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Reference Intervals of Complete Blood Count in Healthy Adult Eritreans

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ABSTRACT

Background: Blood count is the most commonly prescribed biological examination in general medical practice. The reference intervals of the hematological parameters of this examination are critical for clinical orientations and therapeutic decisions. Because there are racial, ethnic, and geographical differences in complete blood count (CBC) reference intervals (RIs), population-specific RIs must be established. The goals of this study were to identify hematological reference ranges in healthy adult Eritreans.

Method: 942 healthy Eritreans between 18 and 60 years old were included, 331 males and 611 females by use of a DXH500 analyzer. The venous blood sample was collected in a tube containing EDTA anticoagulant for the blood tests. SPSS version 25 statistical software was used for data analysis, P value<0.05 was considered significant. A non-parametric test was used for the determination of upper (97.5th percentile) and lower (2.5th percentile) reference interval limits with 95% CI. The Harris and Boyd Rule was used to determine the need for partitioning of reference intervals based on gender.

Results: The established 95% reference intervals combined median (2.5th-97.5th percentile) for both males and females were: WBCs: 6.37 (3.02 µL-13.55 µL × 103/µL), Lymph%:39.34 (21.39%-60.54%), Mono%:8.98 (5.18-14.54%), Neut%: 49.13 (16.90%-81.98%), Baso%: 0.22 (0.00%-0.63%), MCV: 87.67 (76.58 fl-97.29 fl), MCH: 27.53 (20.46 pg-32.70 pg), MCHC: 31.38 (25.20 g/dl-35.30 g/dl, RDW: 14.65 (12.70%-18.60%), PLT: 286.83 (131.62 µL-453.13 µL × 103/µL) and MPV: 8.92 (7.28 fl-11.01 fl). The parameters that demand separate RI and their respective median (2.5th-97.5th percentile) for males versus females were: Eosin: 3.86 (0.29%-16.68%) versus 1.80 (0.20%-6.73%), RBCs: 5.57 (4.47-7 µL.69 µL × 106/µL) versus 4.97 (3.98 µL-6.38 µL × 106/µL), Hb: 15.28 (11.48 g/dl-17.99 g/dl) versus 13.50 (10.74 g/dl-16.54 g/dl), and HCT: 48.75 (38.96%-61.17%) versus 43.19 (34.86%-58.60%).

The median of WBCs was significantly higher in females than males, the mean WBCs were lower in people residing at high altitudes compared to those leaving at low altitudes, and the WBC is significantly higher among obese participants. The median Platelet count is significantly higher in females than in males.

Conclusion: The reference intervals established in this study differ from the international one and thus should be used for the interpretation of laboratory results in diagnosis and follow-up in Eritrea. The study showed significant variations in Hb levels, RBCs count, WBCs count, and platelet according to gender, Age, BMI, and physical activity.

Keywords: Reference intervals; Blood counts; Hemoglobin; Eritrea; Red blood cells; White blood cells

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INTRODUCTION

Complete Blood Count (CBC) is the most frequently used laboratory investigation in health care. The most important aspect of laboratory test interpretation is the concept of reference interval (RI), where test values that fall inside the range are considered normal and those occurring outside the range are considered abnormal [1]. Population-based RI, which first came into use in human medicine in 1969, is the range of values that 95% of a healthy population fell within [2]. The reference ranges universally used are mostly from studies conducted in Western countries. However, these reference intervals differ based on many socio-demographic characteristics. Several factors such as age, gender, dietary patterns, ethnic differences and altitude affect the reference ranges for different groups and the Western RI may not be applicable in most regional settings [3]. The Clinical and Laboratory Standards Institute (CLSI) recommended each country should establish its organic standards to avoid misinterpretation of blood count results [4]. The objective of this study is to determine the Hematological reference intervals in healthy adult Eritreans.

MATERIALS AND METHODS

Study Design

This is descriptive and cross-sectional.

