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Reference intervals for hematology test parameters from apparently healthy individuals in southwest Ethiopia

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Abstract

Background: Clinical laboratory reference intervals are an important tool to identify abnormal laboratory test results. The generating of hematological parameters reference intervals for local population is very crucial to improve quality of health care, which otherwise may lead to unnecessary expenditure or denying care for the needy. There are no well-established reference intervals for hematological parameters in southwest Ethiopia.

Objective: To generate hematological parameters reference intervals for apparently healthy individuals in southwest Ethiopia.

Methods: A community-based cross-sectional study was conducted involving 883 individuals from March to May 2017. Four milliliter of blood sample was collected and transported to Jimma University Medical Center Laboratory for hematological analysis and screening tests. A hematological parameters were measured by Sysmex XS-500i hematology analyzer (Sysmex Corporation Kobe, Japan). The data were analyzed by SPSS version 20 statistical software. The non-parametric independent Kruskal–Wallis test and Wilcoxon rank-sum test (Mann–Whitney U test) were used to compare the parameters between age groups and genders. The 97.5 percentile and 2.5 percentile were the upper and lower reference limit for the population.

Results: The reference interval of red blood cell, white blood cell, and platelet count in children were 4.99×10^{12}/L (4.26–5.99×10^{12}/L), 7.04×10^{9}/L (4.00–11.67×10^{9}/L), and 324.00×10^{9}/L (188.00–463.50×10^{9}/L), respectively. The reference interval of red blood cell, white blood cell, and platelet count in adults was 5.19×10^{12}/L (4.08–6.33×10^{12}/L), 6.35×10^{9}/L (3.28–11.22×10^{9}/L), and 282.00×10^{9}/L (172.50–415.25×10^{9}/L), respectively. The reference interval of red blood cell, white blood cell, and platelet count in geriatrics were 5.02×10^{12}/L (4.21–5.87×10^{12}/L), 6.21×10^{9}/L (3.33–10.03×10^{9}/L), and 265.50×10^{9}/L (165.53–418.80×10^{9}/L), respectively. Most of the hematological parameters showed significant differences across all age groups.

Conclusion: Most of the hematological parameters in this study showed differences from similar studies done in the country. This study provided population-specific hematological reference interval for southwest Ethiopians. Reference intervals should also be established in the other regions of the country.

Keywords

Reference interval, hematological parameters, southwest Ethiopian

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Introduction

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] A RI is defined by threshold values between which the test results of a specified percentage (usually 95%) of apparently healthy individuals would fall.[2] RIs are very useful to provide medical information that ensures correct medical decisions. As laboratory results are interpreted in comparison with these intervals, the reliability of the RI can play major role in result interpretation and as a measure of quality of the result itself.[3,4]

The Clinical and Laboratory Standards Institute (CLSI) recommends that RIs should be established for each region and specific populations.[5] The characteristics of the population in which the reference range is determined and the population to which it is applied must be compatible.[6] Hematological tests are done routinely and are useful in the diagnosis of many diseases as well as in the investigation of the extent of damage to blood.[7] Hematologic RIs have been established long ago for Caucasian population in Europe and North America. Most low- and middle-income countries are adopting these RIs for their own consumption without considering the potential difference between localities and populations.[8] RIs for hematology parameters are often influenced by individual variables such as race, age, and gender; dietary habits, exposure to pathogens, ecological factors; condition of assay, variations in instrumentation techniques and laboratory personnel.[9]

Lack of appropriate local hematological parameters RI is a challenge in interpreting results for patient management and other decision-making. Use of inappropriate RI may increase the risk of unnecessary additional investigations, failure to detect underlying disease and mismanagement of patients.[10] The RIs for African countries indicated in the literatures are different from values quoted in accompanying manual or western countries due to many reasons. A study in Ghana reported a fallacy in using the previous RI as opposed to the locally generated one, pointing that 53% of potential study participants would have been declared as having abnormal results.[11–18] Compared to white communities, blacks show significantly lower total white blood cell (WBC) count, neutrophil counts, platelet (PLT) counts, hematocrit (Hct), mean cell hemoglobin concentration (MCHC), mean cell hemoglobin (MCH), and hemoglobin (Hb) and significantly higher mononuclear and lymphocyte percentage.[9] The lower limit of the RI of Hb, Hct, mean cell volume (MCV), and PLT counts for the Ugandan children was found to be less than the conventional RI of Caucasian children while the lower limit of WBC count was higher.[19]

