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Impact of Obesity on Hematological Parameters in Adolescents in Brazzaville, Congo

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Abstract

Obesity-induced hematologic changes in children in sub-Saharan Africa are poorly documented. The aim of this study is to determine obese adolescents' hematological profiles and analyze the associations between some anthropometric and hematological parameters. A cross-sectional and comparative study was carried out in Brazzaville among adolescents attending school. A total of 82 adolescents (aged 11 - 17 years: mean age: 14.9 years), were enrolled in the study and were divided into 45 obese, 17 overweight and 20 normal-weight subjects. Anthropometric measurements were performed. Blood samples were taken to determine the number of leukocytes, red blood cells, platelets, hemoglobin and hematocrit levels. Our results show that values of hematological parameters noted in obese adolescents were significantly higher than normal-weight subjects: leukocytes, 7.14 vs. 6.17 ($\times 10^{12}$/L); red blood cells, 4.90 vs. 4.84 ($\times 10^6$/mm^3); platelets, 305.03 vs. 380.41 ($\times 10^6$/L), hemoglobin, 14.16 vs. 13.92 (g/dL), hematocrit, 42.62% vs. 40.83%. The same trend was found after adjustment for age and sex. After adjustment for age, the BMI Z-score remained closely correlated with all hematological variables. Correlation analysis showed a significant positive relationship between waist circumference and red blood cell levels (r = 0.258; p = 0.024), and hemoglobin levels (r = 0.213; p = 0.031). In conclusion, these results highlight the need to strengthen the management of obese children in order to prevent potential risk factors for cardiovascular disease in adulthood.

Subject Areas

Pediatric Obesity

Keywords

Blood Count, Obesity, Adolescence, School Setting, Sub-Saharan Africa

1. Introduction

Childhood obesity has become a public health issue. Its prevalence is constantly increasing: nearly 6% per year over the last ten years, adding more than 2.3 million obese individuals to the pediatric population. In 2016, more than 340 million children and adolescents (Ng *et al*., 2014) [1] had obesity. In low- and middle-income countries, analysis of available epidemiological data notes a significant and rapid increase in obesity (Li *et al*., 2008 [2]; Nitzan Kaluski *et al*., 2009 [3]; Bishwalata *et al*., 2010 [4]). Sub-Saharan African countries are not spared from this scourge, although the phenomenon is not of the same magnitude; indeed, there is talk of an epidemiological transition in developing countries given the high prevalence of this non-communicable condition.

In Congo-Brazzaville, Mabiala-Babela *et al*. (2004) [5] report an increase in the prevalence of obesity between 1963 and 2003, from 1.9% to 7.1% among children and adolescents aged 7 to 16 years. Due not only to the increase in prevalence, but also to the association with an increased risk of morbidity, the fight against obesity concerns all health systems worldwide. Indeed, obesity is associated with several complications (cardiovascular, metabolic, respiratory, and orthopedic hematological pathologies) (Kim and Lee, 2021 [6]; Stefanick *et al*., 1987 [7]). These make it the leading cause of indirect mortality in adults and children (Kim *et al*., 2006 [8]). Regarding hematological changes, following the inflammatory state induced by obesity, there is an increase in the number of leukocytes (white blood cells, WBC), red blood cells (RBCs), platelets, and hemoglobin (Hb) and hematocrit (Hct) levels (Foschini *et al*., 2009 [9]; Santilli *et al*., 2012 [10]). Red blood cell and platelet counts, and hemoglobin levels are known to be related to cardiorespiratory problems (Jones, 2008) [11], oxidative metabolism (Schwartz and Weiss, 1991) [12], and cardiovascular events (Asdie *et al*., 2009) [13]. Several studies on hematological changes in obese subjects have focused on adults; few have focused on obese children (Do Nascimento Ferreira *et al*., 2013) [14]. To our knowledge, no study was found in sub-Saharan Africa. The aim of this study is to determine the profile of hematological parameters in obese adolescents attending school in Brazzaville and to establish correlations between some anthropometric indicators and hematological parameters.

2. Materials and Methods

2.1. Study Area

A cross-sectional and comparative study (obese vs overweight vs normal-weight) was conducted in Brazzaville, Republic of Congo, in middle schools. It involved adolescents aged 11 to 18 years attending these schools.

