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Changes in haematological parameters of children aged 5 to 18 years in Abidjan, Côte d'Ivoire

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The Millennium Development Goals include an aspect of children's health. The main purpose of this study was to indicate possible changes in different blood cells on one hand and secondly to establish standards of various parameters of the counts in the blood. The study involved 1,157 children aged 5 to 18 years in four selected municipalities of Abidjan. Blood sampling was done fasting in the morning, between 7 and 9 h for each child to complete blood count. In addition, an electrophoretic profile of each subject was performed from a volume of red blood cells. All observed haematological parameters in children was analyzed by a program Statistical Statsoft Windows version 7.1. The results of the study showed that all haematological parameters in children aged 5 to 18 years did not differ significantly by gender ($p > 0.05$) except for the red blood cells and thrombocytes. The red blood cells were significantly ($p < 0.05$) higher among boys ($4.9 \pm 0.02 \times 10^{12}$/L) than girls ($4.4 \pm 0.02 \times 10^{12}$/L). In contrast, girls ($297.5 \pm 5.4 \times 10^{6}$/L) in our study showed a significant increase in thrombocytes when compared with boys ($285.6 \pm 5.6 \times 10^{6}$/L). Morever, significant differences were observed between groups of children according to their age for red blood cells, hemoglobin, hematocrit and thrombocytes. Our investigations in these children have reported normal haematological status (11.5%) against 88.5% for abnormal haematological status. Furthermore, in all, 47% of the children presented with anaemia. The prevalence of studied children with normal hemoglobin was 84.4% against 15.6% for abnormal hemoglobin. Haematological parameters of the selected children are degraded in all. Nutrition, infectious and inflammatory syndromes and hemoglobinopathies could be the main factors.

Key words: Children, haematological status, anaemia, hemoglobin phenotype, Côte d'Ivoire.

INTRODUCTION

In September 2000, the United Nations government approved the Millennium Development Goals (MDGs). These goals, eight in number, must be achieved until 2015 (World Health Organization, 2000). The fourth objective to be achieved concerns the reduction of child mortality. The health of children around the world is a major preoccupation for many governments (Pelletier, 1994; The United Nations Children's Fund (UNICEF), 1996;

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Scrimshaw, 1998). An essential component of biological monitoring in children is quantitative and qualitative analysis of the blood cells. This blood cell counts are the main component of haematological parameters commonly sought and determined in the laboratories. The change of these biological blood parameters contributes to the assessment of the health status of children (Mian et al., 2002; Khattak and Ali, 2010).

In industrialized countries, the standards of the components of blood counts have long been established and available to the international institutions (WHO and UNICEF) to be used throughout the world. In poor countries and developing countries, malnutrition, infectious and inflammatory syndromes are regularly encountered. These factors lead to changes in haematological parameters in populations, thus leading to considerable prevalence of anaemia (Yip and Dallman, 1988, 1989; Dillon, 2000). So, are these standards applicable to poor and developing countries? Some developing countries have initiated setting standard components of the complete blood count for the well being of their populations (El-Hazmi and Warsy, 2001; Rakoto et al., 2000; Thakar et al., 2011).

In Côte d'Ivoire, studies have reported prevalences of anaemia in children, with few risk factors (Assobayire et al., 2001; Yapi et al., 2005). However, to the best of our knowledge, no study on the changes and the establishment of haematological parameters standards in children aged 5 to 18 have been reported. This study aims to determine and assess the haematological status of children aged 5 to 18 years in Abidjan. In this context, our investigation is specifically to: (1) Determine the prevalence of anaemia and estimate possible changes in haematological parameters in these children; (2) propose standards of haematological parameters according to age groups and sex and; (3) determine the profile of hemoglobin electrophoresis of these children.

MATERIALS AND METHODS

Subjects and study design

The study subjects were children aged 5 to 18 years for both sexes. This study was originally conducted among 1,293 children over a period, from October, 2008 to December, 2010. The children belonged to different social strata. Anthropometric data collection for this study was carried out on a questionnaire sent to children, with free and informed assent of parents, after an explanation of the goals and interests of the study. For the selection of subjects, a set of criteria including clinical and biological signs allowed the exclusion and inclusion of subjects for the needs of our investigations. It was effected in any pregnancy (female subject), gynecological, haematological, digestive complications, and inflammation in the three months preceding the study. All these observations were performed by a medical team from the National Institute of Public Health (INSP) in Côte d'Ivoire. Depending on these criteria, 1,157 subjects were selected (583 boys representing 50.4% and 574 girls representing 49.6%). These children were enrolled in primary schools, secondary schools and households in 4 municipalities (Abobo, Adjamé, Cocody and Yopougon) of Abidjan. A total of 455 children were selected in Abobo, 219 in Adjamé, 102 in Cocody and 381 children Yopougon (Figure 1).

Assays of blood samples

In each child, 5 ml of blood by venipuncture bend of the elbow were performed during fasting in the morning, between 7 and 9 h in a tube containing an anticoagulant (Ethyl diamine tetra acetic acid/EDTA). The blood sample was used to determine both blood count and hemoglobin electrophoresis. The automatic hematological analyzer "Sysmex KX-21N" was used to measure the blood count. An electrophoretic profile of each subject was performed from a volume of packed red blood cells. Helena was used to evaluate types of hemoglobin by electrophoresis on alkaline pH cellulose acetate. Each assay of the blood sample from the same sample was duplicated to minimize potential misuse and the average of the two obtained was used for the study.

Evaluation and statistical analysis of biological parameters

To better obtain different prévalences of haematological status of study population, reference limits of each parameter were used (FSH, 2006). Thus, prévalences and proportions of main haematological parameters such as type of anaemia have been defined. Data were expressed as means ± standard error of mean (SEM). Statistical analysis of the results was determined by using the unpaired Student's t-test according to sex. The possible change of haematological parameters by sex and age of children was highlighted by a factorial analysis of variance (ANOVA) with two factors (sex and age). This treatment was associated Newman-Keuls as post hoc statistical multivariate test. The first two statistical tests were performed from Statistica Statsoft version Windows 7.1 (Statsoft, 2005). For the comparison of different obtained proportions, the G test was performed by R software version 2.1.1 windows (Ihaka and Gentleman, 1996). A value of $p < 0.05$ was considered as indicative of significance.

Ethics

Experimental procedures and protocols used in this study were approved by ethical committee of Health Sciences, Nangui Abrogoua University. These guide lines were in accordance with the internationally accepted principles for laboratory use and care. Approval was also obtained from the Ministry of Higher Education and Scientific Research and the Ministry of Health and Public Hygiene in the Republic of Côte d'Ivoire.