In Ethiopia, a country with heterogeneous population and diverse geographic variability, there is no nationally established RI for hematological parameters, although few attempts have been made to determine hematological RI in some populations.[20–22] A recent study done in Gojjam zones in Amhara region, Ethiopia, indicated that some of the hematological RIs of healthy adults showed variations with the reference ranges used and reported so far in Ethiopia, Africa, and Western countries.[21]

Although those studies done in different parts of Ethiopia were not comprehensive, they indicated the presence of variations in the RIs and recommended further studies to be done across the country. Moreover, the hematological RIs which are currently used in the country are adopted from textbooks which are not representative of the populations. Therefore, this study aimed to generate hematological parameter RIs in apparently healthy individuals living in southwest Ethiopia.

Materials and methods

Study setting

A community-based cross-sectional study was conducted in southwest Ethiopia from March to May 2017. The sample size was determined according to the CLSI recommendation to use well-defined exclusion and portioning criteria for the selection of the reference individuals. Thus, based on this guideline, the minimum sample size required for RI determination would be 120 healthy individuals for each partitioning.[5] However, according to previous large-scale studies in other African countries, about 30%[23] did not qualify for RI determination for various reasons when tested for the common viral infections and inflammation. Based on this finding, we aimed to recruit 1030 individuals to achieve a minimum sample size of 720, that is, $30\% \times 1030 = 309$ which is $1030 - 309 = 721$. However, we could only recruit 998 participants; 12% (N = 115) of these were excluded with post-exclusion criteria. Finally, the actual sample size used for final analysis was 883. Non-probability convenience sampling technique was used to recruit volunteers from schools, university students, employees, pensioners, and other volunteers residing in three towns (Jimma, Mizan, and Bonga) in southwest Ethiopia.

Apparently healthy individuals aged 5 years and above who have lived in the study areas for more than 1 year were included in the study. We excluded individuals who had a positive result from the screening tests (C-reactive protein (CRP), hepatitis B surface antigen (HBsAg), anti-hepatitis C virus (HCV) antibody). In addition, individuals with known acute and chronic diseases; known history of hematologic disorders; recent history of blood loss; blood donation in the last 6 months; blood transfusion in the previous year; immunization in the last 6 months; major surgical procedures in the past 6 months; those taking pharmacologically active agents including oral contraceptives; replacement or supplementation therapy such as insulin; smokers; and pregnant women were also excluded.

Operational definitions

Apparently healthy: An individual who has no sign and symptoms and history for any disease and negative result for the screening tests.

A pensioner: A person who collects a pension, most commonly because of retirement from the government job.

RI: The 95 percentile interval between the 97.5 percentile and 2.5 percentile which form the upper and lower reference limit.

Other volunteers: Individuals who wanted to participate in the study for the purpose of health checkup.

Data collection and analysis

A structured, pre-tested questionnaire was used to collect socio-demographic characteristics. Anthropometric measurements (height and weight) and related physical examination data like blood pressure were taken using calibrated equipment's and standardized techniques on site. Physical examinations and interviews were done by a trained clinical nurse.

Four milliliter of venous blood sample was collected in ethylenediaminetetraacetic acid (EDTA) vacutainer tubes and transported to Jimma University Medical Center (JUMC) laboratory for hematological analysis and screening tests. Hematological analysis was done by Sysmex XS-500*i* hematology analyzer (Sysmex® Corporation Kobe, Japan). CRP was determined by a qualitative method, HumaTex CRP testes (Human, Germany). Hepatitis B virus was screened by One Step HBsAg test and HCV was screened by One Step HCV antibody (Guangzhou Wondfo Biotech Co., Ltd, China).