2.2. Sample

The study sample was determined after randomization according to a two-stage cluster survey, stratified by gender and the commune where the school is located (*i.e.*, the sectoral inspection of the middle schools to which it belongs). We proceeded in the same way within each school. A selection of classes was made by drawing 1/3 by level of study. This selection was made by computer. In practice, 52 schools were selected and 1725 students were chosen: 673 (39.0%) boys and 1052 (61.0%) girls. Due to financial difficulties inherent to the costs of haematological analyses, a draw was made at 1/3 within the group of obese subjects and at 1/5 for overweight and normal-weight subjects. At the end of this process and after consent from the student and/or parents (guardians), 151 adolescents (obese, overweight, normal-weight) were selected. The inclusion criteria for the study were: parental consent for subjects aged 11 to 17 years, and individual consent for the student aged 18 years; a BMI above the 97.5th percentile or IOTF-30 curve for the age group for obese children, a BMI between the 85th and 97.5th percentile for the overweight subject, a BMI between the 25th and 85th percentile for the normal-weight subject. Exclusion criteria were any chronic and acute illnesses, the chronic use of alcohol, smoking, metabolic (diabetes mellitus, dyslipidemia), infectious and allergic diseases at the time of blood collection, sickle cell disease continuous use of anti-inflammatory drugs taking an antibiotic treatment, recent history of blood loss, blood transfusion in the last one year, immunization in the last 6 months, major surgical procedures in the past 6 months, having any intestinal and hemoparasites. However, due to the cost of the hematological examinations and the lack of funding for the study, only 82 students (41 boys, 51 girls) participated in the study, of which 45 were obese, 17 were overweight and 20 were normal-weight.

2.3. Anthropometric Measurements

At the beginning of the study, measurements of height (T) using a wall-mounted height gauge (model 220 Seca, Hamburg, Germany, accuracy: 0.1 cm default), weight (P) using an electronic scale (HW200, A&D Mercury Pty Ltd, Thebarton, SA), percentage fat (PCTG), waist circumference (TT) using a tape measure, subscapular (SS) and tricipital (TRI) fold thicknesses using a Harpenden calipers (British Indicators Ltd, West Sussex, UK), were performed. Measurement protocols were as described in the Anthropometric Standardization Reference Manual (Lohman *et al.*, 1991) [15]; children were dressed lightly. Body mass index (BMI) was calculated using the formula: BMI (kg/m^2) = Weight (kg)/[height (m)]^2.

For a more refined assessment of obesity, the BMI Z-score was calculated in obese subjects using the World Health Organization AnthroPlus software (Geneva, Switzerland). Fat percentage was assessed from the subscapular (SS) and tricipital (TRI) skinfolds using the equations of Brook (1971), reported by Forbes (1986) [16]. The waist-to-waist ratio (WHtR) was calculated.

2.4. Hematological Analyses

Blood samples were collected from each participant using the EDTA anticoagulated test tubes from 8 to 9 am from fasting adolescents in an appropriate, hygienic, air-conditioned room (temperature ranging from 25˚C to 27˚C). The number of leukocytes, red blood cells, platelets, hemoglobin and hematocrit were determined by fluorescence cytometry using the Sysmex XT 100TM.

Approximately 4 ml of venous blood was collected in a dry tube from each adolescent at the elbow, forearm, or posterior aspect of the hand (depending on the ease of finding a superficial vein). Samples were labeled with unique identification; they were transported in a cooler cooled to 2˚C - 8˚C and analyzed within 5 hours of collection. Before analysis, each sample stored at 2˚C - 8˚C was placed in the room for 30 minutes. This collected blood was placed in a water bath for use at 37˚C or room temperature. Whole blood samples were used for analysis of hematological tests. Centrifugation of this blood yielded the serum to be assayed. For the assays, pre-prepared kits (reagents) including buffer solution, enzymes and standards were used.

Lifestyle-related behaviors were assessed using a questionnaire, which was distributed and completed after interviews with health professionals and the investigator. It included items on tobacco and alcohol consumption, smoking status, area of residence (urban vs rural), physical activity (intense for ≥3 days/week, moderate (≥30 min/day and ≥3 days/week, or inactivity for <30 min/day and <5 days/week), history of pathologies (diabetes, dyslipidemia, etc.), history of family disease.