RESULTS

Description of study population

The males predominated with a sex ratio of 1.02. The average age of the study population was 11.2 ± 0.1 years with 11.1 ± 0.1 years for males and 11.3 ± 0.2 for females. From the age groups, 26.1% of children were 5 to 10 years, 51.9% from 11 to 15 years and 19.4% from 16 to 18 years. The average value of body mass index (BMI) was 18.6 ± 0.1 kg/m^{-2} for the population aged 12 to18 and -1.3 ± 0.01 (Z-rated score). Most subjects were schooled, 96.3% against 1.3% out of school and 3.8% dropouts (Table 1).

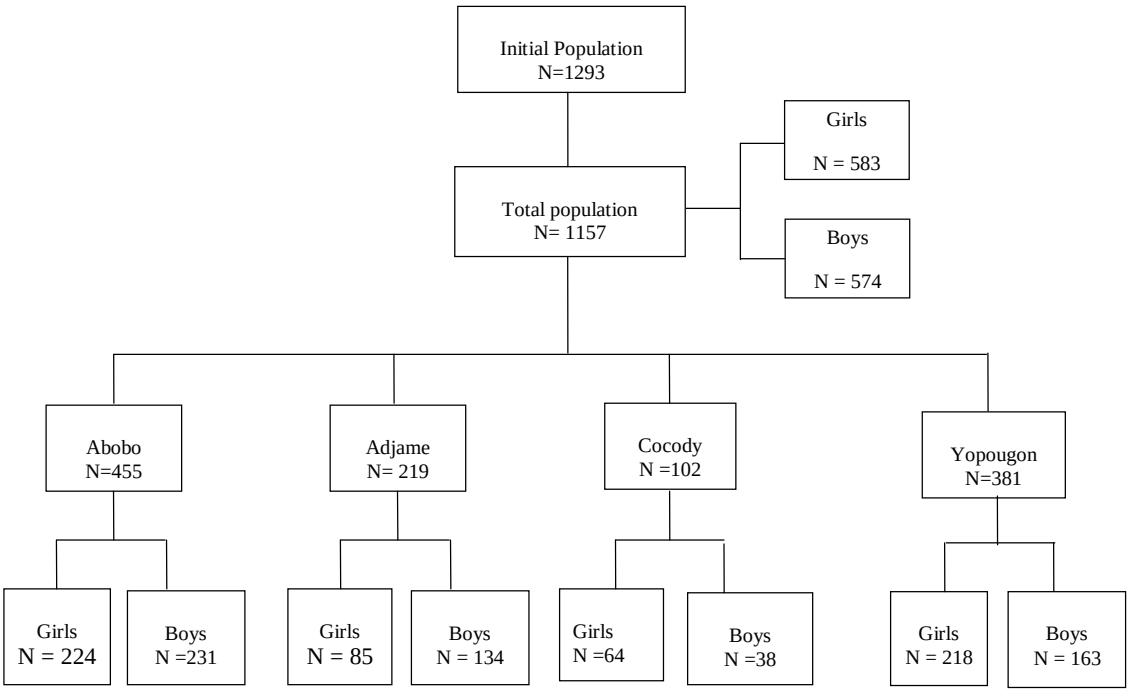

Figure 1. Size of the selected study populations.

Change in haematological parameters according to the sex of children

The results of the study showed that all haematological parameters in children aged 5 to 18 years did not differ significantly ($p > 0.05$) except for red blood cells and platelets. In this context, the mean red blood cell count was significantly ($p < 0.05$) higher among boys ($4.9 \pm 0.02 \times 10^{12}$/L) than girls ($4.4 \pm 0.02 \times 10^{12}$/L). In contrast, girls ($297.5 \pm 5.4 \times 10^{6}$/L) in our study reported increased level of thrombocytes when compared with boys ($285.6 \pm 5.6 \times 10^{6}$/L). The values of all hematological parameters were normal compared to references made by international institutions except mean corpuscular volume (MCV < 80 fl), the hematocrit (< 35%) hemoglobin boys (< 13 g/dl) and mean corpuscular hemoglobin (< 27 pg) (Table 2).

For non-anaemic children, only the number of red blood cells, hemoglobin, hematocrit levels and thrombocytes were significantly ($p < 0.05$) different between the two groups of children among all determined haematological parameters. In this context, the boys showed the highest values of red blood cells, hemoglobin and hematocrit ($5.2 \pm 0.03 \times 10^{12}$/L, 13.6 ± 0.1 g/dl, and 41.9 ± 0.2%, respectively) than the girls ($4.8 \pm 0.03 \times 10^{12}$/L, 12.7 ± 0.1 g/dl, and 38.5 ± 0.2%, respectively) in the study. However, girls showed that the rate of thrombocytes significantly ($p < 0.01$) increased ($289.5 \pm 5.4 \times 10^{6}$/L) compared to boys ($254.3 \pm 5.2 \times 10^{6}$/L). In addition, all the values of haematological parameters were normal in children who were non-anaemic with the exception of hematocrit (< 35%) compared with established reference limits (Table 3).

Prevalence of anaemia and hemoglobin phenotype by gender

Our investigations in children showed that very few of them had normal haematological status of 11.5% against 88.5% in abnormal haematological status (Table 4). The same observation in all was reported in boys (11.3% against 88.7%) than girls (11.7% against 88.3%). No significant difference in haematological status was observed in the different sexes. The overall prevalence of anemia in the study population was 47%. Boys (54.9%) showed a prevalence which was significantly ($p = 0.03$) higher than girls (39.3 %). In addition, 15 (1.3%) girls reported values above standard hemoglobin (polycythemia) against any boy (0%). The children in the study showed no severe anemia. However, 84.4% of children aged 5 to 18 years revealed moderate anaemia against 15.6% for mild anaemia. The prevalence of fruste anaemia was significantly higher among girls (23.6%) compared to boys (9.8%).The prevalence of hypochromic microcytic anaemia, microcytic normochromic anaemia, hypochromic normocytic anaemia, normochromic normocytic anaemiaand normochromic macrocytic-anaemia were observed (18.3, 0.4, 9.2, 9.7 and 0.3%, respectively). Among different observed prevalences,

Table 1. Characteristics of study population.

