higher WBC, lymphocytes, and eosinophils than African Arabs. Asian-Arab young (>18: <40 years) males had significantly higher Hb and lymphocytes and lower monocytes than older males (>40 years). African-Arab young males had significantly higher lymphocytes and lower monocytes than older males. Asian-Arab young females had higher WBC and absolute neutrophil count than older Asian Arabs.

The findings of this study will help in establishing specific reference intervals in the Arab world. The differences in hematology reference intervals considering age, gender, and geographical location highlight the importance of establishing blood reference intervals in each country considering the ethnic diversity of each country.

Abbreviations: ANC = absolute neutrophil count, CBC = complete blood count, RDW = red cell distribution width, WBCs = White Blood Cells.

Keywords: African Arabs, Asian Arab, differential leucocytic count, hemoglobin, reference intervals, white cell count
1. Introduction

The majority of physicians’ medical judgments are based on clinical information supported by laboratory reports.[11] The availability of a reference interval for different lab values facilitates interpretation.[2,3] The establishment of a normal reference interval is essential for accurate clarification of the disease diagnosis and follow-up. Moreover, the diagnosis and management of several blood disorders are not possible without the development of various novel blood cell parameters.[4-6] However, significant differences exist in the reference intervals based on several variables for example, gender, age, genetic, ethnic, geographical and environmental factors.[7-9]

On the other hand, occupational exposures and dietary habits could affect reference intervals.[10,11] Reference values were established by large population studies in primarily Western population which is often not directly extrapolatable to Eastern Arab population. Therefore, there is an unmet need for each country/region to establish its guidelines for reference intervals.

To date, no country-specific comprehensive studies on the reference intervals for the Arab population in Qatar considering several variables such as age, gender, and geographic location. Therefore, this is the first study in Qatar intended to investigate reference intervals for complete blood count (CBC) concerning age, gender, and blood grouping. Previous recent published reference values for other Arab gulf countries shall be compared to those from Qatar because of the potential difference due to different geographical and ethnic factors.

2. Methods

2.1. Data collection

The Blood Transfusion Center is under the Ministry of Public Health (MoPH) in Qatar. Before blood donation, a specific assessment must be done to determining eligibility and fitness to donate which include physical examination, demographic, medical, and other information. All methods were performed in accordance with the relevant WHO guidelines and regulations.[12] As per the WHO Global Database on Anemia, all subjects with hemoglobin <12.0 g/dL for and <13.0 g/dL for men were excluded.[11]

Ethical approval for the study was obtained from the Institutional Review Board (IRB) at the Medical Research Center (MRC), Hamad Medical Corporation, Doha, Qatar (MRC-01–19-240). The informed consent has been waived by the IRB at Hamad Medical Corporation due to the retrospective nature of this study.

K3EDTA (2mL) tubes were used to collect the peripheral blood specimens. A sample was collected from each of the 750 eligible healthy Arab adult blood donors (selected from n = 1119 subjects screened; n = 369 subjects eliminated because of not fulfilling the WHO guidelines for donors) included in the final analysis who donate blood between January 2015 and May 2019. The main reason for exclusion from the study was low hemoglobin level <12 d/dL in females (79/311) and <13 g/dL (58/808) in males.[11]

Of the 750,515 were males (male donors largely exceeds female donors in Qatar), between 18 and 65 (median age was 30 years). The samples were collected routinely between 8 am and 12 pm and processed within 2 hours. Criteria for donating blood in Qatar (Fig. 1).

2.2. Measurements

The collected blood specimens were analyzed at Hamad General Center (the largest general hospital) in Doha, Qatar. CBC parameters were measured using Cell-Dyn Sapphire (Abbott Laboratories, Diagnostic Division, Abbott Park, IL, USA) and Sysmex XS-1000i (Sysmex Corp., Kobe, Japan) hematology analyzers. Eleven hematology parameters investigated, which including red blood cells count, hemoglobin (Hb), hematocrit (HCT), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), red cell distribution width (RDW), white blood cells count (WBC), absolute neutrophil count (ANC), absolute lymphocyte count (LYMPH), absolute eosinophil count (EOS), absolute basophil count (BASO), absolute monocyte count (MONO), and platelet count (PLT). Anthropometric data, including weight and height, were accurately measured before blood collection; the Body Mass Index and height SDS (HtSDS) were calculated for each adult.

