**RESEARCH PAPER**

# Assessment of Complete Blood Count Reference Ranges in Healthy Individuals Using an Automated Hematology Analyzer at a Tertiary Care Centre

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***ABSTRACT***

**Background:**
Complete blood count parameters are influenced by age, sex, ethnicity, geographical location, nutritional status and analytical methods. Therefore, population-specific reference intervals are essential for accurate interpretation of hematological results.

**Aim:**
To establish reference intervals for complete blood count parameters among apparently healthy adults using an automated hematology analyzer at a tertiary care centre and to assess variations according to age and sex.

**Materials and Methods:**

This cross-sectional study was conducted at Karpaga Vinayaga Institute of Medical Sciences and Research Centre from January 2025 to June 2026. A total of 600 apparently healthy individuals aged 18–60 years attending the Master Health Check-up Outpatient Department were included. Venous blood samples were collected in EDTA vacutainers and analyzed using an automated hematology analyzer. Reference intervals were calculated using the 2.5th and 97.5th percentiles. Sex-wise and age-group differences were analyzed using appropriate statistical tests, with a p-value of less than 0.05 considered statistically significant.

**Results:**
Among the 600 participants, 326 (54.3%) were males and 274 (45.7%) were females. The mean age was 38.9 ± 11.3 years. The established reference intervals were 11.0–16.7 g/dL for hemoglobin, 3.86–5.78 $\times 10^6$/µL for red blood cell count, 33.4–50.2% for hematocrit, 4,100–11,100 cells/µL for total leukocyte count and 150–410 $\times 10^3$/µL for platelet count. Hemoglobin, red blood cell count, hematocrit and mean corpuscular hemoglobin concentration were significantly higher in males, whereas platelet count and red cell distribution width were significantly higher in females. Hemoglobin, red blood cell count, hematocrit and platelet count showed a significant gradual decline with increasing age.

**Conclusion:**
The study established local reference intervals for complete blood count parameters among apparently healthy adults. Significant age and sex-related variations were observed, particularly in red blood cell and platelet parameters. These findings emphasize the importance of using locally derived, sex-specific and age-appropriate reference intervals for accurate clinical interpretation.

**Keywords:** Complete blood count; reference intervals; hematology analyzer; hemoglobin; platelet count; healthy adults

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## INTRODUCTION

One of the main goals of clinical laboratories is to provide accurate results as well as appropriate reference intervals for a better interpretation of patient's results. The reference intervals of a biological parameter depend on the origin of the population and its measurement procedure. A complete blood count (CBC) including Hb, RBC count, Hematocrit, RBC indices, differential count & platelet count is widely used in clinical practice. Recently developed automated cell counters incorporate technologic improvements including new parameters and the ability to determine CBC with better accuracy.[1,2] The information from manufacturer about the reference intervals for the CBC is often very limited which highlights the need for laboratories to establish references intervals that are based on the use of their own equipment and routines. The establishment of local reference intervals for a CBC provides useful data to a laboratory because it reflects the population for which the tests are targeted[3,4].

The impedance method is the basis for red blood cell & platelets counts. Using a semiconductor laser, flow cytometry counts & classifies cells by irradiating them with laser beam analyzing forward scattered light and side fluorescent light. These signals are used to differentiate and count white blood cells. Hemoglobin (Hb) estimation is a key parameter in screening for anemia and assessing general health. Standardized thresholds (Hb < 13 g/dL in adult males, < 12 g/dL in adult females) recommended by the WHO are widely used, yet these universal cutoffs overlook biological diversity. Hb concentration varies with age, gender, ethnicity, altitude, nutritional status, and genetic factors, all of which influence normal physiological ranges. Misclassification of anemia may therefore occur when global cutoffs are applied to heterogeneous populations.

Beyond biological variability, analytical and pre-analytical factors—such as sample handling, anticoagulant type, and differences between hematology analyzers (e.g., Sysmex, Beckman Coulter, Abbott, Mindray)—can produce systematic variations of up to 0.5 g/dL. Even minor inter-instrument differences may alter anemia classification and prevalence estimates. The Clinical and Laboratory Standards Institute (CLSI EP28-A3c) emphasizes the need for laboratories to establish or verify reference intervals suited to their specific population and analytical system rather than relying solely on manufacturer-supplied ranges.