Study Site

The study was conducted on Eritreans from all over the country in the period from 2019 up to 2022. Samples used in this study were collected from the following sites in Eretria:

- Central region (Asmara)
- Anseba region (Keren)
- Southern region (Mendefera) and
- Northern Red Sea region (Massawa)

Volunteer Recruitment

The areas from which participants were drawn were chosen using a multistage sampling technique (Stratified sample). The zone was the first-stage sampling unit. Out of several zones in the city, we chose one at random. The second stage involved a random sub-zone selection. We chose one of the zone's sub-zones at random. The third stage was the random selection of sub-zone blocks. We chose four blocks at random from the sub-zone. The fourth stage involved systematically selecting households from a randomly selected reference point. After identifying a household, we contacted the zone administrators and requested that one employer be assigned to educate the population of the intended blocks about the study's objectives. Recruitment was stratified into 4 age groups: 18-29, 30-39, 40-49, and 50-60 years. Before drawing blood, we obtained written informed consent from all participants. The team used a questionnaire to collect anthropometric measurements, demographic data, medical status, medical history, physical activity, and sleeping hours from each blood donor. Blood pressure and BMI measurements were taken for all participants.

Reference Population

This cross-sectional study included 942 healthy adult Eritreans from various social, ethnic, and professional groups. The Clinical and Laboratory Standards Institute guidelines were used to select participants for this study. Our reference sample included 331 men with an average age of 40 and 611 women with an average age of 41; the study lasted from November 2019 to January 2022.

Ethical Clearance

The Eritrean Ministry of Health's ethics committee granted ethical approval for this study.

Blood Collection

An early morning visit was from 8 AM to 12 AM. Blood samples were collected by a trained phlebotomist, blood drawn by venipuncture 2 ml of venous blood was collected into tetra-acetic acid (EDTA) vacutainer tubes for a complete blood count. Blood samples were transported to the laboratory, where all the analyses were conducted at the Hematology Department within 5 hours of blood extraction.

Statistical Analysis

Analysis was done in SPSS (Version 25) after a careful check-up on completeness, cleaning, and editing processes. Extreme values that might greatly affect the result within each gender were identified using the D/R ratio, where D is the absolute difference between an extreme observation (large or small) and the next largest (or smallest) observation, and R is the range (maximum-minimum). The identified extreme values were deleted if D/R ≥ 1/3 (4). Descriptive analysis of the demographic variables, stratified by gender, was performed using mean, median, standard deviation, frequencies, and percent, as appropriate. The Clinical Laboratory Standards Institute/International Federation for Clinical Chemistry (CLSI/IFCC) was employed to compute the reference intervals. As per the standard, a nonparametric method median (IQR), range (Minimum and maximum), combined and separate 95% RIs (2.5^{th} and 97.5^{th} percentiles), 95% CI for the lower limit of RI, and upper limit of RI were computed (using 1000 bootstrapped simple random sampling). Harris and Boyd test vis-à-vis Mann-Whitney U test, was performed to determine whether combined or separate RIs are needed [5,6]. However, results from Harris and Boyd were finally endorsed. Upon using Harris and Boyd, the statistical Z result was compared with a critical Z* value: Separate gender specific reference range are needed when Z>Z*.

Where $Z=\frac{\text{Mean 1}-\text{Mean 2}}{\left(\frac{SD_1}{N_1}+\frac{SD_2}{N_2}\right)^{1/2}}$ and $Z^*=3[(N1+N2)/240]1/2.$

To assess the relationship of the hematological parameters with the socio-demographic and basic background characteristics, the spearman rank correlation (for continuous variables), Mann-Whitney U test (categorical variables having dichotomous outcome), and Kruskal-Wallis test (categorical variables having more than two outcomes) were employed. Post-hoc analysis using the Bonferroni test was also performed for the results that were found to be significant using Kruskal-Wallis. Agreement between the currently estimated reference inter-

vals and currently used RIs was performed using the Kappa statistic. Interpretation of the Kappa statistic was done using Landis and Koch classification [7].

RESULTS

A total of 942 individuals volunteered to participate in our study and were included, including 331 males and 611 females. The percentages of male and female participants were 35.14% and 64.86% respectively. Combined and separate (male and female) descriptive characteristics, which include mean (SD), median (IQR), and range, of study participants for the four cities are displayed in **Table 1**. The combined mean age was 39.69 (± 12.38) years. The combined mean (SD) of height and weight were 1.62 (± 0.09) meters and 58.85 (12.23) kilograms, respectively. The combined mean body mass index was also 22.49 (± 4.56) kg/m2. Moreover, the combined mean (SD) values of SBP and DBP were 118.03 (16.32) and 76.32 (9.69) respectively. The mean sleeping hour (per day) of both males and females was 7.75 (0.86) hours. A detailed characterization of the study participants stratified by gender is given in **Tables 1 and 2** (continuous variables and categorical variables).