Associations between some anthropometric parameters (BMI Z-score, waist circumference, WHtR, skin folds) and blood count parameters were investigated.

2.5. Operational Definitions

Adolescence was defined as the age range from 10 to 19 years.

The child was defined as obese if the BMI was above the 97.5th percentile or IOTF-30 values for the age range (Schwartz and Weiss, 1991) [12].

The subject was declared overweight if the BMI was between the 85th and 97.5th percentile.

The subject was considered normal-weight if BMI was between the 25th and 85th percentile. Percentiles in this study were based on the 2001 growth reference values for French children and adolescents (Rolland-Cachera *et al*., 1991) [17], because of the lack of Bantu growth references.

Waist circumference was considered elevated according to the French values [18] and the International Diabetes Federation criteria (Zimmel *et al*., 2007) [19]: 1) for TT ≥ 90th percentile values in subjects of both sexes aged 6 to 15 years; 2) if TT strictly greater than 94 cm for boys and 80 cm for girls in subjects aged 16 - 18 years.

2.6. Statistical Analysis

The statistical package for the Social Sciences (SPSS, version 21.0) was used for statistical analysis. Data were presented as mean ± standard deviation when the distribution of values was normal; otherwise, they were expressed as median. Categorical variables were presented in terms of numbers and percentages. The analysis of differences between the two groups used the non-parametric Kruskal-Wallis test. Differences between the three groups of students (obese, overweight, normal-weight) were analyzed using analysis of variance (ANOVA) for continuous variables and the Chi-2 test for categorical variables. Adjusted means and standard deviations of hematological indices (leukocytes, red blood cells, platelets, Hb, Hct) were determined for each group from 3 analyses of co-variance (ANCOVA) models after adjustment for potential confounders. In the first ANCOVA 1 model, statistical analysis was performed based on body build after adjustment for age and sex for all study participants. Adjusted means and standard deviations of hematological indices were expressed after controlling for age and sex. In ANCOVA models 2 and 3, statistical analyses were also performed according to corpulence after adjustment for age in boys for model 2, and for age in girls for model 3. Adjusted means and standard deviations of hematological indices were after controlling for age for boys and girls. To assess the correlations between some anthropometric parameters (BMI Z-score, waist circumference, WHtR) and hematological indices, Pearson correlation analysis was used. Furthermore, because the measurement of plasma lipoprotein concentrations is commonly used to estimate cardiovascular disease risk, we investigated the potential relationships between 2 anthropometric indicators (WHtR, BMI Z-score) and lipoprotein concentrations in our obese sample. For this, Spearman's simple correlation analysis was used. For the relationship between BMI Z-score (independent variable) and hematological parameters (dependent variables) in the obese, multiple linear regression analysis was performed. The significance level of the tests was set at 5%. All data were processed using PASW Statistics software, version 18.0 for Windows (SPSS Inc., Chicago, IL, USA).

3. Results

3.1. Clinical Characteristics of the Study Population

Table 1 shows the clinical of 151 subjects of the study population.

The proportion of adolescents who drank alcohol was highest in the overweight group. The majority of adolescents lived in urban communes. However, one-third of the normal-weight adolescents resided outside the city of Brazzaville.

3.2. Adolescent Hematological Values According to Body Weight

Data on hematological parameters (leukocytes, red blood cells, hemoglobin,

Table 1. Clinical characteristics of the study population.

	Obesity (n = 53)	Overweight (n = 21)	Normal-weight (n = 77)
Sex			
Boys, n (%)	21 (39.6)	9 (42.8)	51 (66.2)
Girls, n (%)	32 (60.4)	12 (57.2)	26 (33.8)
Age (years)	14.3 ± 1.2	14.5 ± 1.8	14.1 ± 2.7
BMI (kg/m^2)	32.3 ± 1.4	28.4 ± 0.6	22.3 ± 2.5
Alcohol, n (%)	5 (9.4)	7 (33.3)	12 (15.6)
Smoker, n (%)	4 (7.5)	3 (14.3)	7 (9.1)
Urban residence, n (%)	48 (90.6)	15 (71.4)	69 (89.6)
Physical activity			
Intense	0	0	16 (20.8)
Moderate	9 (16.9)	15 (71.4)	52 (67.5)
Inactivity	44 (83.0)	6 (28.5)	9 (11.7)
Diagnosis of diabetes	0	0	16 (20.8)
Diagnosis of dyslipidemia	0	0	16 (20.8)
History of family diseases			
Diabetes	2 (3.8)	0	0
Obesity	9 (16.9)	0	0
Hypertension	3 (5.7)	2 (9.5)	0

hematocrit and platelets) for all three groups of adolescents are shown in Table 2.