2.3. Quality control & assurance

The hematology laboratory in HMC is accredited by the College of American Pathologists (CAP) Laboratory Accreditation Program. Three different levels (high, medium, and low) of quality control for the respective analyzers; were run thrice a day. Calibration of the analyzers and quality control monitoring were carried out instantly to ensure the validity and reliability of results.

Our laboratory’s statistical quality control (SQC) design adheres to HMO 1301/2007 recommendations for frequency of quality control (every 8 hours) and Standard ISO 15189:2013 recommendations for 3 layers of control. To comply with all requirements, 9 control points (3 × 3 model, 3 times/day × 3 control levels N = 9) are calculated using stabilized commercially control blood every 24 hours (3 × 3 model, 3 times/day × 3 control levels N = 9). Commercial stabilized blood is produced for each of the 2 instruments, Sysmex XT 1800i (Sysmex Corporation, Japan) and Cell-Dyne Ruby (Abbott, Illinois, USA).[12]

2.4. Statistical analysis

Data were analyzed using the Excel Statistical Package (Version 2010). Horn’s algorithm was used to identify the upper and lower extremities’ outliers.[11] The Student t test was used to compare hematological and anthropometric data among groups of different variables such as age, gender, and geographical location. ANOVA test was used when multiple comparisons among groups were needed. Nonparametric tests (Wilcoxon Rank and Mann-Whitney tests) were used when the data were not normally distributed. The CBC values between the –2SD and +2SD that included 95% of the sample were calculated. A linear regression model was performed to explore the effect of all variables. HtSDS: Height in cm is converted to height standard deviation score (SDS) by subtracting the mean and dividing by the SD. HtSDS between –2 and +2 is accepted as normal for age, and gender.

3. Results

Hematological data (mean ± 2SD) at 95% confidence intervals for all the study groups are presented as follows: Arab males (n = 515) had significantly higher Hb 14.74, 12.740 (14.614–14.866, 11.770–13.058), Hct 44.03, 38.5 (43.63–44.43, 35.650–39.443),
RDW 15.610, 14.320 (14.979–16.241, 11.930–14.864), ANC 3.17, 2.78 (1.763–4.577, 1.020–3.138), lymphocytes 3.78, 1.94 (2.895–4.665, 1.380–2.058) and monocytes 0.570, 0.390 (0.536–0.604, 0.200–0.429) than adult females (n = 235), respectively (Table 1). The hematological data of Asian-Arab females did not differ from those for African-Arab females. Asian-Arab males had significantly higher Hb concentration and higher WBC, lymphocytes and eosinophil count than African-Arab males. Asian Arab young males had significantly higher Hb levels and lymphocyte and lower monocyte counts than old males. African Arab young females had higher WBC 6.980, 4.920 (4.873–9.087, 4.288–5.552), ANC 3.180, 2.490 (2.598–3.762, 1.999–2.981) than old Asian Arab females, respectively. No significant correlation was found between growth parameters (weight, Height, HtSDS, Body Mass Index) and hematological parameters.

Outliers can exist in healthy samples as well as in non-healthy ones. Combining conventional and robust statistical approaches is an effective way of finding outliers in a reference interval context. In general, laboratories lack a well-defined healthy population from which to construct reference intervals. The influence of nonhealthy people in the computation increases the breadth of the reference interval by around 10%. Though, there is a significant variation among analytes. On the other hand, the skewed gender is a result of males are donating blood more than females do. However, the total number of females studied was reasonable acceptable for statistical analysis.

4. Discussion
Most physicians’ medical judgments are based on clinical information supported by laboratory reports, where CBC is the most requested. Several studies around the world reported marked differences in some CBC parameters when linked to demographic variables.

A study in Oman reported that Africans were less susceptible to Plasmodium vivax infections as they have a lower reference interval (RIs) for absolute neutrophil counts.[13] In contrast to RIs for ANC from the US (1800 ± 7700 cells/μL),[14] in our study, RIs for males and females was significantly lower at 1050 ± 4080 cells/μL, which is consistent with what has been found in other reports from Africa (500 ± 840 cells/μL).[4,15,16] Measuring CBC parameters have been previously published by the International Council for Standardization in Hematology (ICSH).[17–19] The reference values/ranges are comparable regardless of analyzers, reagents, or analytical principles. Therefore, the laboratories could validate reference intervals on a small number of subjects and combine it with other laboratories from multiple to establish consensus reference intervals.[20]

There are very few published reports explaining the CBC reference intervals for the Arab populations. In this study, the CBC reference intervals were calculated for a cohort of adult Arabs living in Qatar and analyzed in relation to age, gender, geographical region, and blood subgroups.