Table 1: Socio-demographic and basic background characteristics of the study participants for continuous variables stratified by gender

Continuous variable	Combined	Male	Female
Age (Years)			
Mean (SD)	39.69 (12.38)	37.00 (13.24)	41.16 (11.58)
Median (IQR)	40.00 (21)	34.50 (25)	42.00 (19)
Height (m)			
Mean (SD)	1.62 (0.09)	1.70 (0.07)	1.57 (0.06)
Median (IQR)	1.61 (0.13)	1.7 (0.10)	1.57 (0.09)
Weight (kg)			
Mean (SD)	58.85 (12.23)	61.81 (12.09)	57.24 (12.01)
Median (IQR)	57.9 (16)	60.10 (15)	56 (16)
Body Mass index (kg/m^2)			
Mean (SD)	22.49 (4.56)	21.36 (4.12)	23.1 (4.65)
Median (IQR)	22.03 (6.2)	21.02 (5)	22.72 (6.7)
SBP			
Mean (SD)	118.03 (16.32)	117.86 (14.24)	118.18 (17.37)
Median (IQR)	118 (17)	120 (16)	118 (20)
DBP			
Mean (SD)	76.32 (9.69)	76.8 (8.55)	76.03 (10.23)
Median (IQR)	78 (10)	78 (10)	78 (10)
Sleeping Hours (per day)			
Mean (SD)	7.75 (0.86)	7.68 (0.81)	7.78 (0.88)
Median (IQR)	8 (0.0)	8 (0.0)	8 (0.0)

Note: SD: Standard Deviation, IQR: Interquartile Range

Table 2: Socio-demographic and basic background characteristics of the study participants for categorical variables stratified by gender

Socio Categorical Variable	Combined		Male		Female	
	N	%	N	%	N	%
City						
Asmara	401	42.4	128	38.7	273	44.7
Massawa	163	17.3	74	22.4	87	14.2
Mendefera	177	18.7	50	15	127	20.8
Keren	204	21.6	79	23.9	124	20.3
Education						
Illiterate	153	16	26	7.3	127	20.8
Primary	137	14.5	28	8.5	108	17.7
Junior	252	26.7	66	19.9	186	30.4
Secondary	277	29.3	120	36.3	157	25.7
College	123	13	92	27.8	31	5.1
Marital Status						
Married	659	69.7	197	59.5	461	75.5
Widowed	24	2.5	1	0.3	23	3.8
Divorced	25	2.6	1	0.3	24	3.9
Separated	5	0.5	0	0	5	0.8

Single/Never married	226	23.9	131	39.6	95	15.5
Ethnic Group						
Afar	27	2.9	13	3.9	14	2.3
Blen	87	9.2	38	11.5	49	8
Nara	1	0.1	1	0.3		
Saho	29	3.1	8	2.4	20	3.3
Tigre	142	15	76	23	66	10.8
Tigrigna	656	69.4	195	58.9	461	75.5
Exercise						
Yes	172	18.3	119	36.1	53	8.7
No	770	81.7	211	63.9	558	91.3
BMI						
Underweight	141	14.9	59	17.8	82	13.4
Normal weight	534	56.5	209	63.1	324	53
Overweight	207	21.9	53	16	154	25.2
Obese	63	6.7	10	3	51	8.3
Sleeping Hours (per day)						
Less than 6 hours	25	2.6	10	3	15	2.5
6-8 hours	849	89.9	301	90.9	547	89.5
More than 8 hours	62	6.6	13	3.9	49	8

Parameters that Demand Partitioned RI and their Distribution

As per the Harris and Boyd recommendation for the need in partitioning the reference interval by gender four hematological parameters, namely, Eosin, RBC, Hb, and HCT were essentially found to have separate RI (Table 3).

