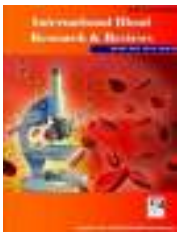

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Haematological Values at Moderate Altitude in a Low-Income Population

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Author's contribution

The author designed and carried out the study, performed the statistical analysis and wrote the manuscript.

Research Article

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ABSTRACT

Aim: To illustrate haematological adaptation to moderate altitude in Rwanda.
Study Design: A population-based cross-sectional study.
Place and Duration of Study: The study was carried out at moderate altitude (1,649-1,768 m) among students of the National University of Rwanda and blood donors from Buhanda, Ruhango and Nyaruteja centres, from August to December 2011.
Methods: Healthy volunteers (238 males and 106 females, age range: 18-40 years) were recruited in the study. Complete blood count was performed on a Coulter AcT 5diff and for some samples on a Sysmex KX-21N automated haematology analyzer.
Results: Results (mean ± SD) were: erythrocyte count: males: 5.28 ± 0.53 X 10^{12}/L, females: 4.72 ± 0.63 X 10^{12}/L; haemoglobin concentration: males: 160 ± 16 g/L, females: 140 ± 18 g/L; haematocrit: males: 45 ± 4 %, females: 40 ± 5 %. The differential leukocyte count showed eosinophilia (4%) and increased lymphocytes (44%).
Conclusion: The values for erythrocyte count, haemoglobin concentration, haematocrit, erythrocyte indices and leukocyte count are comparable to sea level values. The fact that haemoglobin concentration is not low as is the case in low-income populations living at sea level can be attributed to adaptation to moderate altitude.

Keywords: Moderate altitude; haematology; Rwanda.

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1. INTRODUCTION

Altitude induces haematological adaptive changes. Different adaptation patterns have been described, with population-dependent variations at similar altitudes. The classical adaptation pattern consists of hypoxaemia due to altitude with compensatory polycythaemia and high haemoglobin concentration. This pattern is mainly observed in the South American Andes [1,2]. The Tibetan adaptation model shows hypoxaemia, but normal haemoglobin concentration [3]. In a recently described Ethiopian adaptation pattern, despite high altitude, there is normoxaemia and normal haemoglobin concentration [4]. It has been suggested that the different adaptation patterns are based on population genetic differences [3,5,6]. At moderate and high altitude, erythropoietin secretion increases due to hypoxia and stimulates erythropoeisis [7]. Erythropoeitin secretion is regulated by hypoxia-inducible factors and the response is variable depending on the adaptation pattern of the population [8-11]. The different altitude adaptation characteristics were described for altitude higher than 2000 m. Increase in haemoglobin concentration is also observed in low-landers sojourning at high altitude [12]. At altitudes lower than 2000 m, there is classically no pathological condition resulting from altitude, but physiological changes are described. Important haematological and physiological adaptations were observed following 46 weeks of residence at a moderate altitude of 2,200 m [13].

At the moderate altitude of 1,768 m (barometric pressure 629 mm Hg), Butare, Rwanda, we previously reported blood gas, acid-base and haemoglobin values, showing a slight chronic respiratory alkalosis with complete metabolic compensation, normoxaemia and normal haemoglobin concentration [14]. We report here the results of a study of haematological parameters in the Rwandan population at different sites at moderate altitude in the Southern Province of Rwanda. The aim is to illustrate the pattern of haematological adaptation to moderate altitude and provide a first set of data for the establishment of reference intervals that are specific for the local population [15].

2. SUBJECTS AND METHODS

The study was carried out among blood donors in the centres of Buhanda (1,649 m), Ruhango (1,739 m) and Nyaruteja (1,667 m) and students of the National University of Rwanda at Butare (1,768 m), from August to December 2011. The study participants were in healthy condition on physical examination and without any history of disease (malaria, infection) in the preceding six months. Alcohol abuse, medication, and smoking were ruled out. Females were not pregnant, breastfeeding or on oral contraception and were not in the menses period. Blood donors comprised different living conditions: rural and semi-urban environment, diverse occupation (peasants, shop keepers, students and civil servants).

