Introduction

The key for accurate diagnosis of hematological abnormalities relies on valid and reliable reference values of particular laboratory tests. It is now a proven fact that there is considerable variation in hematological parameters in apparently healthy individuals (1). Multiple factors were known to contribute to this variation including age, sex and genetic background (1, 2, 3). These factors must be considered while establishing hematological normal values for any population for the reason that a hematological value within the recognized normal range of certain population may be pathological in another population or situation. It is of great importance to have national hematological reference values for proper diagnosis, orientation and treatment decision. The hematological reference values were determined many years ago for the Western populations (4). Recently several authors tried out to establish reference values of hematological parameters for African countries (5, 6, 7). In Sudan they were few studies addressing this issue (8, 9). This study aims to establish reference ranges for Sudanese young adults males. The study is expected to create national reference ranges of hematological parameters which can be used safely in clinical practice. The study findings were expected to raise the national awareness toward the need of setting reference values to Sudanese population in the future. A 200 young healthy adult males, with age ranging between 18-25 years were participated in the study. Venous blood sample was collected in a tube containing EDTA anticoagulant for the blood tests. SPSS version 20 statistical software was used for data analysis, P value < 0.05 was considered significant and 95% CI was accepted. In Comparison with African and American population, the study group showed significant variation in Total WBCs counts, neutrophils count, lymphocytes count and platelets count. It was evident from this study that the study group and may be Sudanese population had significant variations in hematological parameters from established parameters elsewhere.

Materials and methods

The study was a cross sectional study involved a total of 200 males, age ranging between18-25 years. Male with chronic illnesses, hematological diseases, or who had recent illness as well as those with family history of hematological diseases were excluded from the study. Informed written consent was obtained from each participant. A questionnaire was filled by the researcher including age, anthropometric measurements and BMI. Then 1.5-2 ml of venous blood was collected into EDTA containing tube for laboratory tests. Blood samples were sent to AL-TIGANA lab in Khartoum where analysis was done using CBC machine (SYSMEX KX 21 hematological automated analyzer).

Data was analyzed using SPSS program version 20. The variables were expressed as mean ± standard deviation and median. Reference range was measured as (2.5th—97.5th) percentile at confidence level 95%. The tests of significance used were; the one sample t-test for comparison of means and Wilcoxon-Rank Signed test to compare medians (at confidence level 95%). P value<0.05 is considered statistically significant. One- Sample Kolmogorov-Smirnov test of normality was used to test normal distribution.

The study was approved by the ethical committee of University of Khartoum.

Results

Age and anthropometric measurements

The mean age of the participants was 20.5 years. Most of the participants (76%) had BMI less than 25.1 and only (4%) had BMI of 30 or more (table 1).

White blood cells and differential counts

The mean total white blood cells count (TWBCs) was 5.9x10^9 cells /L and the (2.5th -97.5th) percentile range was (3.2x10^9-9.4x10^9 cells /L). Neutrophils represented 51% of total WBCs count, the mean count was 3.1x10^9...
Reference ranges of white blood cells and platelets counts.

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/L and the range was 1.2 x 10^9-6.1 x 10^9 cells /L. Lymphocytes represented 38.9%; the mean count was 2.2 x 10^9 cells /L and the range was 1.1 x 10^9-3.6 x 10^9 cells /L. The mean mixed white cells count was 0.5 x 10^9 cells /L and the range was 0.1 x 10^9-1.1 x 10^9 cells /L (table 2).

All white blood cells variables were normally distributed except TWBCs and neutrophils count (table 2).

### Platelets count and indices

Mean platelets count was 258.2 x 10^9 cell /L and the (2.5th -97.5th) percentile range was (150 x 10^9 -383 x 10^9) (table 3).

### Discussion

The hematological reference values were determined many years ago for the Western population. Recently African countries tried to do so (5, 6, 7). This study tried to establish normal hematological reference ranges for Sudanese young adult males in order to be used in clinical practice for this group.

Because of the reported variations in hematological parameters with age and gender, the comparison of hematological parameters of the study participants with other ethnics was made with male gender with the nearest age group.

### White blood cells count

No significant correlation was observed between TWBCs count and anthropometric measurements in contradiction to the reported correlation between BMI and WBCs count (10).

The study group showed significantly higher mean TWBCs count in comparison with TWBCs counts of Tanzanians (11), Botswanan (12), Nigerian (13) and Malawian (14). The study group showed insignificantly higher mean TWBCs count in comparison with TWBCs count of Ugandan and Ethiopian (6, 15). In comparison with TWBCs count of American population, the study group showed less TWBCs count (16).

### Neutrophils count

The study group had higher neutrophils indices than...
Tanzanians, Malawians and Ugandans (6, 11, 14). The percentage of neutrophils was consistent with Botswanans and Nigerian (12, 13). The study group showed lower neutrophils count and percentage than Americans (16).

Lymphocytes count
The study group had higher lymphocytes indices than Tanzanians and Malawians lymphocyte counts (40.8%, 1.7×10^9 cell /L P value 0.005, 0.000 respectively) (11, 14) while it was lower than Ugandans lymphocytes count 2.6×10^9 cell /L, P value=0.000 (6). Lymphocytes Percentage of the study group was consistent with Botswanan and Nigerians (37.6 %, 40% P value 0.001, 078 respectively) (12, 13). In comparison with the Americans, the study group had higher lymphocytes percentage 31.4% P value 0.000 (16).

Mixed cell count
In comparison with Tanzanians mixed cell count (0.51 x 10^9cell/L), the study group showed similar value P value=0.080 (11).

Platelets
The study group has near the same count of Ethiopians (265 x10^9 cell/L)(15) , significantly more than Tanzanian 221 x 109 cell /L (11), Malawians 170 x 109 cell /L(14) and Ugandans 235 x 109 cell /L (6), significantly lower count than Botswanans 277 x 109 cell /L(12)

There is no significant difference between the study group platelets count and American platelets count (257 x 10^9 cell /L)(16)although American MPV (8.4 FL) was lower than MPV of the study group (10.2 FL).

Study hematological parameters and SYSMEX KX 21
Reference ranges of the study group were different from that one used in manual of Sysmex KX-21 Analyzer (of same gender). In comparison with Sysmex values; TWBCs and lymphocytes ranges were less than study group ranges while the range of platelets count was more than the device range.(17) Neutrophils count, mixed white cell count and platelets indices showed no obvious differences.

Conclusions
This study showed significant variations in TWBCs count and differential count, platelets count and indices of Sudanese young adult healthy males in comparison with the reference ranges of African and American hematological parameters. Sudanese hematological parameters were significantly different from others. The study results revealed an urgent need to build national reference ranges for all hematological and immunological parameters for Sudanese population in the near future. Further studies to confirm these results and establish reference range for different age groups, female gender and different Sudanese tribes are highly recommended.

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Conflict of interest
The authors declare they have no conflict of interest.

References