Characteristic parameter	Total population	Boys	Girls
		% (n)	
Age (years)	11.2±0.1	11.1±0.1	11.3±0.2
5-10	26.1 (302)	23.3 (134)	28.8 (168)
11-15	51.9 (600)	49.3 (283)	54.4 (317)
16-18	19.4 (255)	27.4 (157)	16.8 (98)
Weight (kg)	34.5±0.4	34.6±0.5	34.3±0.4
Height (m)	1.5±0.01	1.4±0.01	1.4±0.01
Body mass index (kg/m^{-2})			
Subjects between 12 and 18 years (N=847)	18.6±0.1	18.2 ± 0.2	19 ± 0.2
<18.5	11.5 (97)	13.8 (60)	9 (37)
18.5-26	85.1 (721)	83.7 (365)	86.6 (356)
>26	3.4 (29)	2.5 (11)	4.4 (18)
Subjects between 5 and 11 years (N=310) (Z-score rated, mean±SEM)	-1.3±0.01	-1.5±0.1	-1.2±0.1
<-2Z	26.8 (83)	30.4 (42)	23.8 (41)
-2Z	72.9 (226)	69.6 (96)	75.6 (130)
>2Z	0.3 (1)	0 (0)	0.6 (1)
Education			
Educated	96.3 (1114)	95.8 (550)	96.7 (564)
Non educated	1.3 (11)	0.9 (4)	1.7 (7)
Dropouts	3.8 (32)	4.6 (20)	2.9 (12)

SEM: Standard error of mean.

Table 2. Mean values of haematological parameters in study population according to sex.

Haematological parameter	Total population			Girls			Boys		
	Mean±SEM	Min	Max	Mean±SEM	Min	Max	Mean±SEM	Min	Max
Red blood cells (10^{12}/L)	4.8±0.02	2.4	7.01	4.4±0.02	2.4	7	4.9±0.02*	2.5	7.01
Hemoglobin (g/dl)	12.2±0.1	6.7	19	12.1±0.04	7.3	19	12.3±0.04	6.7	18.1
Hematocrit (%)	37.8±0.2	20.8	59.9	37.2±0.02	20.8	59.9	38.3±0.2	21	56.2
MCV (fl)	79±0.3	34.7	100	79.2±0.4	56	100	78.7±0.5	34.7	98.9
MCH (pg)	25.6±0.1	16.6	37.9	25.7±0.2	17.4	37.9	25.5±0.2	16.6	36.4
MCHC (g/dl)	32.5±0.5	20	36	32.6±0.1	20	36	32.4±0.1	23.3	36
Leukocytes (10^6/L)	5.8±0.1	2	13.1	5.8±0.01	2	13.1	5.9±0.04	2.2	12.2
Neutrophils (%)	22±0.5	11	77	43.2±0.5	15	75	43.8±0.3	11	77
Eosinophils (%)	1.1±0.1	0	5	1.9±0.1	0	5	1.8±0.1	0	1
Basophils (%)	0.001±0.01	0	1	0	0	1	0.01±0.01	0	1
lymphocytes (%)	27±0.4	15	86	50.1±0.5	15	83	49.5±0.7	19	86
Monocytes (%)	2.6±0.1	1	8	4.9±0.1	2	8	4.8±0.4	1	8
Thrombocytes (10^6/L)	291.6±3.9	34	695	297.5±5.4	34	604	285.6±5.6*	52	695

MCV: mean corpuscular volume; MCH: mean corpuscular hemoglobin; MCHC: mean corpuscular hemoglobin concentration; *: statistically significant difference for $p < 0.05$, Min: minimum; Max: maximum.

hypochromic microcytic anaemia predominated in all study subjects. Non-significant difference was indicated for the prevalence of anaemia between boys and girls. In addition, 39.2% of children aged 5 to 18 years reported hematocrit values below the norm. For these values of hematocrit, a highly significant difference ($p = 0.005$) was observed between boys and girls in our study (Table 4). To this end, the boys (51.7%) reported the highest prevalence compared to girls (26.9%). In addition, 23 (2%) children of our work showed hematocrit values above the reference limit (polycythemia). The prevalence of microcytosis, macrocytosis and hypochromia observed

Table 3. Normal mean values of haematological parameters in non anaemic subjects.

Haematological parameter	Total population			Girls			Boys		
	Mean±SEM	Min	Max	Mean±SEM	Min	Max	Mean±SEM	Min	Max
Red blood cells (10^{12}/L)	5±0.2	4	7.01	4.8±0.03	4	6.6	5.2±0.03*	4.1	7.01
Hemoglobin (g/dl)	13.1±0.04	11.5	18	12.7±0.1	11.5	15.4	13.6±0.1*	11.5	18
Hematocrit (%)	40.1±0.1	36.1	49.3	38.5±0.2	36.1	47.3	41.9±0.2*	36.1	49.3
MCV (fl)	81±0.3	70.3	100	80.4±0.4	70.3	100	81.6±0.4	70.3	98.9
MCH (pg)	26.6±0.1	24.1	36.4	26.6±0.1	24.1	33	26.6±0.2	24.3	36.4
MCHC (g/dl)	33.1±0.1	32.1	35.9	33.2±0.1	32.1	35.9	33.03±0.1	32.1	35.8
Leucocytes (10^6/L)	5.7±0.1	4.1	10.4	5.7±0.1	4.1	9.6	5.6±0.1	4.1	10.4
Neutrophils (%)	44.3±0.4	40	68	43.9±0.6	40	67	44.9±0.6	40	68
Eosinophils (%)	1.7±0.03	1	5	1.7±0.1	1	4	1.7±0.1	1	5
Basophils (%)	0.01±0.003	0	1	0.01±0.005	0	1	0.01±0.006	0	1
lymphocytes (%)	49.3±0.4	22	40	49.8±0.6	22	40	48.7±0.6	20	40
Monocytes (%)	4.6±0.1	4	8	4.6±0.1	4	8	4.5±0.1	4	8
Thrombocytes (10^6/L)	273.4±3.5	151	398	289.5±5.4	156	398	254.3±5.2**	151	396

MCV: Mean Corpuscular Volume; MCH: Mean corpuscular hemoglobin; MCHC: Mean corpuscular hemoglobin concentration; *: Statistically significant difference for $p < 0.05$; **: Statistically significant difference for $p < 0.01$.

in our study were 35.3, 1.4 and 53.7%, respectively. These different prevalence among boys and girls showed no significant difference ($p < 0.05$).