Quality control

To ensure the quality of data, training was given to data collectors prior to data collection. We used a standard operating procedure (SOP) for pre-analytical, analytical, and post-analytical procedures implemented during hematological tests measurement. All samples were analyzed in one laboratory (Jimma University Medical Center Laboratory) with the same hematology analyzer and the same trained professionals. For Sysmex XS-500*i* hematology analyzer, daily initialization background check, three levels (tri level) of commercially available whole blood quality control material (high, normal, and low) used to check the analytical capability of the machine daily on startup. Repeated analysis of randomly selected specimens for reproducibility check (delta check) was carried out to evaluate instrument performance consistently and accurately. Moreover, this laboratory had >95% of the acceptability limit of the external assessor.

Data analysis

All the data were coded and checked for completeness, then entered to Epidata, and analyzed using SPSS version 20 statistical software for windows. The data were tested for normality of its distribution by Kolmogorov–Smirnov; most of the RI parameters were not normally distributed. Therefore, the nonparametric methods for determination of RI were used as recommended by CLSI.[5] Median, central 95 percentile, and 95% confidence interval (CI) were calculated. The 97.5 percentile and 2.5 percentile were the upper and lower reference limit for the population. The significant difference between sex among age groups was determined using Wilcoxon rank-sum test (Mann–Whitney U test) and significance difference among age groups between sex was determined using independent Kruskal–Wallis test. P value < 0.05 was considered as statistically significant.

Table 1. Socio demographic characteristic of study participants in southwest Ethiopian.

Variable	Socio demographic characteristic	Frequency	Percentage (%)
Sex	Male	430	48.7
	Female	453	51.3
Age group	Children	334	37.8
	Adult	289	32.7
	Geriatrics	260	29.5
Educational status	Illiterate	3	0.3
	Read and write	3	0.3
	Primary	418	47.4
	Secondary	133	15.1
	College/university	326	36.9

Ethical considerations

Ethical clearance was obtained from Jimma University, Institute of Health Ethical Review Board. Support letter from Health Research and Postgraduate director's office was written to the concerned body and the permission was obtained from concerned offices. A written informed consent was obtained from the study participants and in case of school children from their parents or guardians. The data were kept confidential through anonymity. The specimens collected from the participants were analyzed only for the intended purposes. Those study participants who had the abnormal laboratory test result during the screening process were referred to the clinician for proper treatment, counseling, and management according to their specific disease condition.

Results

Socio demographic characteristics

A total of 883 (334 children, 289 adults, and 260 geriatrics) study participants were included in the final statistical analysis for hematological RI estimation. From these, 430 were males and 453 were females. The mean age of the study participants was 27.61 ± 18.5 years (male $= 28.5 \pm 18.9$ and female $= 26.7 \pm 18$), with range of 5–71 years (Table 1).

Table 2. Median and 95% RI values of hematological parameters in relation to sex for healthy southwest Ethiopian children.

Parameter	Sex	Unit	N	Median	Min	Max	95%		P-value
							2.5	97.5	
WBC	M	10^9/L	152	7.05	3.29	14.10	4.04	11.72	0.933
	F	10^9/L	182	7.02	3.21	12.18	3.74	11.42	
RBC	M	10^{12}/L	152	5.04	3.48	8.28	4.06	6.57	0.177
	F	10^{12}/L	182	4.96	3.49	6.61	4.32	5.63	
Hb	M	g/L	152	141.0	111.0	208.0	120.4	196.0	0.409
	F	g/L	182	140.0	97.0	182.0	115.7	159.4	
Hct	M	%	152	41.40	33.1	60.6	35.60	55.19	0.820
	F	%	182	41.50	31.3	52.7	35.97	46.92	
MCV	M	fl	152	82.35	72.1	95.5	75.03	93.01	0.104
	F	fl	182	83.20	69.4	94.3	74.51	91.08	
MCH	M	pg	152	27.95	24.2	32.0	25.18	31.05	0.675
	F	pg	182	28.0	21.5	31.7	25.08	30.8	
MCHC	M	g/L	152	340.0	315.0	364.0	321.0	362.0	0.073
	F	g/L	182	338.0	310.0	368.0	320.7	354.4	
PLT	M	10^9/L	152	326.5	122.0	494.0	158.5	469.9	0.834
	F	10^9/L	182	321.0	110.0	483.0	197.7	460.4	
RDW-CV	M	%	152	13.85	12.30	18.80	12.70	16.07	0.021*
	F	%	182	13.70	9.40	19.30	12.30	15.97	
Neutrophil	M	10^9/L	152	3.34	0.90	8.71	1.26	7.39	0.633
	F	10^9/L	182	3.41	0.80	8.31	1.00	6.99	
Lymphocyte	M	10^9/L	152	2.62	1.00	4.86	1.50	4.25	0.501
	F	10^9/L	182	2.60	1.15	4.78	1.41	4.47	
Monocyte	M	10^9/L	152	0.54	0.17	1.61	0.27	1.05	0.431
	F	10^9/L	182	0.53	.22	1.47	0.27	1.06	
Eosinophil	M	10^9/L	152	0.43	0.04	1.81	0.048	1.49	0.370
	F	10^9/L	182	0.36	.02	1.96	0.055	1.31	
Basophil	M	10^9/L	152	0.02	0.0	0.07	0.01	0.051	0.220
	F	10^9/L	182	0.02	0.0	0.4	0.01	0.06	