Sampling was done in the morning after overnight fasting or, in some cases, four hours after a light breakfast. Five mL of venous blood were sampled from the cubital vein in a tube with ethylenediaminetetraacetic acid (EDTA) as anticoagulant. Complete blood count was performed in the services of haematology and immunology of the laboratory of Butare University Teaching Hospital, using a Coulter AcT 5diff or for some samples a Sysmex KX-21N automated haematology analyzer. CD4 T lymphocyte count was carried out on a Becton Dickinson Facscount apparatus. Laboratory procedures were performed after suitable calibration and internal quality control as per the instructions of the manufacturer. Statistical analysis was done with the Excel 2007 software for the determination of the mean, standard deviation and the 2.5^{th}-97.5^{th} percentiles. The test of normality of the distribution was performed with the one sample Kolmogorov-Smirnov test on rough data, using the

statistical package for the social sciences (SPSS version 16.0). We considered the distribution as Gaussian when the two-tailed asymptotic significance was >.05 and non Gaussian when it was <.05. As the distribution was non Gaussian in several cases and considering that the Kolmogorov-Smirnov test is not very reliable in case of small sample size, we used 2.5^{th}-97.5^{th} percentiles, as required for reference intervals in case of non Gaussian distribution. For the comparison between males and females, we used a non parametric test, the Wilcoxon Rank Sum test.

3. RESULTS AND DISCUSSION

In total, CD4 T lymphocyte count was done on 344 samples and complete blood count on 302 samples. Six outliers were removed. Results from 338 subjects (235 males and 103 females) were retained for CD4 T lymphocyte count analysis and results from 296 subjects (206 males and 90 females) were retained for complete blood count analysis. The mean age was 25 years for males and 23 years for females; range 18-40 years. The body mass index was 21.2 ± 2.1 (range: 15.7-29.3) kg/m² for males and 22.0 ± 2.7 (range: 17.3-27.4) kg/m² for females.

The test of normality of distribution using the one sample Kolmogorov-Smirnov test on rough data gave a two-tailed asymptotic significance >.05 for erythrocyte count, haemoglobin concentration, haematocrit, mean cell volume, mean cell haemoglobin, mean cell haemoglobin concentration, CD4 T lymphocyte count and platelet count in males and for mean cell volume, mean cell haemoglobin, mean cell haemoglobin concentration, leukocyte count, eosinophil count, lymphocyte count, monocyte count, CD4 T lymphocyte count and platelet count in females. The distribution of these parameters was considered as Gaussian. The two-tailed asymptotic significance was <.05 for leukocyte count, neutrophil count, eosinophil count, basophil count, lymphocyte count and monocyte count in males and for erythrocyte count, haemoglobin concentration, haematocrit, neutrophil count and basophil count in females. The distribution of these parameters was considered as non Gaussian.

The difference between males and females, analyzed with the Wilcoxon Rank Sum test, was statistically significant (*P* <.05) for erythrocyte count, haemoglobin concentration, haematocrit, platelet count and CD4 T lymphocyte count. For these parameters, specific results are presented for males and females. The difference between males and females was not statistically significant (*P* >.05) for MCV, MCH, MCHC and leukocyte count. For these parameters, common results are presented for males and females. The results for complete blood count are presented in Table 1.

The erythrocyte count, haemoglobin concentration and haematocrit are higher in males than in females, a well-established difference, which was also observed in other African studies [16]. The erythrocyte indices are comparable to those observed in the American population [17], even though population and environmental factors are different.

In a previous study [14], we showed that at the moderate altitude of Butare there was a decreased PaO_2 (83 and 84.5 mm Hg in the males and the females respectively). However it was sufficiently high to ensure normal haemoglobin saturation with oxygen (97% in the males and 94.7% in the females). This explains why the haemoglobin concentration in the present study (altitude between 1,649 and 1,768 m) is similar to sea level values [17]. However, the fact that haemoglobin concentration is not low as is the case for low-income populations living at sea level [18] can be attributed to adaptation to moderate altitude. The effects of low nutritional status and parasitic diseases which would result in low haemoglobin

concentration are counteracted by the effect of altitude, resulting in similar values as at sea level.