In Table 5, the proportions of leukocyte and thrombocyte parameters of all children were summarized. From analysis, comparing these proportions, no significant difference ($p < 0.05$) was observed between boys and girls in this study. However, high rates of leukopenia, neutropenia and lymphocytosis in our study were reported (26.8, 21.5 and 26%, respectively). In contrast, lower proportions of leukocytosis, lymphopenia, thrombocytopenia and thrombocytosis were observed (0.8, 0.1, 5.2 and 5.9%, respectively).The electrophoretic profile of hemoglobin was reported in Table 6. The prevalence of children with normal hemoglobin was 84.4% against 15.6% for abnormal hemoglobin. Different abnormal hemoglobins phenotypes observed in children in this study were, AS (7.4%), SS (0.1%), CA (7.2%), CC (0.4%), and SC (0.5%). Hemoglobin phenotypes AS and AC predominated in study subjects. For all these observed proportions, no significant difference ($p > 0.05$) was revealed between boys and girls in our investigation.Among the phenotypes of abnormal hemoglobins, the SS phenotype was not observed in boys.

Interaction of sex and age on haematological status

On haematological parameters

In Table 7, the results of our work indicated variations in the red blood cells, hemoglobin, hematocrit and mean corpuscular volume according to age of children and the sex. Thus, these 4 haematological parameters remained constant from 5 to 15 years before increasing significantly ($p < 0.05$) for boys up to 18 years. However, among girls, the red blood cells ($4.8 \pm 0.03 \times 10^{12}$/L, $4.7 \pm 0.03 \times 10^{12}$/L, and $4.4 \pm 0.1 \times 10^{12}$/L, respectively), the hemoglobin (12 ± 0.1, 12.2 ± 0.1, and 12.3 ± 0.1 g/dl, respectively) and hematocrit (37.4 ± 0.2, 37.1 ± 0.2, and 36.6 ± 0.4%, respectively) were significantly ($p < 0.05$) decreased between 16 and 18 years. In contrast, mean corpuscular volume (77.9 ± 0.4, 79.3 ± 0.3, and 84.2 ± 0.7 fl, respectively) was significantly ($p < 0.05$) increased between girls of 16 and 18 years in our investigation. For this purpose, the values of these three haematological parameters were significantly higher among boys compared to girls. Moreover, no influence was observed between gender, age and mean corpuscular volume (MCV) in study children. However, the number of thrombocytes presented variations between boys and girls according to the age of the children. To this end, between 5 and 10 years on one hand, and the other between 16 and 18 years, thrombocytes were significantly ($p < 0.05$) higher in girls ($329.5 \pm 7.1 \times 10^6$/L and $237.6 \pm 7.6 \times 10^6$/L, respectively) compared to boys ($319.4 \pm 7.8 \times 10^6$/L and $217.1 \pm 5.3\ 10^6$/L, respectively). Sex and age were therefore interacted with these haematological parameters among children in Abidjan for ages 5 to 10 years and 16 to 18 years.

Anaemia and proportions of major haematological parameters

The haematological status of children by sex and age summarized in (Table 8) was degraded. The results showed

Table 4. Proportions (%) of the main erythrocyte parameters and types of anaemia.

Biological parameter	Total population		Girls		Boys		p-value
	n	% (95% CI)	n	% (95% CI)	n	% (95% CI)	
Haematological status							
Normal	133	11.5 (9.7-13.3)	68	11.7 (9.1-14.3)	65	11.3 (8.7-13.9)	0.9 (NS)
Abnormal	1024	88.5 (86.7-90.3)	515	88.3 (85.5-90.8)	509	88.7 (86.1-91.3)	0.9 (NS)
Hemoglobin (g/dl)							
Low	544	47 (44.1-49.9)	229	39.3 (35.3-43.2)	315	54.9 (50.8-58.9)	**0.03 (S)**
Normal	598	51.7 (48.8-54.6)	339	58.1 (54.1-62.2)	259	45.1 (41.1-49.2)	0.2 (NS)
High	15	1.3 (0.6-1.9)	15	2.6 (1.3-3.9)	0	0	0.6 (NS)
Types of anaemia							
Light	85	15.6 (12.6-18.7)	54	23.6 (18.1-29.1)	31	9.8 (6.5-13.1)	**0.02 (S)**
Moderate	459	84.4 (81.4-87.5)	175	76.4 (70.9-81.9)	284	90.2 (86.9-93.5)	0.3 (NS)
Severe	-	-	-	-	-	-	-
MHA	212	18.3 (16.1-20.6)	109	18.7 (15.5-21.9)	103	17.9 (14.8-21.1)	0.9 (NS)
MNA	5	0.4 (0.1-0.8)	4	0.7 (0-1.4)	1	0.2 (-0.2-0.5)	0.6 (NS)
NHA	107	9.2 (7.6-10.9)	60	10.3 (7.8-12.8)	47	8.2 (5.9-10.4)	0.6 (NS)
NNA	112	9.7 (8-11.4)	69	11.8 (9.2-14.5)	43	7.5 (5.3-9.6)	0.3 (NS)
mNA	4	0.3 (0-0.7)	2	0.3 (-0.1-0.8)	2	0.3 (-0.1-0.8)	1 (NS)
Hematocrit (%)							
Low	454	39.2 (36.4-42.1)	157	26.9 (23.3-30.5)	297	51.7 (47.7-55.8)	**0.005 (S)**
Normal	680	58.8 (55.9-61.6)	416	71.4 (67.7-75)	264	46 (41.9-50.1)	**0.02 (S)**
High	23	2 (1.2-2.8)	10	1.7 (0.7-2.8)	13	2.3 (1-3.5)	0.8 (NS)
MCV (fl)							
Low	408	35.3 (32.5-38)	203	34.8 (31-38.7)	205	35.7 (58.6-66.5)	0.9 (NS)
Normal	733	63.4 (60.6-66.1)	374	64.2 (60.3-68)	359	62.5 (58.6-66.5)	0.9 (NS)
High	16	1.4 (0.7-2.1)	6	1 (0.2-1.8)	10	1.7 (0.7-2.8)	0.7 (NS)
MCH (pg)							
Low	621	53.7 (50.8-56.5)	294	50.4 (46.4-54.5)	327	57 (52.9-61)	0.5 (NS)
Normal	536	46.3 (43.5-49.2)	289	49.6 (45.5-53.6)	247	43 (39-47.1)	0.5 (NS)

n: subjects number observed in each group; MCV: mean corpuscular volume; MCH: mean corpuscular hemoglobin; MCHC: mean corpuscular hemoglobin concentration; NNA: normocytic normochromic anaemia; MNA: microcytic normochromic anaemia; NHA: normocytic hypochromic anaemia; MHA: microcytic hypochromic anaemia; mNA: macrocytic normochromic anaemia; S: Significant difference for $p < 0.05$; NS: not significant for $p > 0.05$.