RI: reference interval; WBC: white blood cell; RBC: red blood cell; Hb: hemoglobin; Hct: hematocrit; MCV: mean corpuscular volume; MCH: mean corpuscular hemoglobin; MCHC: mean corpuscular hemoglobin concentration; PLT: platelet; RDW-CV: red cell distribution width-coefficient of variation; M: male; F: female; N: number of participants.
*$P < 0.05$ by (Mann–Whitney U test) for comparison of medians between genders.

Hematological RI for children

A total of 334 children participated in this study. The median and 95% RI of RBC count, Hb concentration, WBC count, and PLT count for these age groups were as follows: 5.04×10^{12}/L ($4.06–6.57 \times 10^{12}$/L), 141 g/L (120–196 g/L), 7.05×10^9/L ($4.04–11.72 \times 10^9$/L), and 326.5×10^9/L ($158.5–469.9 \times 10^9$/L), respectively, for males and 4.96×10^{12}/L ($4.32–5.63 \times 10^{12}$/L), 140 g/L (115.7–159.4 g/L), 7.02×10^9/L ($3.74–11.42 \times 10^9$/L), and 321×10^9/L ($197.7–460.4 \times 10^9$/L), respectively, for females (Table 2).

Hematological RI for adults

There were 289 adults in our study. In adult age group, males had higher value of most of the RBC parameters. The median RIs of RBC count, Hb concentration, and Hct in males were 5.32×10^{12}/L ($4.26–6.68 \times 10^{12}$/L), 155 g/L (120.6–187.6 g/L), and 45.2% (36.7%–54.5%), respectively. In females, these were 5.02×10^{12}/L ($4.02–6.15 \times 10^{12}$/L), 146 g/L (123–178.6 g/L), and 43.1% (36.8%-51.5%), respectively. Similarly, the median eosinophil count for males, 0.28×10^9/L (0.05–1.21×10^9/L), was significantly higher than the corresponding value for females, 0.22×10^9/L (0.04–1.12×10^9/L) ($P = 0.011$). The median RI for WBC count did not show significant difference between sexes: 6.36×10^9/L (3.31–11.62×10^9/L) and 6.34×10^9/L (3.24–10.05×10^9/L) for males and females, respectively ($P = 0.826$). On the other hand, the median RI of MCV and PLT values in males, 84.3 fl (74.8–93.8 fl) and 275×10^9/L (164–403.4×10^9/L), respectively, were lower than the females, 86.15 fl (77.3–98.8 fl) and 288×10^9/L (202.3–444.5×10^9/L) (Table 3).

Hematological RI for geriatrics

A total of 260 geriatrics took part in the study. In geriatric age group, males had higher median and 95% RI for

Table 3. Median and 95% RI values of hematological parameters in relation to sex for healthy southwest Ethiopian adults.