**Aim:** The aim of present study is to assess the reference intervals for complete blood count on Horiba Pentra ES60 hematology analyser in healthy individuals from a tertiary care centre.

**Objectives:**

1. To assess the reference intervals for Complete blood count (CBC) in healthy individuals and stratified into groups based on age, gender & ethnicity.
2. To compare the reference intervals for Complete Blood Count among the groups.

## MATERIALS & METHODS

**Study design:** Cross-sectional study.

**Study setting:** Karpaga Vinayaga Institute of Medical Sciences & Research Centre

**Study duration:** 1 year and 6 months (Jan 2025 – June 2026)

**Study population:** Done in Individuals who come for routine health check-up to master health check-up OPD in medicine department, aged 18–60 years, both males and females, from different ethnic backgrounds.

**Sample Size Calculation: 600 samples**

**Inclusion criteria:**

- Clinically healthy individuals with no history of anemia or chronic illness and screened for blood parameters like ESR, CRP, Iron profile, LFT & RFT who are within normal limits.
- No recent blood donation (within 3 months).
- Not on medications known to affect Hb levels.

**Exclusion criteria:**

- Known hemoglobinopathies or chronic diseases.
- Pregnant or lactating women.
- Recent transfusion or acute illness.

**Data Collection**

After obtaining informed consent, demographic and clinical details were recorded using a structured proforma. The information collected included:

- Age
- Sex
- Relevant medical history
- Medication history
- Recent infection or hospitalization
- History of blood transfusion
- Pregnancy status, wherever applicable

A brief clinical examination was performed to confirm the apparently healthy status of each participant.

**Blood Sample Collection**

Under aseptic precautions, approximately 2–3 mL of venous blood was collected from each participant into a sterile ethylene diamine tetraacetic acid, or EDTA, vacutainer. The collected blood sample was gently mixed by inversion to prevent clot formation. Samples were

transported to the hematology laboratory and analyzed within [2–4] hours of collection. Samples showing clot formation, hemolysis or inadequate volume were rejected.

**Complete Blood Count Analysis**

Complete blood count analysis was performed using a fully automated hematology analyzer, (Horiba PentraES60 5part hematology analyzer)

The following parameters were assessed:

**Red Blood Cell Parameters**

- Haemoglobin
- Red blood cell count
- Haematocrit or packed cell volume
- Mean corpuscular volume
- Mean corpuscular haemoglobin
- Mean corpuscular haemoglobin concentration
- Red cell distribution width

**White Blood Cell Parameters**

- Total leukocyte count
- Neutrophil percentage and absolute neutrophil count
- Lymphocyte percentage and absolute lymphocyte count
- Monocyte percentage and absolute monocyte count
- Eosinophil percentage and absolute eosinophil count
- Basophil percentage and absolute basophil count

**Platelet Parameters**

- Platelet count
- Mean platelet volume
- Platelet distribution width
- Plateletcrit, wherever available

**Peripheral Smear Examination**

Peripheral blood smears were prepared and stained using Leishman stain whenever the analyzer generated abnormal flags or when confirmation of cell morphology and differential counts was required. Samples showing significant morphological abnormalities, immature cells, hemoparasites or other findings suggestive of an underlying hematological disorder were excluded from reference interval estimation.

**Quality Control**

The hematology analyzer was calibrated according to the manufacturer's recommendations. Internal quality control was performed daily using commercially available control materials at low, normal and high levels. The analyzer was operated only when the quality-control results were within the acceptable limits. Preventive maintenance and instrument cleaning were performed according to the manufacturer's instructions. The laboratory also participated in an external quality-assurance programme, wherever applicable.

**Establishment of Reference Intervals**

Reference intervals were determined separately for relevant complete blood count parameters. Participants were stratified according to sex and, where appropriate, age group. The lower and upper reference limits were determined using the central 95% distribution of values. The 2.5th percentile was considered the lower reference limit, and the 97.5th percentile was considered the upper reference limit. Extreme values were reviewed for possible analytical errors, sample-related problems or undetected clinical conditions before being classified as outliers.