showed that girls from 16 to 18 years indicated no normal haematological status. For this age group, there was an interaction of sex and age on all haematological parameters. The last two age groups of children namely 11 to 15 years and 16 to 18 years reported the highest prevalences of anaemia (60.7 and 37.3%, respectively). However, children aged 11 to 15 were most at risk of anaemia in this study, with a high rate of boys compared to girls (80.9% against 42.6%). In addition, no child in this investigation showed severe anemia. Moreover, only children aged 11 to 15 years revealed polycythemia (1.6%), with a higher prevalence among girls (2.8%) than boys (0.4%). In changes of erythrocyte indices, this same age group of children reported the highest rate of hypochromic microcytic anaemia (36.2%).The boys are still the most vulnerable to this type of anaemia, with 46.6% against 26.8% for girls (Table 8). On the contrary, there were children of 5 to 10 years who showed the lowest prevalence of hypochromic microcytic anaemia (5.3%). However, only those children reported a prevalence of normochromic macrocytic anaemia (1.3%). For erythrocyte parameters, the proportions of children under the limits of MCV were not known with associated impact of sex and age. In contrast, the rate of hematocrit and mean corpuscular hemoglobin (MCH) were influenced by the sex and age of children in the study. Thus

Table 5. Proportions of main white blood cells and thrombocytes parameters.

Erythrocytes parameter	Total population		Girls		Boys		p values
	n	% (CI 95%)	n	% (CI 95%)	n	% (IC 95 %)	
Leucocytes (10^6/L)							
Low	310	26.8 (24.2-29.3)	151	25.9 (22.3-29.5)	159	27.7 (24-31.4)	0.8 (NS)
Normal	838	72.4 (69.9-75)	427	73.2 (69.6-76.8)	411	71.6 (67.9-75.3)	0.9 (NS)
High	9	0.8 (0.3-1.3)	5	0.9 (0.1-1.6)	4	0.7 (0-1.4)	0.9 (NS)
Neutrophils (%)							
Low	249	21.5 (19.2-23.9)	125	21.4 (18.1-24.8)	124	21.6 (18.2-25)	0.9 (NS)
Normal	897	77.5 (75.1-79.9)	453	77.7 (74.3-81.1)	444	77.4 (73.9-80.8)	0.9 (NS)
High	11	1 (0.4-1.5)	5	0.9 (0.1-1.6)	6	1 (0.2-1.9)	0.9 (NS)
Eosinophils (%)							
Low	83	7.2 (5.7-8.7)	36	6.2 (4.2-8.1)	47	8.2 (5.9-10.4)	0.6 (NS)
Normal	1074	92.8 (91.3-94.3)	547	93.8 (91.9-95.8)	527	91.8 (89.6-94.1)	0.9 (NS)
Basophils (%)							
Normal	1155	99.8 (99.6-100.1)	583	100 (100-100)	572	99.7 (99.2-100.1)	0.9 (NS)
High	2	0.2 (-0.1-0.4)	0	0	2	0.3 (-0.1-0.8)	0.9 (NS)
Lymphocytes (%)							
Low	1	0.1 (-0.1-0.3)	1	0.2 (-0.2-.05)	0	0	0.9 (NS)
Normal	855	73.9 (71.4-76.4)	409	70.2 (66.4-73.9)	446	77.7 (74.3-81.1)	0.5 (NS)
High	301	26 (23.5-28.5)	173	29.7 (26-33.4)	128	22.3 (18.9-25.7)	0.3 (NS)
Monocytes (%)							
Low	55	4.8 (3.5-6)	22	3.8 (2.2-5.3)	33	5.7 (3.8-7.7)	0.5 (NS)
Normal	1102	95.2 (94-96.5)	561	96.2 (94.7-97.8)	541	94.3 (92.3-96.2)	0.9 (NS)
Thrombocytes (10^6/L)							
Low	60	5.2 (3.9-6.5)	26	4.5 (2.8-6.1)	34	5.9 (4-7.9)	0.7 (NS)
Normal	1029	88.9 (87.1-90.7)	513	88 (85.4-90.6)	516	89.9 (87.4-92.4)	0.9 (NS)
High	68	5.9 (4.5-7.2)	44	7.5 (5.4-9.7)	24	4.2 (2.5-5.8)	0.3 (NS)

n: subjects number observed in each group; NS: not significant for $p > 0.05$.

Thus, the boys aged 11 to 15 years indicated a significantly higher proportion (84.1%) in lower values of hematocrit compared to girls (24.6%). In contrast, girls aged 16 to 18 years showed an increased proportion of values below the standard hematocrit (31.6%) compared to boys (12.1%). For MCH, only the prevalence of hypochromia was impacted simultaneously by gender and age in children aged 5 to 10 years. In fact, the boys in this age group have shown a high proportion of hypochromia (46.3%) against 27.4% for girls (Table 8). However, the proportions of children according to the threshold values of MCV were not influenced by sex and age parameters. For leukocyte and thrombocyte parameters, no proportion of children according to their limits showed any influence of gender and age except those of eosinophils. In this context, the boys of the age group 16 to 18 years revealed a high rate of eosinophils lower values (Table 9).

DISCUSSION

The study of haematological parameters in children based on established references shows an alteration in all parameters according to sex (FSH, 2006). The results of this study indicate that 88.5% of children have an abnormal haematological status. These results are similar to those of Atto et al. (2012), with a rate of 90.6% in children (adolescents) aged 12 to 18 years in Abidjan. Most Haematological changed parameters concern the number of red blood cells, hemoglobin, hematocrit and thrombocytes. The first cited haematological parameters

Table 6. Hemoglobin profile of children.

Subject group	Normal		Abnormal		Abnormal									
					AS		SS		AC		CC		SC	
	n/%	(95%CI)	n/%	(95%CI)	n/%	(95%CI)	n/%	(95%CI)	n/%	(95%CI)	n/%	(95%CI)	n/%	(95%CI)
Total population	976/84.4	(82.3-86.4)	181/15.6	(13.6-17.7)	86/7.4	(5.9-8.9)	1/0.1	(0.1-0.3)	83/7.2	(5.7-8.7)	5/0.4	(0.1-0.8)	6/0.5	(0.1-0.9)
Boys	472/82.2	(79.1-85.4)	102/17.8	(14.6-20.9)	49/8.5	(6.3-10.8)	0/0	0	47/8.2	(5.9-10.4)	2/0.3	(0.1-0.8)	4/0.7	(0-1.4)
Girls	504/86.4	(83.7-89.2)	79/13.6	(10.8-16.3)	37/6.3	(4.4-8.3)	1/0.2	(0.2-0.5)	37/6.3	(4.4-8.3)	3/0.5	(0.1-1.1)	1/0.2	(0.2-0.5)
p-value	0.7 (NS)		0.5 (NS)		0.6 (NS)		0.6 (NS)		0.6 (NS)		0.8 (NS)		0.6 (NS)	

n: subjects number observed in each group; NS: not significant for $p > 0.05$.