Parameter	Sex	Unit	N	Median	Min	Max	95%		P-value
							2.5	97.5	
WBC	M	10^9/L	143	6.36	2.66	12.14	3.31	11.62	0.826
	F	10^9/L	146	6.34	2.86	13.22	3.24	10.05	
RBC	M	10^{12}/L	143	5.32	3.26	8.00	4.26	6.68	0.000*
	F	10^{12}/L	146	5.02	3.67	6.75	4.02	6.15	
Hb	M	g/L	143	155.0	111.0	233.0	120.6	187.6	0.001*
	F	g/L	146	146.0	91.0	190.0	123.0	178.6	
Hct	M	%	143	45.2	34.2	65.40	36.72	54.48	0.001*
	F	%	146	43.1	30.4	56.10	36.86	51.59	
MCV	M	fl	143	84.3	57.9	111.3	74.8	93.94	0.003*
	F	fl	146	86.15	70.7	114.2	77.3	98.82	
MCH	M	pg	143	29.0	18.8	38.0	24.86	32.84	0.098
	F	pg	146	29.4	21.20	39.90	26.3	33.58	
MCHC	M	g/L	143	343.0	303.0	370.0	320.6	365.0	0.084
	F	g/L	146	339.5	299.0	368.0	320.0	360.0	
PLT	M	10^9/L	143	275.0	134.0	637.0	164.0	403.4	0.021*
	F	10^9/L	146	288.0	144.0	508.0	202.3	444.5	
RDW-CV	M	%	143	13.7	12.1	21.0	12.46	17.56	0.032*
	F	%	146	13.6	12.1	27.3	12.4	15.59	
Neutrophil	M	10^9/L	143	3.3	0.69	7.96	1.01	7.22	0.760
	F	10^9/L	146	3.3	0.57	9.29	1.08	6.69	
Lymphocyte	M	10^9/L	143	2.14	0.84	4.26	1.1	3.84	0.462
	F	10^9/L	146	2.16	0.86	4.73	1.2	3.98	
Monocyte	M	10^9/L	143	0.48	0.19	1.1	0.24	0.88	0.865
	F	10^9/L	146	0.48	0.23	1.12	0.27	0.87	
Eosinophil	M	10^9/L	143	0.28	0.03	1.53	0.05	1.21	0.011*
	F	10^9/L	146	0.22	.02	1.38	0.04	1.12	
Basophil	M	10^9/L	143	0.02	0.0	0.07	0.01	0.05	0.190
	F	10^9/L	146	0.02	0.0	0.07	0.0	0.05	

RI: reference interval; WBC: white blood cell; RBC: red blood cell; Hb: hemoglobin; Hct: hematocrit; MCV: mean corpuscular volume; MCH: mean corpuscular hemoglobin; MCHC: mean corpuscular hemoglobin concentration; PLT: platelet; RDW-CV: red cell distribution width-coefficient of variation; M: male; F: female; N: number of participants.
*$P < 0.05$ by (Mann–Whitney U test) for comparison of medians between genders.

hematological parameters than females, RBC count 5.16×10^12/L ($4.25–5.99 \times 10^{12}$/L) versus 4.92×10^{12}/L ($3.91–5.72 \times 10^{12}$/L) ($P < 0.001$), Hb of 151 g/L (126.4–179 g/L) versus 142 g/L (119.1–177.8 g/L) ($P < 0.001$), and Hct of 44.5% (38.3%–52.4%) versus 42.6 (36.2–51.4) ($P < 0.001$). The other hematological parameters show no significant difference between male and female ($P > 0.05$) (Table 4).

Comparison of hematological parameters between age groups by sex

Independent Kruskal–Wallis test was used to compare the distribution of hematological parameters between age groups by sex (Table 5). There were statistically significant differences between children and adult age groups; adults had higher RBC count, Hb concentration, Hct value, and MCV in males and Hb, Hct, and MCV in females. Similarly, significant difference was observed between children and geriatrics age groups in Hb concentration and Hct value in both sexes. Adult male had higher median value of RBC and MCV than geriatric males. Adult females had higher median RBC count and Hb concentration than female geriatrics.

There were statistically higher WBC, lymphocyte, monocyte, and eosinophil count in children than adult and geriatrics in both sexes. Except for eosinophils in male study participants, none of the values for the WBC subset showed any differences between the adults and the geriatrics. There were significant differences in PLT counts between all age groups in both sexes. PLT counts declined steadily with age increment.

Discussion

A community-based cross-sectional study was conducted to determine hematological RIs for southwest Ethiopian. Most of

Table 4. Median and 95% RI values of hematological parameters in relation to sex for healthy southwest Ethiopian geriatrics.