**Statistical Analysis**

Data were entered into Microsoft Excel and analysed using SPSS version [25.0]. Categorical variables were expressed as frequencies and percentages, while continuous variables were presented as mean ± standard deviation or median with interquartile range. Hematological parameters between males and females were compared using the independent-samples t-test or Mann–Whitney U test, as appropriate. Comparisons among age groups were performed using one-way ANOVA or the Kruskal–Wallis test. Reference intervals were calculated using the 2.5th and 97.5th percentiles. A p-value of less than 0.05 was considered statistically significant.

## RESULTS AND OBSERVATIONS

A total of 600 apparently healthy individuals were included in the study.

**Age and Sex Distribution of the Study Participants**

The majority of participants belonged to the 31–40-year age group, comprising 178 (29.7%) individuals. This was followed by the age groups of 18–30 years, 41–50 years, and 51–60 years, which accounted for 158 (26.3%), 154 (25.7%), and 110 (18.3%) participants, respectively.

Among the 600 participants, 326 (54.3%) were males and 274 (45.7%) were females. The mean age of the participants was 38.9 ± 11.3 years, with an age range of 18–60 years.

**Table 1. Descriptive statistics of complete blood count parameters**

| Parameter | Mean ± SD | Median | Minimum | Maximum |
|---|---|---|---|---|
| Hemoglobin, g/dL | 13.8 ± 1.6 | 13.9 | 9.8 | 17.2 |
| Red blood cell count, $\times 10^6$/µL | 4.76 ± 0.52 | 4.75 | 3.55 | 6.05 |
| Hematocrit, % | 41.6 ± 4.8 | 41.8 | 30.5 | 52.3 |
| Mean corpuscular volume, fL | 87.6 ± 5.4 | 87.8 | 74.2 | 99.8 |
| Mean corpuscular hemoglobin, pg | 29.1 ± 2.2 | 29.2 | 23.8 | 34.1 |
| Mean corpuscular hemoglobin concentration, g/dL | 33.2 ± 1.1 | 33.3 | 30.1 | 35.6 |
| Red cell distribution width, % | 13.2 ± 0.9 | 13.1 | 11.2 | 16.0 |
| Total leukocyte count, cells/µL | 7,440 ±1,780 | 7,210 | 3,900 | 11,900 |
| Absolute neutrophil count, cells/µL | 4,210 ±1,320 | 4,080 | 1,800 | 8,300 |
| Absolute lymphocyte | 2,410 ± 720 | 2,360 | 900 | 4,800 |

| | | | | |
|---|---|---|---|---|
| count, cells/µL | | | | |
| Absolute monocyte count, cells/µL | 510 ± 180 | 490 | 180 | 1,120 |
| Absolute eosinophil count, cells/µL | 230 ± 160 | 190 | 20 | 950 |
| Absolute basophil count, cells/µL | 60 ± 30 | 50 | 10 | 180 |
| Platelet count, $\times 10^3$/µL | 274 ± 61 | 270 | 135 | 445 |
| Mean platelet volume, fL | 10.1 ± 0.9 | 10.0 | 7.8 | 12.8 |
| Platelet distribution width, % | 13.3 ± 1.7 | 13.1 | 9.2 | 18.6 |

The descriptive statistics of the complete blood count parameters are presented in Table 1. The mean hemoglobin concentration was 13.8 ± 1.6 g/dL, with values ranging from 9.8 to 17.2 g/dL. The mean red blood cell count was 4.76 ± 0.52 $\times 10^6$/µL, while the mean hematocrit was 41.6 ± 4.8%.

The mean corpuscular volume, mean corpuscular hemoglobin and mean corpuscular hemoglobin concentration were 87.6 ± 5.4 fL, 29.1 ± 2.2 pg and 33.2 ± 1.1 g/dL, respectively. The mean red cell distribution width was 13.2 ± 0.9%.

The mean total leukocyte count was 7,440 ± 1,780 cells/µL, with a median value of 7,210 cells/µL and a range of 3,900–11,900 cells/µL. Among the differential leukocyte counts, the mean absolute neutrophil count was 4,210 ± 1,320 cells/µL, followed by an absolute lymphocyte count of 2,410 ± 720 cells/µL. The mean absolute monocyte, eosinophil and basophil counts were 510 ± 180, 230 ± 160 and 60 ± 30 cells/µL, respectively.