Parameters	Harris and Boyd	More than 8 hours	More than 8 hours
	Z	Z*	Decision
WBCs 10^3/µL	1.59	5.94	Combined
Lymphocytes (%)	2.26	5.94	Combined
Monocytes (%)	2.04	5.94	Combined
Neutrophils (%)	0.12	5.94	Combined
Eosinophils (%)	8.02	5.94	Separate
Basophils (%)	3.48	5.92	Combined RI
RBCs ×10^6/µL	12.99	5.94	Separate RI
HB (g/dl)	17.92	5.94	Separate RI
HCT (%)	15.32	5.94	Separate RI
MCV (fl)	1.62	5.94	Combined RI
MCH (pg)	1.93	5.94	Combined RI
MCHC (g/dl)	1.46	5.94	Combined RI
RDW (%)	0.52	5.94	Combined RI
RDW-SD	0.64	5.94	Combined RI
Platelets × 10^3/µL	2.87	5.93	Combined RI
MPV (fl)	5.21	5.93	Combined RI

To make comparisons with other studies, the reference intervals for all the parameters were computed separately (males and females) as well as the combined data.

Hematological Reference Intervals

Tables 4 and 5 shows the mean (SD), median (IQR), range (minimum to maximum), 95% reference range (2.5^{th} to 97.5^{th} percentile), 95% CI for the lower limit (2.5^{th} percentile), and 95% CI for the upper limit (97.5^{th} percentile).

As per the recommendation of Harris and Boyd, the combined median (2.5^{th} – 97.5thpercentile) for both males and females of WBC, Lym, Mono, Neut, Baso, MCV, MCH, MCHC, RDW, RDW-SD, PLT and MPV were 6.37 (3.02 µL-13.55 µL × 103/µL), 39.34 (21.39%-60.54%), 8.98 (5.18%-14.54%), 49.13 (16.90%-81.98%), 0.22 (0.00%-0.63%), 87.67 (76.58 fl-97.29 fl),27.53 (20.46 pg-32.70 pg), 31.38 (25.20 g/dl-35.30 g/dl), 14.65 (12.70%-18.60%), 41.58 (33.56-54.04), 286.83 (131.62 µL-453.13 µL × 103/µL), and 8.92 (7.28 fL-11.01 fL) respectively.

The parameters that demand separate RI were Eosin, RBC, Hb, and HCT. Their respective median (2.5^{th} – 97.5^{th} percentile) for males versus females were 3.86 (0.29%-16.68%) versus 1.80 (0.20%-6.73%), 5.57 (4.47 µL-7.69 µL × 106/µL) versus 4.97 (3.98 µL-6.38 µL × 106/µL), 15.28 (11.48 g/dl-17.99 g/dl) versus 13.50 (10.74 g/dl-16.54 g/dl), and 48.75 (38.96%-61.17%) versus 43.19 (34.86%-58.60%).

Table 4: Complete descriptive analysis of the hematological parameters along with the 95% reference range (2.5th to 97.5th percentile)

Parameter (Unit)	Gender	N	Mean (SD)	Median (IQR)	Range (Min.-Max.)	2.5th-97.5th Percentile
WBCs 10^3/µL	Male	331	6.63 (2.94)	6.03 (4.58-8.04)	1.68-23.19	2.47-14.18
	Female	611	6.93 (2.47)	6.47 (5.19-8.16)	2.57-18.39	3.35-13.29
	Combined	942	6.83 (2.64)	6.37 (5.01-8.10)	1.68-23.19	3.02-13.55
Lymphocytes (%)	Male	331	38.37 (10.17)	37.95 (30.81-45.72)	13.85-67.13	20.25-60.72
	Female	611	39.95 (10.28)	40.17 (32.18-46.76)	12.34-74.30	21.71-60.54
	Combined	942	39.40 (10.26)	39.34 (31.75-46.34)	12.34-74.30	21.39-60.54
Monocytes (%)	Male	331	9.22(2.97)	9.08 (7.67-10.98)	0.03-16.79	0.13-15.62
	Female	611	8.85 (2.13)	8.62 (7.3-10.02)	4.33-21.50	5.67-13.57
	Combined	942	8.98 (2.44)	8.72 (7.44-10.30)	0.03-21.50	5.18-14.54
Neutrophils (%)	Male	331	49.07 (10.91)	50.30 (41.04-56.81)	21.81-72.87	26.76-67.95
	Female	611	49.16 (11.12)	48.70 (41.12-57.65)	16.90-81.98	26.41-68.95
	Combined	942	49.13 (11.04)	49.16 (41.10-57.02)	16.90-81.98	26.70-68.55
Eosinophils (%)	Male	331	3.86 (4.45)	2.11 (1.00-4.23)	0.03-24.45	0.29-16.68
	Female	611	1.80 (1.85)	1.28 (0.72-2.29)	0.07-15.08	0.20-6.73
	Combined	942	2.52 (3.18)	1.46 (0.80-2.77)	0.03-24.45	0.22-13.23
Basophils (%)	Male	331	0.19 (0.15)	0.16 (0.08-0.28)	0.00-0.68	0.00-0.57
	Female	611	0.23 (0.16)	0.19 (0.11-0.31)	0.00-0.91	0.02-0.67
	Combined	942	0.22 (0.16)	0.18 (0.10-	0.00-0.91	0.00-0.63
RBCs × 10^6/µL	Male	331	5.57 (0.77)	5.45 (5.05-5.88)	3.43-8.16	4.47-7.69
	Female	611	4.97 (0.62)	4.90(4.60-5.27)	3.30-8.77	3.98-6.38
	Combined	942	5.18 (0.73)	5.06 (4.7-5.51)	3.30-8.77	4.02-7.19
HB (g/dl)	Male	331	15.28 (1.51)	15.42 (14.35-16.13)	8.97-22.46	11.48-17.99
	Female	611	13.50 (1.42)	13.49 (12.72-14.27)	6.92-22.89	10.74-16.54
	Combined	942	14.13 (1.68)	13.98 (13.08-15.17)	6.92-22.89	11.03-17.62
HCT (%)	Male	331	48.75 (5.44)	48.5 (45.00-51.8)	32.6-66.5	38.96-61.17
	Female	611	43.19 (5.09)	42.9 (40.5-45.5)	5.2-70.5	34.36-54.74
		942	45.15 (5.85)	44.4 (41.5-48.5)	5.2-70.5	34.86-58.60