Table 7. Changes in haematological parameters according to age groups.

Haematological parameter	Age group (Years)								
	5-10			11-15			16-18		
	Total population	Girls	Boys	Total population	Girls	Boys	Total population	Girls	Boys
Red blood cells (10^{12}/L)	4.8±0.02	4.8±0.03^{a}	4.9±0.03^{b}	4.7±0.02	4.7±0.03^{a}	4.8±0.03^{b}	5±0.04	4.4±0.1^{b}	5.2±0.04^{a}*
Hemoglobin (g/dl)	11.9±0.1	12±0.1^{a}	11.8±0.1^{b}	12.3±0.1	12.2±0.1^{a}	12.3±0.1^{b}	12.9±0.1	11.5±0.1^{b}	13.8±0.1^{a}*
Hematocrit (%)	37.2±0.1	37.4±0.2^{a}	37±0.2^{b}	37.1±0.2	37.1±0.2^{a}	37.2±0.2^{b}	41±0.3	36.6±0.4^{b}	43.8±0.3^{a}*
MCV (fl)	77.3±0.3	77.9±0.4^{b}	76.5±0.5^{b}	78.9±0.3	79.3±0.3^{b}	78.4±0.4^{b}	84.6±0.4	84.2±0.7^{a}	84.9±0.5^{a}
MCH (pg)	24.9±0.1	25.2±0.2	24.6±0.2	26.1±0.1	26.2±0.1	26±0.1	26.6±0.2	26.2±0.3	26.9±0.2
MCHC (g/dl)	32.1±0.1	32.2±0.1	32±0.1	33±0.1	33.1±0.1	32.9±0.1	32.6±0.2	32.4±0.3	32.7±0.2
Leucocytes (10^{6}/L)	6±0.1	6±0.1	6.1±0.1	5.8±0.1	5.7±0.1	5.8±0.1	5.1±0.1	4.8±0.1	5.3±0.1
Neutrophils (%)	41.5±0.5	40.9±0.6	42.3±0.8	44.9±0.4	44.9±0.5	44.9±0.6	46.5±0.6	47.3±0.9	46±0.9
Eosinophils (%)	2.1±0.1	2.1±0.1	2.1±0.1	1.6±0.03	1.6±0.05	1.6±0.1	1.6±0.1	1.8±0.1	1.5±0.1
Basophils (%)	0±0	0±0	0±0	0.01±0.003	0.01±0.004	0.01±0.005	0.01±0.01	0±0	0.02±0.01
lymphocytes (%)	51.2±0.6	51.9±0.7	50.4±0.9	49.1±0.4	49±0.6	49.1±0.6	47±0.6	45.5±0.9	48±0.9
Monocytes (%)	5.2±0.1	5.1±0.1	5.2±0.1	4.4±0.1	4.4±0.1	4.3±0.1	4.7±0.1	5.3±0.1	4.2±0.1
Thrombocytes (10^{6}/L)	325±5.2	329.5±7.1^{b}	319.4±7.8^{b}*	274±3.2	275.9±4.4^{a}	271.8±4.7^{a}	225±4.4	237.6±7.6^{b}	217.1±5.3^{b}*

MCV: mean corpuscular volume; MCH: mean corpuscular hemoglobin; MCHC: mean corpuscular hemoglobin concentration; *: statistically significant difference for $p < 0.05$ between boys and girls in each group of age; a and b: statistically significant difference for $p < 0.05$ between different groups of age in boys or girls.

are increasing in boys than girls.However, the number of thrombocytes is more considerable among girls than boys. Several conducted studies by the WHO (1986), Dallman and Sijmes (1979) and the Center for Disease Control of the United States of America (CDC) (1998) confirm the observations reported in this investigation. In Côte d'Ivoire, Atto et al. (2012) revealed a similar observation in their work in Abidjan. However, during their investigation, the authors found that some haematological parameters were degraded. The alterations in haematological parameters

Table 8. Proportions (%) of the main erythrocyte parameters and types of anaemia according the age group.