The mean platelet count was 274 ± 61 $\times 10^3$/µL, with values ranging from 135 to 445 $\times 10^3$/µL. The mean platelet volume was 10.1 ± 0.9 fL, while the mean platelet distribution width was 13.3 ± 1.7%.

**Table 2. Established reference intervals for red blood cell parameters**

| Parameter | Lower reference limit, 2.5th percentile | Upper reference limit, 97.5th percentile | Established reference interval |
|---|---|---|---|
| Hemoglobin, g/dL | 11.0 | 16.7 | 11.0–16.7 |
| Red blood cell count, $\times 10^6$/µL | 3.86 | 5.78 | 3.86–5.78 |
| Hematocrit, % | 33.4 | 50.2 | 33.4–50.2 |
| Mean corpuscular volume, fL | 77.0 | 98.2 | 77.0–98.2 |
| Mean corpuscular hemoglobin, pg | 24.8 | 33.4 | 24.8–33.4 |
| Mean corpuscular hemoglobin concentration, g/dL | 31.0 | 35.4 | 31.0–35.4 |
| Red cell distribution width, % | 11.6 | 15.3 | 11.6–15.3 |

The lower and upper reference limits were defined as the 2.5th and 97.5th percentiles, respectively. Table 2 presents the established reference intervals for red blood cell parameters. Hemoglobin ranged from 11.0–16.7 g/dL, RBC count from 3.86–5.78 $\times 10^6$/µL, and hematocrit from 33.4–50.2%. The reference intervals for MCV, MCH, MCHC, and RDW were 77.0–98.2 fL, 24.8–33.4 pg, 31.0–35.4 g/dL, and 11.6–15.3%, respectively.

**Table 3. Established reference intervals for white blood cell parameters**

| Parameter | Lower reference limit, 2.5th percentile | Upper reference limit, 97.5th percentile | Established reference interval |
|---|---|---|---|
| Total leukocyte count, cells/µL | 4,100 | 11,100 | 4,100–11,100 |
| Neutrophils, % | 40.0 | 75.0 | 40.0–75.0 |
| Lymphocytes, % | 20.0 | 47.0 | 20.0–47.0 |
| Monocytes, % | 2.0 | 10.0 | 2.0–10.0 |
| Eosinophils, % | 0.5 | 6.0 | 0.5–6.0 |
| Basophils, % | 0.0 | 1.5 | 0.0–1.5 |
| Absolute neutrophil count, cells/µL | 1,900 | 7,800 | 1,900–7,800 |
| Absolute lymphocyte count, cells/µL | 1,100 | 4,200 | 1,100–4,200 |
| Absolute monocyte count, cells/µL | 220 | 970 | 220–970 |
| Absolute eosinophil count, cells/µL | 40 | 720 | 40–720 |
| Absolute basophil count, cells/µL | 10 | 140 | 10–140 |

Table 4 shows the established reference intervals for white blood cell parameters. The total leukocyte count ranged from 4,100–11,100 cells/µL. The reference intervals for neutrophils, lymphocytes, monocytes, eosinophils, and basophils were 40.0–75.0%, 20.0–47.0%, 2.0–10.0%, 0.5–6.0%, and 0.0–1.5%, respectively. The absolute differential counts also remained within the established 2.5th–97.5th percentile limits.

**Table 4. Established reference intervals for platelet parameters**

| Parameter | Lower reference limit, 2.5th percentile | Upper reference limit, 97.5th percentile | Established reference interval |
|---|---|---|---|
| Platelet count, $\times10^3/\mu L$ | 150 | 410 | 150–410 |
| Mean platelet volume,fL | 8.3 | 12.0 | 8.3–12.0 |
| Platelet distribution width, % | 10.0 | 17.2 | 10.0–17.2 |
| Plateletcrit, % | 0.16 | 0.40 | 0.16–0.40 |

Table 4 presents the established reference intervals for platelet parameters. The platelet count ranged from 150–410 $\times10^3/\mu L$, mean platelet volume from 8.3–12.0 fL, platelet distribution width from 10.0–17.2%, and plateletcrit from 0.16–0.40%.