In our study, the prevalence of neutropenia (ANC < 1.5 × 10^9/L) was significantly lower in Arab males (9.8%) compared to Arab females 28% (P < .001). These confirmed the relatively

1- The person must be between 18 to 60 years of age.
2- He/she must be in good health in general at the day of donation.
3- Must not have any chronic heart, lung or circulatory illnesses.
4- Weight must be 50 kg and above.
5- Donors must not be anemic (Hb < 12g/dl), insulin dependent or hypertensive.
6- Donors must inform the unit about medications being taken.
7- Pregnant, lactating, or menstruating women may not donate.
8- Should have not donated blood in the last 8 weeks (56 days)

Figure 1. The exclusion criteria for blood donation.
## Table 1

Normal hematological reference interval for Arabs in Qatar.

| Age (g) | Hb SDS | Ht (cm) | weight (kg) | BMI | Hb g/dl | WBC | PLT | MCV | MCHC | RDW | ANC | LYMP | MONO | EOS | BASO |
|---------|--------|---------|-------------|-----|---------|-----|-----|-----|------|------|-----|-------|-------|-----|-----|-----|
| Arab Females | Mean | | | | | | | | | | | | | | | |
| n = 225 | | | | | | | | | | | | | | | | |
| SD | 12.13 | 0.98 | 0.06 | 17.9 | 6.99 | 0.07 | 2.10 | 59.40 | 12.85 | 2.68 | 11.00 | 2.90 | 2.50 | 1.76 | 0.50 | 0.19 | 0.15 |
| CI | 0.338 | 0.944 | 12.4 | 6.93 | 0.044 | 2.02 | 58.60 | 12.73 | 2.70 | 11.00 | 2.90 | 2.50 | 1.76 | 0.50 | 0.19 | 0.15 |
| Lower CI (95%) | 0.09 | 11.77 | 3.850 | 210.3 | 36.50 | 0.40 | 20.1 | 72.35 | 31.60 | 11.90 | 1.00 | 1.38 | 0.20 | 0.01 |
| Upper CI (95%) | 0.159 | 16.66 | 6.72 | 257.1 | 44.40 | 0.40 | 21.0 | 84.40 | 33.49 | 14.84 | 3.13 | 2.08 | 0.49 | 0.19 |
| Arab Males | Mean | | | | | | | | | | | | | | | |
| n = 216 | | | | | | | | | | | | | | | | |
| SD | 11.48 | 0.89 | 0.06 | 18.8 | 6.82 | 0.12 | 2.10 | 62.30 | 21.00 | 2.60 | 6.30 | 1.00 | 2.50 | 0.84 | 0.19 | 0.06 |
| CI | 0.310 | 0.211 | 6.09 | 24.1 | 6.97 | 0.40 | 0.91 | 69.25 | 32.00 | 2.70 | 7.00 | 0.94 | 0.06 | 0.01 |