Table 1. Complete blood count values in adults

Parameter	Unit	Mean ± SD		2.5^{th}-97.5^{th} percentile interval	
		Males	Females	Males	Females
Erythrocyte count	X 10^{12}/L	5.28 ± 0.53	4.72 ± 0.63	4.2-6.3	3.4-5.5
Haemoglobin concentration	g/L	160 ± 16	140 ± 18	127-175	110-160
Hematocrit	%	45.5 ± 4.4	40.1 ± 5.5	38-54	36-48
MCV	fL	85.72 ± 4.82		77-95	
MCH	pg	30.17 ± 2.07		26-33	
MCHC	g/dL	35.14 ± 1.43		32-37	
Leukocyte count	X 10^{9}/L	4.66 ± 1.22		2.90-7.11	
Neutrophils	X 10^{9}/L	2.02 ± 0.84		1.0-4.1	
	%	43.3		21-62	
Eosinophils	X 10^{9}/L	0.19 ± 0.19		0.05-0.74	
	%	4.1		1-15	
Basophils	X 10^{9}/L	0.03 ± 0.02		0.01-0.08	
	%	0.7		0.2-1.5	
Lymphocytes	X 10^{9}/L	2.04 ± 0.55		1.1-3.2	
	%	44		21-59	
Monocytes	X 10^{9}/L	0.33 ± 0.11		0.2-0.6	
	%	7.1		3-10	
CD4 T-lymphocytes	Cells/µL	784 ± 203	933 ± 200	377-1191	533-1334
Platelet count	X 10^{9}/L	226 ± 55	271 ± 68	115-336	134-408

SD: standard deviation

MCV: mean cell volume; MCH: mean cell haemoglobin; MCHC: mean cell haemoglobin concentration
n = 206 (males); 90 (females); 296 (males + females); for CD4 count: n=235 (males); 103 (females)

The red cell count, haemoglobin concentration and haematocrit in the present study are comparable to those observed by Tsegaye et al. at 2400 m in the Ethiopian highlands (erythrocyte count: 5.1 X 10^{12}/L in males and 4.5 X 10^{12}/L in females; haemoglobin concentration: 161 g/L in males and 143 g/L in females; haematocrit: 48.3% in males and 42.0% in females) [19]. Our results also compare well with those reported by Saathoff et al. at 1,400-1,700 m in the highlands of south-western Tanzania (erythrocyte count: 5.21 X 10^{12}/L in males and 4.69 X 10^{12}/L in females; haemoglobin concentration: 154 g/L in males and 135 g/L in females; haematocrit: 46.6% in males and 41.5% in females) [20]. Our haemoglobin results are higher than those reported at a lower altitude of about 1,100 m in Kenya, 142 g/L in males and 121 g/L in females [21].

For the differential leukocyte count, our results show eosinophilia, in line with results from other African studies [22,23]. It can be attributed to high frequency of parasitic diseases in African populations. A lower number of neutrophils than lymphocytes is observed in our study as has been described in other African studies [21,23,24]. Our results for CD4 T lymphocyte count is lower in males than in females; similar findings were reported in other African studies [21,25]. The lower limit for CD4 count in males in our study is lower than in most African studies, with lower limit >400 cells/µL [22,25], but it is higher than the lower limit of 362 cells/µL in males aged >24 years reported by Lugada et al.[16] and the one of 291

cells/µL in males reported by Ngowi et al. [26]. The platelet count is lower in males than in females. This difference has been observed in other African studies [23].

4. CONCLUSION

The results of our study compare well with other African studies. At moderate altitude, there is no increase in haemoglobin concentration and the erythrocyte count is normal, compared to sea level values. However, the fact that haemoglobin concentration is not low as is seen in low-income populations living at sea level can be interpreted as a result of adaptation to moderate altitude. Increased eosinophil and lymphocyte counts are observed. Small sample size constitutes a limitation of our study. A comprehensive study needs to be done to establish haematological reference intervals that are specific for the local population.

CONSENT

The author declares that written informed consent was obtained from the study participants before enrolment.

ETHICAL APPROVAL

The research project was approved by the ethics committee of the Faculty of Medicine of the National University of Rwanda.

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COMPETING INTERESTS

The author has declared that no competing interests exist.

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