Haematological status	5-10 years			11-15 years			16-18 years		
	Total population	Boys	Girls	Total population	Boys	Girls	Total population	Boys	Girls
					n (%)				
Normal	14 (4.6)	8 (6)[a]	6 (3.6)	16 (2.7)	5 (1.8)[b]	11 (3.5)	17 (6.7)	17 (10.8)[a]	0 (0)*
Abnormal	288 (95.4)	126 (94)[a]	162 (96.4)	584 (97.3)	278 (98.2)[a]	306 (96.5)	238 (93.3)	140 (89.2)[a]	98 (100)
Hemoglobin (g/dl)									
Low	96 (31.8)	46 (34.3)[a]	50 (29.8)	364 (60.7)	229 (80.9)[b]	135 (42.6)**	95 (37.3)	34 (21.7)[a]	61 (62.2)***
Normal	206 (68.2)	108 (80.6)[a]	118 (70.2)	226 (37.7)	53 (18.7)[b]	173 (54.6)**	160 (62.7)	123 (78.3)[a]	37 (37.8)***
High	0 (0)	0 (0)[a]	0 (0)	10 (1.6)	1 (0.4)[a]	9 (2.8)*	0 (0)	0 (0)[a]	0 (0)
Types of anaemia									
Light	7 (2.3)	5 (3.7)[a]	2 (1.2)	347 (57.8)	224 (79.2)[b]	123 (38.8)**	63 (24.7)	29 (18.5)[c]	34 (34.7)*
Moderate	89 (29.5)	41 (30.6)[a]	48 (28.6)	17 (2.9)	5 (1.8)[b]	12 (3.8)	32 (12.6)	5 (3.2)[b]	17 (17.3)*
Severe	0 (0)	0 (0)[a]	0 (0)	0 (0)	0 (0)[a]	0 (0)	0 (0)	0 (0)[a]	0 (0)
MHA	20 (5.3)	14 (7.5)[a]	6 (3.6)*	217 (36.2)	132 (46.6)[b]	85 (26.8)*	28 (11)	11 (7)[a]	17 (17.3)*
MNA	0 (0)	0 (0)[a]	0 (0)	11 (1.8)	7 (2.5)[a]	4 (1.3)	0 (0)	0 (0)[a]	0 (0)
NHA	38 (12.6)	19 (14.2)[a]	19 (11.3)	43 (7.2)	21 (7.4)[a]	22 (6.9)	45 (17.6)	16 (10.2)[a]	29 (29.6)*
NNA	34 (11.3)	11 (8.2)[a]	23 (13.7)	91 (15.2)	61 (21.6)[b]	30 (9.5)*	22/8.6	7 (4.5)[a]	15 (15.3)*
mNA	4 (1.3)	2 (1.5)[a]	2 (1.2)	0 (0)	0 (0)[a]	0 (0)	0 (0)	0 (0)[a]	0 (0)
Hematocrit (%)									
Low	87 (28.8)	41 (30.6)[a]	46 (27.4)	316 (52.7)	238 (84.1)[b]	78 (24.6)***	50 (19.6)	19 (12.1)[c]	31 (31.6)*
Normal	215 (71.2)	93 (69.4)[a]	122 (72.6)	268 (44.7)	39 (13.8)[b]	229 (72.2)***	197 (77.3)	130 (82.8)[c]	67 (68.4)*
High	0 (0)	0 (0)[a]	0 (0)	16 (2.7)	6 (2.1)[a]	10 (3.2)	8 (3.1)	8 (5.1)[ab]	0 (0)*
MCV (fl)									
Low	31 (10.3)	19 (14.2)[a]	12 (7.1)	329 (54.8)	163 (57.6)[b]	166 (52.4	51 (20)	31 (19.7)[a]	20 (20.4)
Normal	258 (85.4)	113 (84.3)[a]	145 (86.3)	271 (45.2)	120 (42.4)[b]	151 (47.6)	203 (79.6)	126 (80.3)[a]	77 (78.6)
High	13 (4.3)	2 (1.5)[a]	11 (6.5)	0 (0)	0 (0)[a]	0 (0)	1 (0.4)	0 (0)[a]	1 (1)
MCH (pg)									
Low	108 (35.8)	62 (46.3)[a]	46 (27.4)*	370 (61.7)	187 (66.1)[a]	189 (59.6)	147 (57.6)	86 (54.8)[a]	61 (62.2)
Normal	194 (64.2)	72 (53.7)[a]	122 (72.6)	230 (38.3)	96 (33.9)[b]	128 (40.4)	108 (42.4)	71 (45.2)[b]	37 (37.8)

n: subjects number observed in each group; MCV: mean corpuscular volume; MCH: mean corpuscular hemoglobin; MCHC: mean corpuscular hemoglobin concentration; NNA: normocytic normochromic anaemia; MNA: microcytic normochromic anaemia; NHA: normocytic hypochromic anaemia; MHA: microcytic hypochromic anaemia; mNA: macrocytic normochromic anaemia *: statistically significant difference for $p < 0.05$ between boys and girls in each group of age; a, b and c: statistically significant difference for $p < 0.05$ between different groups of age in boys or girls.

Table 9. Proportions of main white blood cells and thrombocytes parameters according the age group

Leukocytes and thrombocytes parameters	5-10 years			11-15 years			16-18 years		
	Total population	Boys	Girls	Total population	Boys	Girls	Total population	Boys	Girls
	n (%)								
Leucocytes (10^6/L)									
Low	13 (4.3)	8 (6)[a]	5 (3)b*	60 (10)	31 (11)[a]	29 (9.1)[a]	46 (18)	24 (15.3)[a]	22 (22.4)[c]
Normal	287 (95)	126 (94)[a]	161 (95.8)[a]	540 (90)	252 (89)[a]	288 (90.9)[a]	208 (81.6)	132 (84.1)[a]	76 (77.6)[a]
High	2 (0.7)	0 (0)[a]	2 (1.2)[a]	0 (0)	0 (0)[a]	0 (0)[a]	1 (0.4)	1 (0.6)[a]	0 (0)[a]
Neutrophils (%)									
Low	134 (44.4)	58 (43.3)[a]	76 (45.2)[a]	155 (25.8)	70 (24.7)[b]	85 (26.8)[b]	57 (22.4)	39 (24.8)[b]	18 (18.4)[b]
Normal	267 (88.4)	76 (56.7)[b]	91 (54.2)[b]	441 (73.5)	212 (74.9)[a]	229 (72.3)[a]	198 (77.6)	118 (75.2)[a]	80 (81.6)[a]
High	1 (0.2)	0 (0)[a]	1 (0.6)[a]	4 (0.7)	1 (0.4)[a]	3 (0.9)[a]	0 (0)	0 (0)[a]	0 (0)[a]
Eosinophils (%)									
Low	0 (0)	0 (0)[b]	0 (0)[b]	64 (10.7)	30 (10.6)[a]	34 (10.7)[b]	19 (7.5)	16 (10.2)[a]	3 (3.1)[c]**
Normal	302 (100)	134 (100)[a]	168 (100)[a]	536 (89.3)	253 (89.4)[b]	283 (89.3)[a]	236 (92.5)	141 (89.8)[b]	95 (96.9)[a]
Basophils (%)									
Normal	302 (100)	134 (100)[a]	168 (100)[a]	600 (100)	283 (100)[a]	317 (100)[a]	255 (100)	157 (100)[a]	98 (100)[a]
High	0 (0)	0 (0)[a]	0 (0)[a]	0 (0)	0 (0)[a]	0 (0)[a]	0 (0)	0 (0)[a]	0 (0)[a]
Lymphocytes (%)									
Low	1 (0.2)	0 (0)[a]	1 (0.6)[a]	1 (0.2)	1 (0.4)[a]	1 (0.3)[a]	0 (0)	0 (0)[a]	0 (0)[a]
Normal	39 (12.9)	25 (18.7)[a]	14 (8.3)b**	106 (17.7)	48 (17)[a]	57 (18)[a]	65 (25.5)	35 (22.3)[a]	30 (30.6)[c]
High	39 (12.9)	109 (81.3)[a]	153 (91.1)[a]	493 (82.2)	234 (82.7)[a]	259 (81.7)[a]	190 (74.5)	122 77.7)[a]	68 (69.4)[b]
Monocytes (%)									
Low	0 (0)	0 (0)[a]	0 (0)[a]	0 (0)	0 (0)[a]	0 (0)[a]	1 (0.4)	1 (0.6)[a]	0(0)[a]
Normal	69 (22.8)	27 (20.1)[b]	42 (25)[b]	600 (100)	283 (100)[a]	317 (100)[b]	254 (99.6)	156 (99.4)[a]	98(100)[b]
High	233 (77.2)	107 (79.9)[a]	126 (75)[a]	0 (0)	0 (0)[b]	0 (0)[b]	0 (0)	0 (0)b	0 (0)[b]
Thrombocytes (10^6/L)									
Low	6 (2)	2 (1.5)[b]	4 (2.4)[a]	30 (5)	14 (4.9)[b]	16 (5)[a]	28 (11)	20 (12.7)[a]	8 (8.2)[a]
Normal	235 (77.8)	109 (81.3)[a]	126 (75)[a]	538 (89.7)	255 (90.1)[a]	283 (89.3)[a]	222 (87.1)	135 (86)[a]	87 (88.8)[a]
High	61 (20.2)	23 (17.2)[a]	38 (22.6)[a]	32 (5.3)	14 (5)[b]	18 (5.7)[b]	5 (1.9)	2 (1.3)[b]	3 (3.1)[b]