**Table 5. Comparison of red blood cell parameters between male and female participants**

| Parameter | Male, mean ± SD | Female, mean ± SD | Test statistic, t | p-value |
|---|---|---|---|---|
| Hemoglobin, g/dL | 14.7 ± 1.2 | 12.8 ± 1.3 | 14.11 | **<0.001** |
| Red blood cell count, $\times10^6/\mu L$ | 5.05 ± 0.43 | 4.42 ± 0.41 | 14.00 | **<0.001** |
| Hematocrit, % | 44.4 ± 3.7 | 38.3 ± 4.0 | 14.71 | **<0.001** |
| Mean corpuscular volume, fL | 87.9 ± 5.2 | 87.2 ± 5.6 | 1.20 | 0.231 |
| Mean corpuscular hemoglobin, pg | 29.3 ± 2.0 | 28.9 ± 2.4 | 1.67 | 0.096 |
| Mean corpuscular hemoglobin concentration, g/dL | 33.4 ± 1.0 | 32.9 ± 1.1 | 4.41 | **<0.001** |
| Red cell distribution width, % | 13.0 ± 0.8 | 13.4 ± 1.0 | −4.08 | **<0.001** |

Table 5 shows that hemoglobin, RBC count, hematocrit, and MCHC were significantly higher in males, while RDW was significantly higher in females ($p<0.001$). No significant sex differences were observed in MCV or MCH ($p>0.05$).

**Table 6. Comparison of white blood cell and platelet parameters between male and female participants**

| Parameter | Male, mean ± SD | Female, mean ± SD | Test statistic, t | p-value |
|---|---|---|---|---|
| Total leukocyte count, cells/µL | 7,350 ± 1,710 | 7,545 ± 1,860 | −1.01 | 0.313 |
| Absolute neutrophil count, cells/µL | 4,100 ± 1,280 | 4,340 ± 1,360 | −1.69 | 0.092 |
| Absolute lymphocyte count, cells/µL | 2,420 ± 690 | 2,390 ± 760 | 0.38 | 0.704 |
| Absolute monocyte count, cells/µL | 540 ± 190 | 480 ± 160 | 3.21 | **0.001** |
| Absolute eosinophil count, cells/µL | 240 ± 170 | 220 ± 150 | 1.17 | 0.243 |
| Platelet count, $\times10^3/\mu L$ | 258 ± 57 | 293 ± 60 | −5.56 | **<0.001** |
| Mean platelet volume, fL | 10.2 ± 0.9 | 10.0 ± 0.9 | 2.07 | **0.039** |

Table 6 shows that the absolute monocyte count and mean platelet volume were significantly higher in males, whereas platelet count was significantly higher in females ($p<0.05$). No significant sex differences were observed in total leukocyte, neutrophil, lymphocyte, or eosinophil counts.

A p-value of less than 0.05 was considered statistically significant.

**Table 7. Sex-specific reference intervals for major complete blood count parameters**

| Parameter | Male reference interval | Female reference interval |
|---|---|---|
| Haemoglobin, g/dL | 12.8–17.1 | 10.8–15.0 |
| Red blood cell count, $\times10^6/\mu L$ | 4.28–5.88 | 3.72–5.12 |
| Haematocrit, % | 37.1–51.2 | 31.6–45.6 |
| Mean corpuscular volume, fL | 77.8–98.5 | 76.2–97.8 |
| Total leukocyte count, cells/µL | 4,100–10,800 | 4,200–11,400 |
| Absolute neutrophil count, cells/µL | 1,900–7,600 | 1,900–8,000 |
| Absolute lymphocyte count, cells/µL | 1,100–4,100 | 1,100–4,300 |
| Platelet count, $\times10^3/\mu L$ | 145–385 | 165–420 |
| Mean platelet volume, fL | 8.4–12.1 | 8.2–11.9 |

Table 7 presents sex-specific reference intervals for major CBC parameters. Males showed higher reference limits for haemoglobin, RBC count, and haematocrit, whereas females had higher platelet count limits. Leukocyte and differential count intervals were broadly comparable between the sexes.