Table 5: Complete descriptive analysis of the hematological parameters along with the 95% reference range (2.5^{th} to 97.5^{th} percentile)

Female	Gender	N	Mean (SD)	Median (IQR)	Range (Min.-Max.)	2.5th-97.5th Percentile
MCV (fl)	Male	331	88.04 (5.66)	88.60 (85.5-91.00)	57.90-111.90	76.72-98.57
	Female	611	87.46 (5.05)	87.70 (84.70-90.60)	59.4-104.3	76.5-96.68
	Combined	942	87.67 (5.27)	88.00 (85.00-90.08)	57.9-111.9	76.56-97.29
MCH (pg)	Male	331	27.83 (3.82)	28.80 (26.40-30.10)	14.6-39.8	19.90-33.60
	Female	611	27.37 (2.81)	28.10(26.50-29.10)	14.8-33.5	20.79-31.30
	Combined	942	27.53 (3.21)	28.30 (26.50-29.40)	14.6-39.8	20.46-32.70
MCHC (g/dl)	Male	331	31.55 (3.13)	32.40 (31.50-33.30)	24.9-36.4	25.30-35.90
	Female	611	31.82 (2.35)	32.10(31.50-32.50)	24.5-34.9	25.10-33.50
	Combined	942	31.38 (2.65)	32.2 (31.50-32.70)	24.5-36.4	25.20-35.30
RDW (%)	Male	331	14.96 (2.06)	14.10 (13.40-15.40)	12.4-31.1	12.70-19.58
	Female	611	14.62 (1.53)	14.30(13.60-15.30)	11.7-22.6	12.63-18.57
	Combined	942	14.65 (1.74)	14.20 (13.50-15.30)	11.7-31.1	12.70-18.60
RDW-SD	Male	331	41.74 (5.91)	41.20 (37.80-44.60)	4.0-69.6	34.20-55.54
	Female	611	41.49 (5.46)	40.90 (37.40-44.90)	31.5-77.2	33.33-53.27
	Combined	942	41.58 (5.62)	41.00 (37.60-44.70)	4.0-77.2	33.56-54.04
Platelets × 10 /µL	Male	331	277.2 (68.89)	274.3 (232.45-320)	68.3-559.7	151.05-405.7
	Female	611	292.02(85.66)	285.1 (241.05-350)	17.1-541.0	117.8-467.38
	Combined	942	286.8 (80.45)	281.2 (236.85-338.63)	17.1-559.7	131.62-453.13
MPV (fl)	Male	331	8.69 (1.04)	8.66 (8.03-9.39)	0.00-11.88	7.03-10.66
	Female	611	9.04 (0.96)	8.95 (8.32-9.66)	7.12-12.88	7.48-11.17
		942	8.92 (1.00)	8.84 (8.24-9.58)	0.00-12.88	7.28-11.01

Correlation of the Hematological Parameters with the Continuous Background

The continuous background that found to have significant correlation with the hematological parameters is age, height, weight, BMI, SBP and DBP as shown in **Table 6**.