Parameter	Sex	Unit	N	Median	Min	Max	95%		P-value
							2.5	97.5	
WBC	M	10^9/L	135	6.59	2.70	13.54	3.18	10.18	0.108
	F	10^9/L	125	6.09	2.77	11.12	3.34	9.98	
RBC	M	10^{12}/L	135	5.16	3.9	6.28	4.25	5.99	0.000*
	F	10^{12}/L	125	4.92	3.72	5.82	3.91	5.72	
Hb	M	g/L	135	151.0	124.0	184.0	126.4	179.0	0.000*
	F	g/L	125	142.0	109.0	184.0	119.1	177.8	
Hct	M	%	135	44.5	37.8	57.7	38.34	52.46	0.000*
	F	%	125	42.6	33.9	52.9	36.27	51.41	
MCV	M	fl	135	87.8	70.8	98.5	79.34	97.08	0.220
	F	fl	125	87.0	72.7	103.0	77.13	99.31	
MCH	M	pg	135	29.6	25.6	34.1	26.62	32.56	0.136
	F	pg	125	29.3	23.0	37.4	25.21	34.1	
MCHC	M	g/L	135	338.0	314.0	363.0	319.0	356.8	0.125
	F	g/L	125	335.0	310.0	363.0	314.3	358.8	
PLT	M	10^9/L	135	262.0	43.0	423.0	145.4	399.2	0.152
	F	10^9/L	125	273.0	148.0	477.0	182.0	439.5	
RDW-CV	M	%	135	14.0	11.6	16.9	12.6	15.5	0.972
	F	%	125	14.0	12.6	21.2	12.81	17.93	
Neutrophil	M	10^9/L	135	3.27	0.75	9.49	1.13	6.53	0.180
	F	10^9/L	125	3.01	0.89	7.38	1.06	5.62	
Lymphocyte	M	10^9/L	135	2.25	0.30	4.18	0.96	3.74	0.631
	F	10^9/L	125	2.28	1.13	5.23	1.22	3.94	
Monocyte	M	10^9/L	135	0.48	0.23	0.86	0.24	0.84	0.330
	F	10^9/L	125	0.48	0.17	1.01	0.21	0.87	
Eosinophil	M	10^9/L	135	0.23	0.02	1.77	0.04	1.15	0.634
	F	10^9/L	125	0.22	0.01	1.53	0.05	1.03	
Basophil	M	10^9/L	135	0.02	0.0	0.08	0.004	0.06	0.224
	F	10^9/L	125	0.02	0.0	.150	0.001	0.078	

RI: reference interval; WBC: white blood cell; RBC: red blood cell; Hb: hemoglobin; Hct: hematocrit; MCV: mean corpuscular volume; MCH: mean corpuscular hemoglobin; MCHC: mean corpuscular hemoglobin concentration; PLT: platelet; RDW-CV: red cell distribution width-coefficient of variation; M: male; F: female; N: number of participants.

* $P < 0.05$ by (Mann–Whitney U test) for comparison of medians between genders.

the hematological parameters showed significant differences across all age groups. However, significant differences by gender were not detected for many of the indices in children.

Adults have higher RBC count, Hb concentration, and Hct values than children in males and higher Hb and Hct in females. It could be due to the gradual increase of Hb and RBC throughout the childhood age to reach almost adult levels by puberty. Thus, with the aging process, modest changes in RBC mass may occur in adults.[24,25]

In the present study, there was no significant difference between genders in the children's age groups with regard to RBC count, Hb concentration, and Hct value ($P > 0.05$) which is similar to other previous reports from Tanzania and Uganda.[26,27] On the other hand, male study participants had higher values in RBC count, Hb concentration, and Hct value than female study participants in adults. The lower values in reproductive age women might be due to menstrual bleeding. This difference might also be due to the fact that a direct stimulatory effect of androgen on erythropoietin production in the kidney in adult men, and an inhibitory effect of estrogen on the bone marrow in women. Apart from a hormonal influence on hemopoiesis, iron deficiency is likely to be a factor influencing the difference in which menstrual blood loss may lead to iron depletion in women.[25,28]