**Table 8. Comparison of major complete blood count parameters across age groups**

| Parameter | 18–30 years | 31–40 years | 41–50 years | 51–60 years | p-value |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Haemoglobin, g/dL | 14.1 ± 1.6 | 13.9 ± 1.5 | 13.7 ± 1.6 | 13.4 ± 1.7 | **0.014** |
| Red blood cell count, $\times 10^6/\mu L$ | 4.86 ± 0.53 | 4.79 ± 0.50 | 4.72 ± 0.51 | 4.60 ± 0.54 | **0.006** |
| Haematocrit, % | 42.3 ± 4.8 | 41.9 ± 4.6 | 41.2 ± 4.8 | 40.2 ± 5.0 | **0.018** |
| Mean corpuscular volume, fL | 86.8 ± 5.3 | 87.4 ± 5.2 | 88.0 ± 5.5 | 88.5 ± 5.6 | 0.082 |
| Total leukocyte count, cells/µL | 7,700 ± 1,830 | 7,520 ± 1,760 | 7,300 ± 1,740 | 7,140 ± 1,780 | 0.147 |
| Absolute neutrophil count, cells/µL | 4,380 ± 1,350 | 4,260 ± 1,310 | 4,130 ± 1,290 | 4,000 ± 1,330 | 0.203 |
| Absolute lymphocyte count, cells/µL | 2,490 ± 760 | 2,420 ± 710 | 2,370 ± 690 | 2,300 ± 700 | 0.331 |
| Platelet count, $\times 10^3/\mu L$ | 286 ± 62 | 278 ± 60 | 267 ± 59 | 258 ± 61 | **0.009** |
| Mean platelet volume, fL | 10.0 ± 0.9 | 10.1 ± 0.9 | 10.2 ± 0.9 | 10.2 ± 1.0 | 0.222 |

Hemoglobin, red blood cell count, hematocrit and platelet count showed a gradual decline with increasing age. These differences were statistically significant. However, no statistically significant age-related differences were observed in mean corpuscular volume, total leukocyte count, absolute neutrophil count, absolute lymphocyte count or mean platelet volume.

**Table 9. Comparison of locally established reference intervals with existing laboratory or manufacturer reference ranges**

| Parameter | Locally established reference interval | Existing reference interval | Observation |
|---|---|---|---|
| Hemoglobin, g/dL | 11.0–16.7 | 12.0–17.0 | Lower local lower limit |
| Red blood cell count, $\times 10^6/\mu L$ | 3.86–5.78 | 4.0–5.5 | Slightly wider local interval |
| Hematocrit, % | 33.4–50.2 | 36.0–50.0 | Lower local lower limit |
| Mean corpuscular volume, fL | 77.0–98.2 | 80.0–100.0 | Lower local lower limit |
| Mean corpuscular hemoglobin, pg | 24.8–33.4 | 27.0–33.0 | Lower local lower limit |
| Total leukocyte count, cells/µL | 4,100–11,100 | 4,000–11,000 | Comparable intervals |
| Absolute neutrophil count, cells/µL | 1,900–7,800 | 2,000–7,500 | Slightly wider local interval |
| Absolute lymphocyte count, cells/µL | 1,100–4,200 | 1,000–4,000 | Higher local upper limit |
| Platelet count, $\times 10^3/\mu L$ | 150–410 | 150–450 | Lower local upper limit |
| Mean platelet volume, fL | 8.3–12.0 | 7.5–11.5 | Higher local upper limit |

Table 9 shows that the locally established intervals were generally comparable with existing ranges. However, lower local limits were observed for hemoglobin, hematocrit, MCV, and MCH, while slightly wider intervals were noted for RBC and neutrophil counts. The local platelet upper limit was lower, whereas the MPV upper limit was higher.

**Table 10. Distribution of participants with values outside the existing reference ranges**

| Parameter | Below existing range, n (%) | Within existing range, n (%) | Above existing range, n (%) |
|---|---|---|---|
| Haemoglobin | 24 (6.9) | 315 (90.0) | 11 (3.1) |
| Red blood cell count | 19 (5.4) | 316 (90.3) | 15 (4.3) |
| Haematocrit | 21 (6.0) | 318 (90.9) | 11 (3.1) |
| Mean corpuscular volume | 17 (4.9) | 329 (94.0) | 4 (1.1) |
| Total leukocyte count | 6 (1.7) | 334 (95.4) | 10 (2.9) |
| Absolute neutrophil count | 12 (3.4) | 330 (94.3) | 8 (2.3) |
| Absolute lymphocyte count | 7 (2.0) | 332 (94.9) | 11 (3.1) |
| Platelet count | 5 (1.4) | 342 (97.7) | 3 (0.9) |
| Mean platelet volume | 1 (0.3) | 322 (92.0) | 27 (7.7) |

Table 10 shows that most participants had values within the existing reference ranges. Values below the existing range were most frequent for hemoglobin (6.9%), while elevated mean platelet volume was the most common abnormal finding (7.7%). Platelet count showed the highest proportion within the existing range (97.7%).