Table 6: Spearman's correlation of the hematological parameters with the continuous background

Parameters	Age	Height	Weight	BMI	SBP	DBP
	r (p-value)	r (p-value)	r (p-value)	r (p-value)	r (p-value)	r (p-value)
WBCs 10^3/µL	0.049 (0.134)	-0.108**(0.001)	0.042 (0.202)	0.118*** (<0.001)	0.087** (0.008)	0.071* (0.030)
Lymphocytes (%)	0.059 (0.069)	-0.078* (0.017)	-0.013 (0.697)	0.024 (0.458)	0.072* (0.029)	0.117*** (<0.001)
Monocytes (%)	0.025 (0.448)	0.812 (0.051)	-0.135*** (<0.001)	-0.130*** (<0.001)	0.048 (0.144)	0.047 (0.156)
Neutrophils (%)	-0.042 (0.196)	0.051 (0.119)	0.045 (0.164)	0.029 (0.381)	-0.056 (0.087)	-0.101** (0.002)
Eosinophils (%)	-0.124*** (<0.001)	0.170*** (<0.001)	0.031 (0.342)	-0.074* (0.024)	-0.068* (0.039)	-0.045 (0.168)
Basophils (%)	0.149*** (<0.001)	-0.105 (0.001)	-0.009 (0.792)	0.054 (0.1)	0.039 (0.232)	-0.019 (0.572)
RBCs × 10^6/µL	-0.127*** (<0.001)	0.253*** (<0.001)	0.070* (0.032)	-0.061 (0.062)	0.031(0.339)	0.074* (0.025)
HB (g/dl)	-0.144*** (<0.001)	0.417*** (<0.001)	0.189*** (<0.001)	-0.041 (0.214)	0.022 (0.501)	0.047 (0.151)
HCT (%)	-0.127*** (<0.001)	0.331*** (<0.001)	0.066* (0.044)	-0.102** (0.002)	0.027 (0.404)	0.048 (0.142)
MCV (fl)	0.017 (0.603)	0.077* (0.018)	-0.012 (0.703)	-0.058 (0.077)	-0.028 (0.389)	-0.083* (0.011)
MCH (pg)	-0.038 (0.239)	0.172*** (<0.001)	0.078* (0.017)	-0.025 (0.438)	-0.022 (0.498)	-0.047 (0.156)
MCHC (g/dl)	`0.075* (0.021)	0.208*** (<0.001)	0.116*** (<0.001)	-0.007 (0.827)	-0.007 (0.828)	0.01 (0.763)
RDW (%)	0.047 (0.152)	-0.108** (0.001)	-0.193*** (<0.001)	-0.132*** (<0.001)	0.027 (0.408)	0.059 (0.071)
RDW-SD	0.04 (0.222)	-0.059 (0.07)	-0.228*** (<0.001)	-0.197*** (<0.001)	-0.009 (0.788)	-0.008 (0.818)
Platelets × 10^3/µL	-0.096** (0.003)	-0.082* (0.012)	-0.006 (0.847)	0.046 (0.158)	-0.03 (0.360)	-0.061 (0.063)
MPV (fl)	0.093** (0.004)	-0.102** (0.002)	0.080* (0.015)	0.145*** (<0.001)	0.038 (0.247)	0.035 (0.289)

DISCUSSION

The purpose of this study was to determine the hematological reference ranges of Eritrean healthy adults, identify factors that influence these values, and compare them to international and neighboring country values. In our study, Eritrean total white blood cell counts were similar to Caucasians, but we found an increased lymphocyte count and a decreased neutrophil count in comparison to Caucasians [8,9]. These findings are in contrast to the study carried out by Chen et al. who found that White subjects had a significantly higher WBC count in all age groups in comparison to black subjects [10]. Many African Americans have WBCs that are persistently below the normal range for people of European descent, a condition called benign ethnic Neutropenia. David et al. explained that neutropenia in Africans is due to a regulatory variant in the Duffy antigen receptor for the chemokines gene [11]. In our study, we found that Eritreans had higher hematocrit levels, higher hemoglobin levels, and higher RBCs than Caucasian and Africans. We hypothesized that the cause for this difference is likely due to altitude deference and Nutritional behavior; which is one of the factors affecting Hb and RBCs indices, Injera is the most important component of food in Eritrea. Teff is the main ingredient in injera, Teff is rich in carbohydrates, and fiber and has a complete set of essential amino acids. Teff is also particularly high in iron and has more calcium, copper, and zinc than other cereal grains in this regard, Alaunyte stated that The high Fe content of teff is reflected by the low prevalence of anemia in places where the teff grain is predominantly consumed [12,13].