Our finding has revealed higher RBC count, Hb concentration, and Hct value RI and lower MCV in adults than the findings in Caucasians and other African countries.[11,22,29,30] The median values in adult males in this study for Hb concentration and Hct value were lower as compared with a study done in Akaki, Ethiopia,[21] and Gojjam, Ethiopia[22] which may be due to difference in altitude of the study area. The effect of altitude is to reduce plasma volume, increase the Hb concentration and Hct value, and raise the number of circulating red cells with a lower MCV. These differences appear to be the result of both increased erythropoiesis which is secondary to the hypoxic stimulus and the decrease in plasma volume that occurs at high altitudes.[25]

Table 5. Independent Kruskal–Wallis test to compare the distribution RI of hematological parameters between age groups by sex for southwest Ethiopians.

Age group	Sex		WBC	RBC	Hb	Hct	MCV	MCH	MCHC	PLT	RDW-CV	Neutrophil	Lymphocyte	Monocyte	Eosinophil	Basophil
Children's and adult	Male	Chi-square	11.453	26.708	50.264	52.357	19.648	30.732	7.387	21.816	2.245	0.968	35.972	10.459	5.213	0.017
		df	1	1	1	1	1	1	1	1	1	1	1	1	1	1
		Asymp. sig.	0.001	0.000	0.000	0.000	0.000	0.000	0.007	0.000	0.134	0.325	0.000	0.001	0.022	0.895
	Female	Chi-square	12.276	1.713	34.926	35.313	37.715	54.096	4.788	17.746	2.585	1.269	25.785	10.584	19.604	5.884
		df	1	1	1	1	1	1	1	1	1	1	1	1	1	1
		Asymp. sig.	0.000*	0.191	0.000*	0.000*	0.000*	0.000*	0.029*	0.000*	0.108	0.260	0.000*	0.001*	0.000*	0.015*
Adults and geriatrics	Male	Chi-square	0.532	11.756	3.779	0.552	30.943	6.455	19.264	3.696	6.557	0.201	2.921	0.731	4.623	1.469
		df	1	1	1	1	1	1	1	1	1	1	1	1	1	1
		Asymp. sig.	0.466	0.001	0.052	0.458	0.000	0.011	0.000	0.055	0.010	0.654	0.087	0.393	0.032	0.226
	Female	Chi-square	1.061	4.937	7.922	2.794	1.730	0.452	14.246	8.342	19.053	2.256	0.208	0.000	0.000	1.599
		df	1	1	1	1	1	1	1	1	1	1	1	1	1	1
		Asymp. sig.	0.303	0.026*	0.005*	0.095	0.188	0.501	0.000*	0.004*	0.000*	0.133	0.648	0.989	0.994	0.206
Children's and geriatrics	Male	Chi-square	5.934	2.373	40.322	54.778	84.051	70.342	4.367	41.162	1.822	0.007	24.323	5.232	17.286	3.411
		df	1	1	1	1	1	1	1	1	1	1	1	1	1	1
		Asymp. sig.	0.015	0.123	0.000	0.000	0.000	0.000	0.037	0.000	0.177	0.933	0.000	0.022	0.000	0.065
	Female	Chi-square	20.932	2.836	6.849	12.486	52.940	42.060	3.268	44.735	9.315	6.693	23.079	8.237	19.278	0.789
		df	1	1	1	1	1	1	1	1	1	1	1	1	1	1
		Asymp. sig.	0.000*	0.092	0.009	0.000*	0.000*	0.000*	0.071	0.000*	0.002*	0.010*	0.000*	0.004*	0.000*	0.374

RI: reference interval; WBC: white blood cell; RBC: red blood cell; Hb: hemoglobin; Hct: hematocrit; MCV: mean corpuscular volume; MCH: mean corpuscular hemoglobin; MCHC: mean corpuscular hemoglobin concentration; PLT: platelet; RDW-CV: red cell distribution width-coefficient of variation; df: degree of freedom.
*$P < 0.05$ by Kruskal–Wallis test between age groups.