N: Total number of each subjects group; n: subjects number observed in each group; *: Statistically significant difference for $p < 0.05$ between boys and girls in each group of age; a, b and c: Statistically significant difference for $p < 0.05$ between different groups of age in boys or girls

influenced by the association of sex and age groups among children in this study. Boys aged 16 to 18 have high values of red blood cells, hemoglobin and hematocrit. In contrast, girls aged 5 to 10 years and 16 to 18 years reported high values of thrombocytes. The work of Celkan et al. (2003) in 1,600 Turkish children aged 6 to 16 years, showed significant differences between the age of 9.5 to 12 years and 12.5 to 16 years. To this end, the boys of both groups of children reported high values of hemoglobin and hematocrit compared to girls. Moreover, it must be noted that the values of hemoglobin and hematocrit are high among Turkish children aged 12.5 to 16 years. In addition, Celkan et al. (2003) showed also that Turkish subjects aged 6 to 9 years indicate no significant difference between boys and girls in haematological parameters. This result is similar to that reported among children aged 5 to 10 years in Abidjan.

According to studies of Dallman and Siimes (1979), no variation was observed between girls and boys under 11 years. As from 12 years, changes in the parameters of the erythrocyte count and indices were found by gender. Moreover, these authors also reported that the values of these parameters are increased in subjects over 11 years (particularly boys for erythrocyte count) compared to less than 11 years. However, the values of hemoglobin in Turkish children between 6 and 9 years are above those of children aged 5 to 10 in Abidjan. The variation of this haematological parameter is related to the race. There is a decrease in hemoglobin in black subjects compared to white people by several studies (Dallman et al., 1978; Yip et al., 1984; Reed and Diehl, 1991).In addition, changes in haematological parameters, specifically those of the red blood cells observed after 11 years is justified by puberty (Dufer, 1990). Children of this age are adolescents. Adolescence is a period of life that is characterized by changes which expose children to nutritional imbalances (Maurage, 1999; Mian et al., 2002). One of the consequences of these nutritional imbalances is anaemia (Bao et al., 1993). Changes in haematological parameters in children of our study revealed anaemia's prevalence of 47% in the study population. The prevalence of anemia was similar to that reported by Asobayire et al. (2001). The results of this study show that boys were less exposed to anemia than girls. In general, girls (from a certain age) are most affected by high prevalence of anaemia. The main reason is the menstrual cycle faced by the girls (Blum, 1991; Straetmans, 2002; Khattak and Ali, 2010). In addition, the report of WHO (2006) indicated that the prevalence of anaemia in Africa is 64.6%, with 25.4% among school-age children and 55.8% among those of preschool. In view of the prevalence of anaemia published by WHO (2006), the overall observed prevalence in subjects is relatively low. In contrast, the prevalence of anaemia among children aged 5 to 10 years (31.8%) is higher compared to that reported by WHO (25.4%) in 2006. The rate of severe anaemia was 5.9%, with a prevalence of 8.8% in 17 African countries according to WHO (2006) These observations are contrary to this study in which no prevalence of severe anaemia is reported.

The associated factors with the occurrence of anaemia are multiple. The main reason for anaemia in people is the imbalances of food intake. This nutritional imbalance between food intake and body needs creates an alteration of reserves and functional compartments. Thus, the main micronutrients that body needs for the synthesis of red blood cells are insufficient (Dillon, 2000), then occurs the degradation of the content and the concentration of hemoglobin, a main molecule of red blood cells (Dillon, 2000).In the same way, we are witnessing the occurrence of microcytosis, macrocytosis and hypochromia. These erythrocyte dysfunctions were observed among children in our study. Moreover, the classification of anaemia according to erythrocyte indices reveals a high prevalence of hypochromic microcytic anaemia. This observation was indicated by Atanda et al. (1997) in Congo and Diagne et al. (2010) in Senegal. The observation of this type of anaemia could justify the nutritional anaemia among children in this investigation (Dallman et al., 1984).

Some confounding factors such as infectious syndromes, inflammatory and hemoglobinopathies may also explain the advent of anaemia among subjects of this study (Yip and Dallman, 1988). High observed rates of leukocytopenia, neutropenia and lymphocytosis in the subjects of this investigation show that these children are victims of infections (Tarallo, 1990a). Moreover, a prevalence of 15.6% is observed in the study population for abnormal hemoglobin. Thus, the study children are concerned with hemoglobinopathies. This observation also revealed by Reed and Diehl (1991) could explain the alteration of all determined haematological parameters in our study subjects. In addition, the high prevalence observed among black people could justify the alteration of haematological parameters. The increased rate of thrombocytes and high indicated prevalence of thrombocytosis in girls in this work could be explained by the process of hemostasis. Thrombocytes are necessary for clotting mechanism in girls during their menstruation (Tarallo, 1990b).

Conclusion

The prevalence of abnormal haematological status is 88.5% for all study children. The haematological parameters such as red blood cells, hemoglobin and hematocrit are largely degraded in children of Abidjan. These modified parameters are higher among boys than girls. In contrast, thrombocytes are increased among girls compared with boys. Moreover, an associated interaction between sex and age on changes of haematological parameters is revealed. Thus, subjects aged 16 to 18 years are more exposed to alteration of haematogical

parameters. High prevalence of abnormal hemoglobin is observed in study children. In addition, work to establish real standards of haematological parameters associating rigorous criteria should be carried out in the country.

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