The study made by Mohammed in pregnant Ethiopian women revealed that a decrease in the frequency of teff consumption was significantly associated with an increase in the likelihood of anemia [14]. We found significant gender effects on the CBC. Female participants had higher WBC, Lym, Baso, PLT, and MPV. while males had higher Mono, Eosin, RBC, HB, HCT, MCV, MCH, and MCHC The reasons for these differences have been attributed to factors such as the influence of the androgen hormone on erythropoiesis and decreased metabolic demand, decreased muscle mass, and lower iron stores due to menstruation in females, In this regard our findings are in agreement with previous studies [15-17].

In a recent study, Bachman et al. reported significantly increased erythropoietin levels and decreased ferritin and hepcidin with testosterone administration [18]. Interestingly, exogenous testosterone was used initially as a treatment for anemia. The American practice guideline on testosterone therapy recommends against the use of testosterone in patients with a hematocrit above 50%. In support of our findings of significantly increased Monocytes in males, many studies showed a decrease in the number of Monocytes when estrogen level is high [19-21]. A new study by Thiago et al. reveals testosterone administration in men increases Monocyte counts [22]. Our results agree with those from a recent study by Hartlet et al. found that Eosinophil is higher in males than in females in all age groups [23]. In this study, the mean WBCs, MPV, PLT, and Baso were significantly higher for women than men. Rukia in their study found that the women had higher white blood cell and platelet counts compared to men, which agrees with our findings [24]. Whereas Kaya have found significantly higher WBCs in men compared to females which are inconsistent with our findings [25]. The significant increase in platelet count and MPV in females might be due to the effect of estrogen on Megakaryopoiesis and platelet production according to previous research [26-28]. Our study also indicated that the variation among the data sets for Eosin, Baso, hemoglobin, RBC, and

HCT of the four age groups was statistically significant. In the present study we found that with an increase in age, there is a significant increase in Baso. The present results are consistent with previous studies [29,30]. Other reports show no age-related changes in Basophile count [31]. The effects of aging on basophil must be explained by many mechanisms. First, aging increases basophil sensitivity to anti-IgE and IgE-mediated release ability of histamine [32]. Second, with aging, gut microbiota composition changes [33]. Basophil hematopoiesis and function are regulated by gut microbiota. The absence of gut microbiota leads to increased. Basophil frequencies however, with an increase in age, a significant decrease in RBC, HB, HCT, and PLT was observed [34]. Similar results have been reported by Isabel in their study MCV, MCH, and RDW showed a significant positive correlation with age, hemoglobin, hematocrit, RBC, and platelet count showed a significant negative correlation [35]. With the aging process the amount of growth hormone secreted declines, it is commonly believed that growth hormone stimulates erythropoiesis by increasing the oxygen consumption of tissues and thereby promoting tissue hypoxia, which in turn accelerates erythropoietin production by the kidneys [36]. Another hypothesis concerning the mechanisms that are responsible for the age-related changes of reduction may reflect a reduction in hematopoietic stem cell reserve during aging [37]. Therefore, there is a definite need to introduce age-specific reference ranges.

AUTHOR CONTRIBUTION

Project administration, methodology review and editing were contributed by Ahmed O Noury, OA. Musa and Elmuiz. Data collection were contributed by Ahmed O Noury, Barakat, Daniel, Zekarias, Omer, Efrem and Filmon Data analysis and interpretation were contributed by Ahmed O Noury and Eyasu H Tesfamariam. Manuscript writing was contributed by Ahmed O Noury. Final approval of manuscript was contributed by all authors. All authors read and approved the final manuscript.

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AVAILABILITY OF DATA AND MATERIALS

Data supporting this study are included within the article.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The Eritrean Ministry of Health's ethics committee granted ethical approval for this study.

CONSENT FOR PUBLICATION

All authors have agreed to publish this manuscript.

COMPETING INTEREST

The authors declare no competing interests

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