| Lower CI (95%) | 0.09 | 12.56 | 4.28 | 235.4 | 38.60 | 0.40 | 2.95 | 77.50 | 37.80 | 15.60 | 3.17 | 3.70 | 0.50 | 0.17 |
| Upper CI (95%) | 0.136 | 15.16 | 7.12 | 266.5 | 43.00 | 0.40 | 2.95 | 84.00 | 37.80 | 15.60 | 3.17 | 3.70 | 0.50 | 0.17 |
| African Females | Mean | | | | | | | | | | | | | | | |
| n = 95 | | | | | | | | | | | | | | | | |
| SD | 8.69 | 0.84 | 0.06 | 12.96 | 5.17 | 0.94 | 1.53 | 23.01 | 6.62 | 0.96 | 0.96 | 0.16 | 1.00 | 0.35 | 0.04 |
| CI | 0.468 | 11.85 | 4.197 | 219.9 | 36.20 | 0.40 | 21.0 | 78.76 | 37.80 | 13.15 | 1.45 | 1.70 | 0.35 | 0.07 |
| Lower CI (95%) | 0.09 | 12.23 | 3.20 | 235.4 | 38.60 | 0.40 | 2.95 | 77.50 | 37.80 | 13.15 | 1.45 | 1.70 | 0.35 | 0.07 |
| Upper CI (95%) | 0.151 | 15.16 | 7.12 | 266.5 | 43.00 | 0.40 | 2.95 | 84.00 | 37.80 | 13.15 | 1.45 | 1.70 | 0.35 | 0.07 |
| Asian Males | Mean | | | | | | | | | | | | | | | |
| n = 222 | | | | | | | | | | | | | | | | |
| SD | 5.28 | 0.85 | 0.06 | 19.3 | 5.86 | 1.19 | 2.08 | 65.50 | 3.44 | 4.40 | 7.50 | 2.60 | 6.20 | 1.24 | 10.70 | 0.36 |
| CI | 0.24 | 14.81 | 6.585 | 250.5 | 43.15 | 0.40 | 21.0 | 80.56 | 32.15 | 15.10 | 3.47 | 2.87 | 0.58 | 0.17 |
| Lower CI (95%) | 0.09 | 12.16 | 6.162 | 269.2 | 45.04 | 0.40 | 21.0 | 80.56 | 32.15 | 15.10 | 3.47 | 2.87 | 0.58 | 0.17 |
| Upper CI (95%) | 0.187 | 15.16 | 7.12 | 266.5 | 43.00 | 0.40 | 2.95 | 84.00 | 37.80 | 13.15 | 1.45 | 1.70 | 0.35 | 0.07 |
| Asian Old males | Mean | | | | | | | | | | | | | | | |
| n = 133 | | | | | | | | | | | | | | | | |
| SD | 5.17 | 0.77 | 0.05 | 14.19 | 5.62 | 0.34 | 2.10 | 65.90 | 3.44 | 4.40 | 7.50 | 2.60 | 6.20 | 1.24 | 10.70 | 0.36 |
| CI | 0.212 | 14.81 | 6.585 | 250.5 | 43.15 | 0.40 | 21.0 | 80.56 | 32.15 | 15.10 | 3.47 | 2.87 | 0.58 | 0.17 |
| Lower CI (95%) | 0.09 | 12.16 | 6.162 | 269.2 | 45.04 | 0.40 | 21.0 | 80.56 | 32.15 | 15.10 | 3.47 | 2.87 | 0.58 | 0.17 |
| Upper CI (95%) | 0.279 | 15.16 | 7.12 | 266.5 | 43.00 | 0.40 | 2.95 | 84.00 | 37.80 | 13.15 | 1.45 | 1.70 | 0.35 | 0.07 |