The current study showed no difference between male and female with respect to total WBC count ($P > 0.05$) which is comparable with the studies done in Mali, Akaki Ethiopia and Gojjam, Ethiopia.[21,22,29] In children, it showed lower WBC and neutrophil count than the Caucasian RI and higher than a report from Tanzania.[27,31] In adult age groups, the RI of WBC and neutrophil count in adult males were higher and females had lower RI than the Mali and Mozambique report.[29,32] In adult age group, the RI of WBC and neutrophil count as compared to the Caucasians population males had higher value in the upper limit of the range and lower value in the lower limit of the 95% range while females had a lower range.[30] The cause of WBC and neutrophil count variability may be partly explicable on the basis of diet and other extraneous influences, but there might be also a true biological difference.[33]

In the current study, higher eosinophil and lower basophil RIs were observed in children than the Caucasians.[31] Adult study participants in the present study showed almost similar lymphocyte RI with the Caucasian population and Ethiopia (Akaki). Monocyte RI of adult participants in the present study was slightly higher than Caucasians population, Mali and Ethiopia (Akaki) studies. Adult study participants in our study also had higher eosinophil count than the Caucasian populations.[21,29,30,33] These observed differences may be suggestive of different factors such as environmental difference, dietary role, ethnic variation, and subclinical illnesses. The higher eosinophil count may be attributed to disease-related causes, particularly parasitic infection.[14,34]

In the present study, PLT count decreased with age, which is consistent with the Italian and Ugandan reports.[26,35] The mechanisms responsible for the age-related changes might be the sharp decrease of PLTs during infancy which may be related to the gradual decline of thrombopoietin from birth to adulthood. The reduction in elderly people may reflect a reduction in hematopoietic stem cell reserve during aging or a survival advantage in subjects with lower PLT counts.

In this study, adult female had higher PLT count than their adult male counter parts, which is similar to other studies done in Italy,[35] Ghana,[36] Gojjam Ethiopia[22] and in Bahir Dar Ethiopia.[20] The observation that women begin to have PLT count higher than men only after the age of 14 supports the hypothesis that puberty makes the difference. The reduction of body iron due to menstuation probably related to their higher PLT count since moderate iron deficiency is known to stimulate PLTs production.[35]

The RI of PLT count of this study in children age group was almost similar to Caucasians and as compared to a study done in Tanzania, the lower limit was higher and the upper limit was lower.[27,31] Adult study participants in the present study have higher PLT count RI than other studies done in Ethiopia (Akaki) and the Caucasian population. Moreover, adult study participants of our study had higher-lower limit and lower-upper limit RI than a study done in Mali.[21,29,30,33] Geriatric study participants had higher PLT count than a report from Ethiopia (Gilgel gibe).[37] The cause of these differences is unknown, although undetected illness, environmental and genetic factors have been proposed.[35]

The strength of this study is that it is the first community-based study in southwest Ethiopia and complements previous findings that regional differences exist for hematological RI. Second, time of blood sampling was in the morning, so the influence of diurnal variation was minimized. The large sample size and the fact that both children and adults were included in the study are strengths of the study. Moreover, all the laboratory procedures were done based on the SOPs and qualified personnel.

This study has also some limitations. The participants were not screen for all medical conditions which might have effect on hematological parameters, such as helminthic infections. Participants with parasitic infections or with other subclinical conditions may have been included, which may have influenced the results. The other limitation is that due to logistic reasons, RIs for other hematological parameters such as coagulation profiles were not done. In addition, including majority of urban dwellers in the study is another limitation worth mentioning.

Conclusion

This study estimated hematological parameter RI from apparently healthy individuals of age ⩾5 years in Southwest Ethiopia. There was difference in hematological parameters RI of Southwest Ethiopian from other Africa countries and the Caucasian populations. Therefore, this study provided hematological parameter RIs which can be used to guide patient management and interpretation of laboratory findings, screening participants for enrollment into clinical trials and potentially improve the quality of health care in the area. RI for hematological parameters should be established in the other regions of the country.

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Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical approval

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Informed consent

A written informed consent was obtained from the study participants (for school children from their parents through the school). The collected data were kept confidential. The specimens collected from the participants were analyzed only for the intended purposes. Those study participants who had the abnormal laboratory test result during the screening process, were referred to the clinician working in the hospitals for proper treatment, counseling, and management according to their disease condition.

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