Hematological parameters were different among three groups, and obese adolescents had higher adjusted or unadjusted mean levels than did normal-weight adolescents.

3.3. Values of Hematological Parameters According to Gender

The distribution of mean values of hematological parameters by gender is shown in Figure 1 in boys and 2 in girls.

Mean WBC increased significantly in boys and girls across normal-weight, overweight and obese groups. In the boys, means of WBC and Platelets were significantly higher in obese adolescents than the normal-weight adolescents, the differences being respectively of: +17.4%, and +12.3%. Differences between obese and normal-weight groups were found no significant for RBC (+1.2%), Hb (+4.1%), and Hct (+2.4%).

Concerning girls group, means of WBC, Platelets and Hct were significantly higher in obese adolescents than the normal-weight adolescents, the differences being respectively of: +17.4%, +10.3%, and +6.4%. Differences between obese

Table 2. Mean values of hematological parameters.

	Obesity (n = 25)		Overweight (n = 17)		Normal (n = 20)	
	NAJ	AJ	NAJ	AJ	NAJ	AJ
WBC ($\times 10^3$/mm^3)	7.14 (1.57)	7.16 (0.05)	6.63 (1.46)	6.66 (0,05)	6.14 (1.38)	6.21 (0.02)
RBC ($\times 10^6$/mm^3)	4.90 (0.35)	4.92 (0.01)	4.87 (0.39)	4,88 (0,01)	4.81 (0.32)	4.82 (0.01)
Hemoglobin (g/dL)	14.16 (1.28)	14.07 (0.04)	14.05 (1.45)	14.04 (0.04)	13.72 (0.64)	13.89 (0.02)
Hematocrit (%)	42.62 (2.76)	42.31 (0.10)	42.01 (2.54)	42.21 (0.09)	40.83 (2.65)	41.91 (0.04)
Platelets ($\times 10^6$/mm^3)	312.17 (1.32)	311.87 (2.04)	297.06 (32.48)	296.38 (2.05)	280.41 (42.68)	282.66 (0.72)

Abbreviations: NAJ, unadjusted; AJ, adjusted; WBC, white blood cells; RBC, red blood cells.