* P < 0.05 among the 2 groups.

BMI = Body Mass Index.
The high prevalence of neutropenia (BN) in the Arab population. In a previous study, benign neutropenia (BN) was present in 10.7% of Arab adults, of whom 2.3% of individuals had moderate neutropenia (ANC 0.5–1.0 × 10⁹/L). In 22 tribe-family groups, the prevalence of benign neutropenia varied between 0% and 38%. Unlike our study that showed a higher prevalence of neutropenia in females, others found no difference in the sexes’ frequency.[21] Another study, the frequency of neutropenia (NP) in Arab children (a neutrophil count < 1.5 × 10⁹/L) was found to be: Green Crescent Arabs 9.8%, Peninsula Arabs 10.9%, and North African Arabs 15.4%. On the other hand, the NP’s frequency was 10.6% in 12,703 Emirati children same as their adult counterparts.[16] Although the inheritance of benign neutropenia in Arabs was consistent with an autosomal dominant pattern; the presence of more than 1 genetic variant for this trait could explain the diversity of the observed phenotypes.[16,21]

These data indicated that due to the high prevalence of low neutrophil count in our Arab population, measures should be taken to prevent the inappropriate investigations of a healthy individual with benign neutropenia. A lower interval for ANC can be adopted.

Our hematological data, including Hb, Hct, PLT, was comparable to data recently published for Omani, Saudi and Sudanese adults (3 Arab countries). However, the lower limit intervals for WBC in our study (2.3 × 10⁹/L for males and 1.7 × 10⁹/L in females) were lower compared to those in the Omani study (2.78–8.1 × 10⁹/L), Saudi study (3.3 × 10⁹/L) and Sudanese study (2.9 × 10⁹/L). However, in the Saudi study, the lower interval was taken as 25th percentile not 2.5th percentile as our study.[22,23] The reduced lower limit interval for WBC count comparable to those reported in our study was reported in 2 African studies from Togo 4.1 (1.9–10.1) and Uganda 4.9 × 10⁹/L (2.8–8.2).[24,25]

On the other hand, another study from Kuwait showed that ANCs, in adult Kuwaiti population were 2.6 to 8 and (2.0–7) for women and 2.7 to 8 and (2.0–7) for men, respectively. Both the WBC and ANC counts were higher compared to reference data for adults in the UK.[26]

Arab males had significantly higher Hb, Hct, RDW, WBC, lymphocytes, and monocytes compared to Arab females. It is already known that males and females have variant mean hemoglobin levels. It is probably a direct effect of sex hormones, both estrogen, and androgens, on erythropoiesis.[14,27]

In our study, Asian-Arab males had significantly higher Hb concentration and higher WBC, lymphocytes, and eosinophil counts compared to African-Arab males. The differences from between Asian-Arabs and African-Arabs is due to ethnic descent rather than geographical location.

Arab-Asian young males had significantly higher PLT, WBC, and lymphocyte counts compared to old Asian males. Arab-Asian young females had higher WBC and ANC counts compared to older Asian Arab females. These supported previously published data by Nah et al confirming age-related changes in the WBC and platelet counts with the highest counts occurred during childhood and decreased with age.[28,29] A large cohort study found that women before age 50 had significantly higher ANC%, lower LY%, and higher neutrophil-to-lymphocyte ratio (NLR) than women after 50 years. These results show that blood leukocyte composition differs between women before and after menopausal age.[30] Another large Korean study showed that age displayed the strongest association with the hemoglobin level in both men and women.[31]

It must be mentioned that within-day biological variation and hour-to-hour reference change values for hematological parameters. However, our blood samples were taken randomly all over the day between 7 am and 9 30 pm which decrease the possibility of the effect of time variation on the results.[32]

4.1. Limitations

The relatively small sample (n = 750) of the studied population was calculated to give a margin of error between 3% and 5%. Bigger sample and prospective design can increase the accuracy of the results. The disproportionately lower number of females was unavoidable because we chose to take sequential samples from all subjects coming during this specific time and usually female donors are less than male donors. However, this shall not significantly affect the margin of error (between 5% and 7%).

5. Conclusions

In the studied Arab population, we found important differences in the hematological parameters based on gender, age, and geographical area (African versus Asian Arabs). The lower limit interval of Arabs for ANC appeared to be markedly lower than the internationally reported reference lower limit. These Arab – specific reference intervals for hematological tests may help improve disease diagnosis, allow for better diagnosing, tracking, and monitoring of health status, and can facilitate clinical decision making.

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References

[1] Katayev A, Bakiza C, Seccombe DW. Establishing reference intervals for clinical laboratory test results: is there a better way? Am J Clin Pathol 2010;133:180–6.
[2] Al-Mawali A, Pinto AD, Al Busaidi R, Al-Zakwani I. Lymphocyte subsets: reference ranges in an age-and gender-balanced population of Omani healthy adults. Cytometry Part A 2013;83:739–44.
[3] Yadav D. Reference interval for clinical laboratory test parameters. Biochem Analy Biochem 2015;13:4–12.
[4] Al-Mawali A, Gillis D, Lewis I. Immunoprofiling of leukemic stem cells CD34+/CD38/CD123+ delineate FLT3/ITD-positive clones. J Hematol Oncol 2016;9:1–12.
[5] Pekelharing J, Hauss O, De Jonge R, et al. Haematology reference intervals for established and novel parameters in healthy adults. Sysmex J Int 2010;20:1-9.

[6] Yassin AT, Soliman FA, et al. Hematological indices reference intervals for healthy Arab population in Qatar: effect of age, gender, geographic location and ABO blood group. Blood 2020;136:22-3.