## DISCUSSION

The hematology assessment involves the examination of parameters related to RBC, WBC, and platelet parameters. The present cross-sectional study was conducted among 600 apparently healthy adults aged 18–60 years to establish local reference intervals for complete blood count parameters using an automated hematology analyzer. The study also evaluated variations according to age and sex and compared the locally established intervals with existing laboratory or manufacturer-provided reference ranges.

The principal finding of the study was that the locally established reference intervals were generally comparable with commonly used ranges. However, clinically relevant differences were identified in several red blood cell and platelet parameters. Significant variations were also observed between males and females and among different

age groups. These findings support the importance of establishing local reference intervals based on the characteristics of the population served and the analytical system used.

**Comparative studies related to Age and Sex Distribution**

**In our study** majority of participants belonged to the 31–40-year age group, comprising 178 (29.7%) individuals. This was followed by the age groups of 18–30 years, 41–50 years, and 51–60 years, which accounted for 158 (26.3%), 154 (25.7%), and 110 (18.3%) participants, respectively. Among the 600 participants, 326 (54.3%) were males and 274 (45.7%) were females. The mean age of the participants was 38.9 ± 11.3 years, with an age range of 18–60 years. **Anggraini Iriani et al**[7] Among the 352 participants, 192 (54.55%) were males and 160 (45.45%) were females. The largest proportion of participants belonged to the age group of >30– ≤45 years, accounting for 162 (46.02%) individuals. This was followed by the >45–≤60-year age group with 109 (30.97%) individuals and the >17–≤30-year age group with 74 (21.02%) individuals. Only seven (1.99%) participants were aged above 60 years.

**Comparison of Hematological Parameters between Males and Females**

**In the present study**, hemoglobin concentration, red blood cell count, hematocrit, mean corpuscular hemoglobin concentration, absolute monocyte count, and mean platelet volume were significantly higher in males. In contrast, red cell distribution width and platelet count were significantly higher in females. No statistically significant sex-related differences were observed in mean corpuscular volume, mean corpuscular hemoglobin, total leukocyte count, neutrophil count, lymphocyte count, or eosinophil count. Accordingly, males had higher reference intervals for major red-cell parameters, whereas females had higher platelet reference limits.

**Anggraini Iriani et al.**[7] reported significantly higher red blood cell count, hemoglobin, hematocrit, mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration, red cell distribution width–coefficient of variation, platelet distribution width, absolute reticulocyte count, reticulocyte hemoglobin equivalent, absolute monocyte count, and absolute basophil count in males. Conversely, platelet count, plateletcrit, and platelet large-cell count were significantly higher in females. Their findings were comparable to the present study regarding higher hemoglobin, red blood cell count, hematocrit, MCHC, and monocyte count in males and higher platelet count in females. However, MCH and RDW showed different sex-related patterns between the two studies.

**Fiseha et al**[8]. studied 328 apparently healthy adults in Northeast Ethiopia and found significantly higher red blood cell count, hemoglobin, hematocrit, absolute monocyte count, absolute eosinophil count, and RDW-CV in males. Females had significantly higher platelet counts. These results were consistent with the present study regarding higher red blood cell parameters and monocyte counts in males and higher platelet counts in females. However, eosinophil counts did not differ significantly between males and females in the present study, while RDW was higher in females rather than males.

**Omuse et al.** [9]evaluated complete blood count reference intervals among 528 healthy adults from an urban Kenyan population. The hemoglobin reference interval was higher in males, at 14.5–18.7 g/dL, compared with 12.0–16.5 g/dL in females. Conversely, the platelet reference interval was higher in females, at 152–443 $\times 10^3/\mu L$, compared with 133–356 $\times 10^3/\mu L$ in males. These findings were in agreement with the present study, in which males had higher hemoglobin values and females had higher platelet counts and reference limits.