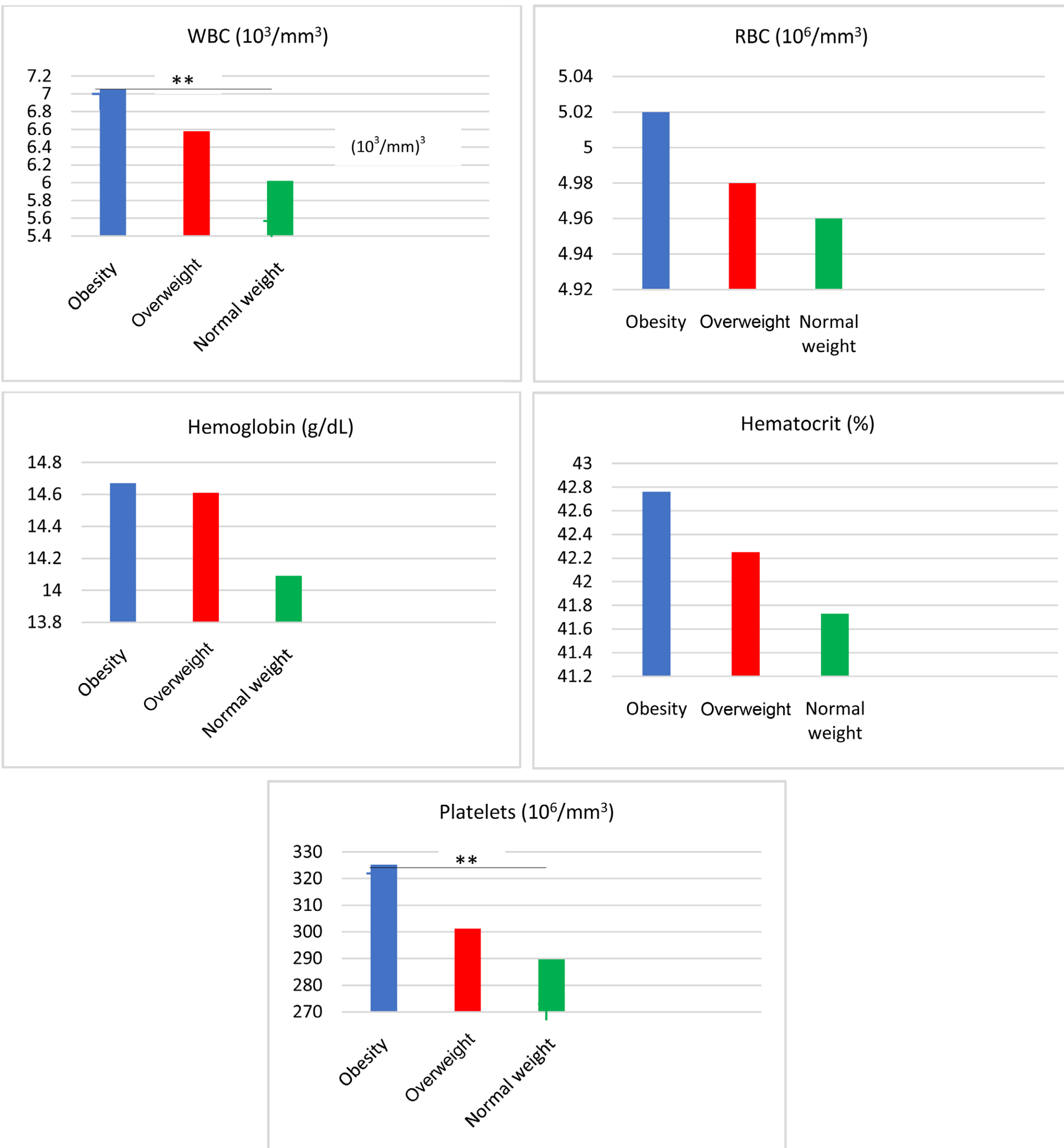

Figure 1. Means for white blood cell (WBC), red blood cell (RBC), hemoglobin, hematocrit, and platelets levels in boys according to obesity.

and normal-weight groups were found no significant for RBC (+2.8%), and Hb (+2.2%).

Table 3 reports the comparative means of CBC counts between obese boys and girls.

The unadjusted means for hematologic parameters were no significantly different among the boys and girls, except for hemoglobin.

4. Discussion

Obese children in our series have increased CBC counts compared with normal-weight children (Table 2). In particular, the BMI Z-score in obese subjects was positively and independently associated with leukocytes, after adjustment for confounding variables [r = 0.617; (p = 0.47) in boys and 0.503 (p = 0.029) in girls]. This increase in WBC counts is undoubtedly associated with obesity. Indeed, it is well known that chronic inflammation around adipocytes plays an important role in obesity-related diseases (Kim and Lee, 2021) [6]. Given that white blood cell counts increase inflammatory status, it is reasonable to assume that white blood cells are elevated in obese youth. One of the most plausible explanations is the role that adipose tissue plays through IL-6, a pro-inflammatory cytokine, in bone marrow granulopoiesis, proliferation, and differentiation of white blood cells (Santilli *et al*., 2012) [10]. In our study, the recovered 0.275 ($\times 10^3/mm^3$) increase in white blood cells with each 1-point increase in BMI Z-score, is consistent with the results of other studies (Veronelli *et al*., 2004) [20]. In addition, relative leukocyte elevation is associated with carotid atherosclerosis and impaired glucose tolerance (Ellulu *et al*., 2017) [18]. In this study, the BMI Z-score was positively associated with red blood cell count [r = 0.654 (p = 0.045) in boys and 0.503 (p = 0.029) in girls], Hb [r = 0.621 (p = 0.046) in boys, and 0.448 (p = 0.048) in girls] and Hct [r = 0.615 (p = 0.048) in boys, and 0.489 (p = 0.035) in girls]; our findings are consistent with other studies. Marginean *et al*. (2019) [21] reported significantly higher RBC levels in obese children compared to controls (normal-weight children), but with no significant difference for Hb levels. The mechanism of the increase in erythrocyte cells in the obese subject is not known. There are reports of more frequent iron deficiency anemia