[7] Abbassi-Ghanavati M, Greer LG, Cunningham FG. Pregnancy and laboratory studies: a reference table for clinicians. Obstet Gynecol 2009;114:1326-31.

[8] Gräsbeck R. Reference values, why and how. Scand J Clin Lab Invest Suppl 1990;50:45-53.

[9] Ozarda Y. Reference intervals: current status, recent developments and future considerations. Biochemia Medica 2016;26:5-16.

[10] Disquita A, Sepulveda JL. Accurate Results in the Clinical Laboratory: a Guide to Error Detection and Correction. 2019;Elsevier, ISBN: 9780128137772.

[11] Horn PS, Feng L, Li Y, Pesce AJ. Effect of outliers and nonhealthy individuals on reference interval estimation. Clin Chem 2001;47:2137-45.

[12] Oprea OR, Hutanu A, Pavelea O, Kodori DR, Dobreanu M. Quality control strategy for automated CBC: a laboratory point of view deducted from an internal study organised in an emergency laboratory. Revista Română de Medicină de Laborator Vol 2020;28:19-27.

[13] Al-Mawali A, Gillis D, Lewis I. Characteristics and prognosis of adult acute myeloid leukemia with internal tandem duplication in the FLT3 gene. Oman Med J 2013;28:432-40.

[14] Yalew A, Terefe B, Alem M, Enawgaw B. Hematological reference intervals determination in adults at Gonder university hospital, Northwest Ethiopia. BMC Res Notes 2016;9:483.

[15] Al-Mawali A. Leukemic stem cells shows the way for novel target of human blood [ICSH standard 1995] and specifications for international haemoglobinocyanide standard. J Clin Pathol 1996;49:271-4.

[16] Horowitz GL, Altaie S, Boyd JC. Defining, Establishing, and Verifying Reference Intervals in the Clinical L; Approved Guideline. 2010;Clinical & Laboratory Standards Institute.

[17] Denic S, Showqi S, Klein C, Takala M, Nagelkerke N, Agarwal MM. Prevalence, phenotype and inheritance of benign neutropenia in Arabs. BMC Hematol 2009;9:1-8.

[18] Alaskar A, Rehan H, Mendoza MA, et al. Hematological Profile in the Saudi Population: Reference Intervals by Gender Age and Regions. Washington, DC: American Society of Hematology; 2019.

[19] Al-Mawali A, Pinto AD, Al-Busaidi R, Al-Lawati RH, Morsi M. Comprehensive haematological indices reference intervals for a healthy Omani population: First comprehensive study in Gulf Cooperation Council (GCC) and Middle Eastern countries based on age, gender and ABO blood group comparison. PLoS One 2018;13:e0194497.

[20] Kueviakoe IM, Segbena AY, Jouault H, Vovor A, Imbert M. Hematological reference values for healthy adults in Togo. ISRN Hematol 2011;2011:1-5.

[21] Tagume SB, Powower EM, Lutalo T, et al. Hematological reference ranges among healthy Ugandans. Clin Diagnostic Lab Immunol 1995;2:233-5.

[22] Al-Jafar H. Provisional study of Kuwait adult hematology reference range. J Hematol Thromb 2016;2:4.

[23] Murphy WG. The sex difference in haemoglobin levels in adults—mechanisms, causes, and consequences. Blood Rev 2014;28:41-7.

[24] Nah E-H, Kim S, Cho S, Cho H-I. Complete blood count reference intervals and patterns of changes across pediatric, adult, and geriatric ages in Korea. Ann Lab Med 2018;38:503-11.

[25] Mandala WL, Gondwe EN, MacLennan JM, Molyneux ME, MacLennan CA. Age and sex-related changes in hematological parameters in healthy Malawians. J Blood Med 2017;8:123-30.

[26] Chen Y, Zhang Y, Zhao G, et al. Difference in leukocyte composition and anthropometric indices in elderly Koreans. PLoS One 2016;11:e0162953.

[27] Lee BJ, Kim JY. Identification of hemoglobin levels based on anthropometric indices in elderly Koreans. PLoS One 2016;11:e0165622.

[28] Hilderink JM, Klinkenberg LJ, Aakre KM, et al. Within-day biological variation and hour-to-hour reference change values for hematological parameters. Clin Chem Lab Med 2017;55:1013-24.