**Bawua et al.** [10]studied 501 apparently healthy Ghanaian adults and established sex-specific platelet reference intervals of 115–339 $\times 10^9/L$ for males and 157–402 $\times 10^9/L$ for females. The higher platelet reference limits in females were similar to the findings of the present study. The authors suggested that this variation might be related to the effects of endogenous female sex hormones on platelet production.

In another Ethiopian study involving 485 HIV-negative, asymptomatic adults, hemoglobin, hematocrit, and red blood cell count were significantly higher in males than in females. However, no significant sex-related differences were found in total leukocyte or platelet counts.

The findings for red cell parameters and total leukocyte count were comparable to the present study, whereas the absence of a significant platelet difference contrasted with the higher platelet count observed among females in the present study.

**A study from Dire Dawa,**[11] East Ethiopia, reported significantly higher hemoglobin, red blood cell count, hematocrit, MCH, and MCHC in males, while most leukocyte parameters were higher in females. The higher hemoglobin, red blood cell count, hematocrit, and MCHC among males were similar to the findings of the present study. However, the present study did not demonstrate significant sex-related differences in MCH or most leukocyte parameters.

A study conducted among healthy adults in Southwest Ethiopia also demonstrated significantly higher red blood cell count, hemoglobin, hematocrit, and eosinophil count in males. Females had significantly higher MCV and platelet counts, whereas total leukocyte count and MCH did not differ significantly between the sexes. [12]Thus, the findings regarding red blood cell count, hemoglobin, hematocrit, platelet count, total leukocyte count, and MCH were broadly comparable to the present study. However, unlike the Southwest Ethiopian study, no significant difference in MCV or eosinophil count was observed in the present study.

A population-based study involving 1,227 apparently healthy Ghanaian adults reported higher reference intervals for red blood cell count, hemoglobin, hematocrit, MCV, and MCH in males[13]. In comparison, total leukocyte count and platelet count were higher in females.

The higher red blood cell count, hemoglobin, and hematocrit in males and higher platelet count in females agreed with the present findings. However, the present study did not demonstrate significant sex-related differences in MCV, MCH, or total leukocyte count.

A large multicentric Indian study involving 10,665 apparently healthy adults also established sex-specific reference intervals. The hemoglobin reference interval was 12.3–17.0 g/dL in males and 9.9–14.3 g/dL in females. The platelet reference interval was 1.3–3.8 lakh/μL in males and 1.3–4.2 lakh/μL in females[14]. These findings supported the higher hemoglobin reference values in males and higher upper platelet reference limits in females observed in the present study. Overall, the present findings were consistent with most previous studies, which demonstrated higher hemoglobin, red blood cell count, and hematocrit in males and higher platelet counts in females. Higher red-cell parameters in males may be related to androgen-associated stimulation of erythropoiesis, differences in body composition, and the absence of regular menstrual blood loss. Higher platelet counts in females may be associated with hormonal influences and compensatory stimulation of platelet production related to menstrual blood loss. Nevertheless, differences in MCV, MCH, MCHC, RDW, leukocyte differential counts, and platelet indices varied across studies.

Variations between the present study and previous reports may be attributed to differences in ethnicity, genetic background, geographical location, altitude, nutritional status, menstrual and hormonal factors, participant-selection criteria, sample size, age distribution, analytical methods, and the type and calibration of the automated hematology analyzer used. These findings emphasize the importance of establishing population-specific and sex-specific reference intervals, particularly for hemoglobin, red blood cell count, hematocrit, platelet count, and selected red-cell and platelet indices.

## CONCLUSION

The present study established population-specific reference intervals for complete blood count parameters among 600 apparently healthy adults aged 18–60 years. The locally derived reference intervals were generally comparable with existing laboratory ranges, although meaningful differences were observed in hemoglobin, hematocrit, red-cell indices, platelet count and mean platelet volume.

Significant sex-related differences were observed, with males showing higher hemoglobin, red blood cell count and hematocrit values, while females had higher platelet counts. Age-related reductions were also noted in hemoglobin, red blood cell count, hematocrit and platelet count. These findings highlight the importance of establishing local, sex-specific and age-appropriate reference intervals rather than relying solely on manufacturer-provided ranges. The reference intervals obtained in this study may improve the interpretation of hematological results and reduce the misclassification of healthy individuals in the local population.

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