Table 3. Comparison of unadjusted means of leukocytes, red blood cells, hemoglobin, hematocrit and platelet levels between obese boys and girls.

	Boys	Girls	p
	n = 9	n = 16	
Leukocytes ($\times 10^3/mm^3$)	7.35 ± 0.06	7.07 ± 0.08	-
Red bloodcells ($\times 10^6/mm^3$)	1.73 ± 0.14	1.71 ± 0.12	>0.05
Hemoglobin (g/dL)	14.67 ± 0.09	13.05 ± 0.10	<0.001
Hematocrit (%)	42.76 ± 0.10	42.48 ± 0.07	>0.05
Platelets ($\times 10^6/mm^3$)	325.19 ± 0.16	1.17 ± 0.09	>0.05

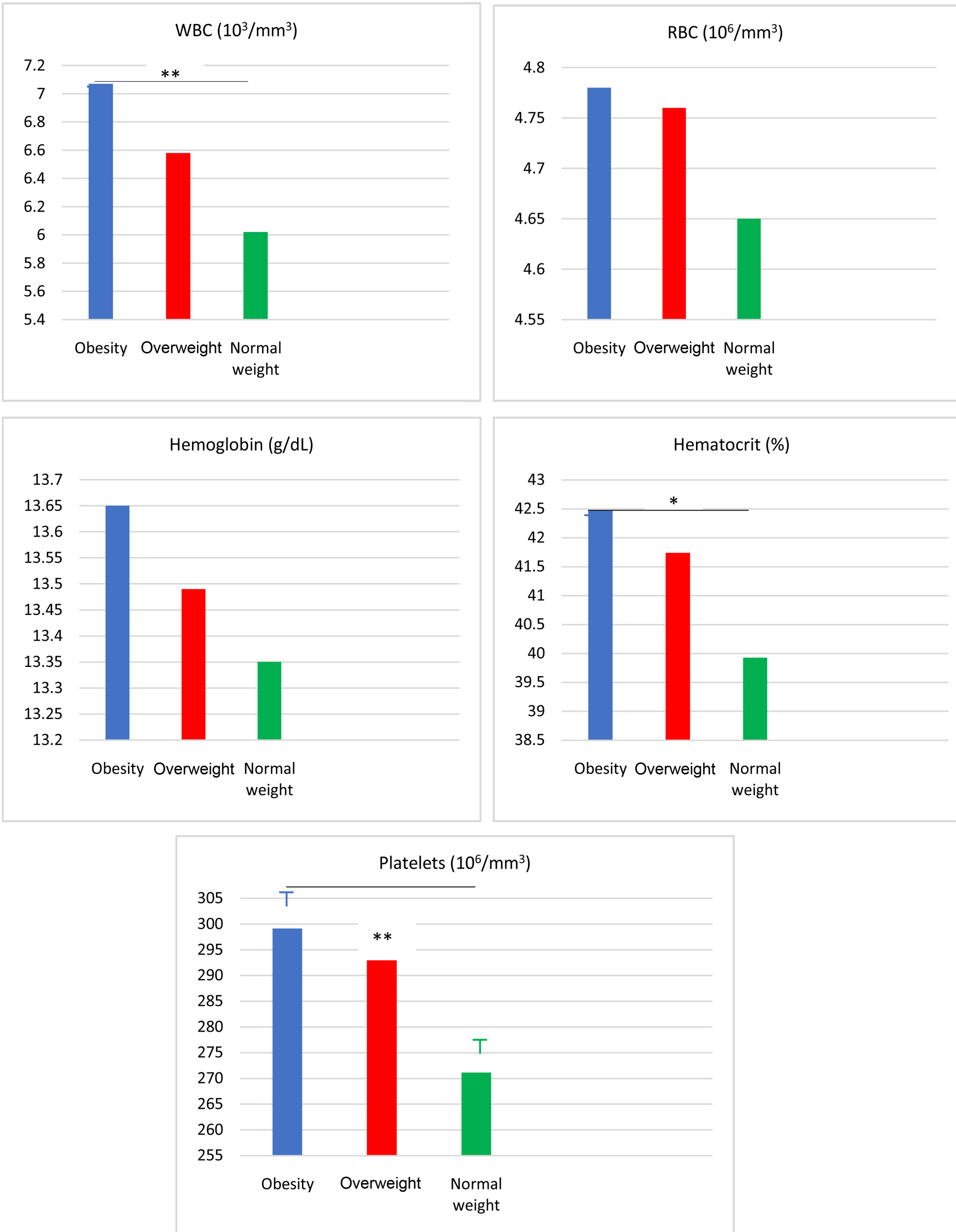

Figure 2. Means for white blood cell (WBC), red blood cell (RBC), hemoglobin, hematocrit, and platelets levels in girls according to obesity.

in obese/overweight subjects compared to normal-weight subjects (Wentzel *et al*., 1962) [22]. This is thought to be largely related to obesity-induced chronic inflammation and the influence of hepcidin. In this regard, Bekri *et al*. (2006) [23] reported that hepcidin, a pro-inflammatory adipokine whose mature form of 25 amino acids is secreted into plasma, reduces iron bioavailability by controlling ferroportin-1 export, thus leading to severe iron deficiency anemia in obesity.

In addition, differences between obese boys and girls were found in red blood cell counts (**Figure 1** and **Figure 2**, **Table 3**). Kim *et al*. (2006) [8] reported that total red blood cell count increased significantly in males with sepsis, but not in females. The increase in red blood cell count in relation to that of the BMI Z-score found in this work in obese boys and girls is also observed in similar studies (Freedman *et al*., 1989) [24]. Indeed, obesity is a state of chronic hypoxia that induces adipose tissue dysfunction, inflammation and insulin resistance. Chronic hypoxia can then contribute to increased red and white blood cell production. In addition, ferritin increases in obesity (Ellulu *et al*., 2017) [18], and may be related to changes in red blood cell counts.

In addition, although adolescent girls generally have more body fat and less muscle mass than boys, they do periodically lose blood and iron due to menstruation. Therefore, it is normal that the increase in red blood cells with increasing BMI Z-score is relatively low in our girls compared to boys. In addition, an elevated platelet count was also noted in obese subjects compared with normal-weight children and adolescents (**Table 2**). Thrombocytosis is thought to reflect the presence of an inflammatory process, and platelet activation plays an important role in accelerating atherothrombosis (Santilli *et al*., 2012) [10]. Lim *et al*. (2015) [25] reported that platelet count was associated with increased prevalence and risk of metabolic syndrome in obese children and adolescents.

Regarding the increase in platelet count with BMI Z-score found in our study, it seems to be influenced by gender. Stefanick *et al*. (1987) [7] reported that obese women have an elevated platelet count compared to normal-weight women, but without a significant increase in platelet count which is observed in men. Charles *et al*. (2007) [26] found a positive association between obesity and leukocyte or platelet counts in women, but not in men. However, the mechanisms involved in explaining the differences between boys and girls in blood cell composition and the risk of complications of obesity are not yet well understood. The differences found between the two sexes remain controversial and further studies should be conducted.

5. Conclusion

The hematological parameters for obese adolescents in this study differ from normal-weight adolescents. Significant higher values in leucocytes and platelets counts were found in obese boys and girls. All reported results were higher in boys than girls. Our results suggest that obesity is related to changes in the blood system, which might be a potential risk factor for obesity-related disease. These findings on the blood count profile of the obese adolescents studied confirm once again that obesity induces changes in the blood system, which could be a potential risk factor for obesity-related disease. When interpretation is completed for blood counts in children and adolescents, it is important to consider the relevance of BMI and to recognize that there are differences between obese boys and girls. This underscores the need to improve the management of obese children in the pediatric setting of Black Africa.

Conflicts of Interest

The authors declare no conflicts of interest.

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