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Depletion of Iron Stores and Main Associated Parameters in Adolescents of Côte D'ivoire

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Abstract: In Côte d'Ivoire, very few studies are devoted to the exploration of iron status in adolescents for early screening of iron deficiency and anaemia. This study aims to assess the iron status in adolescents aged 12 to 18 years apparently healthy living in Abidjan (Côte d'Ivoire). It also intended to identify the influence of infectious and inflammatory syndromes on indicators of iron status. Eight hundred and forty seven (847) adolescents enrolled in three municipalities of Abidjan, blood samples were carried out for the determination of biological parameters of iron status. Our study indicated that about three on four adolescents have abnormal iron status. This abnormal iron status is composed of 33.9 of iron deficiency, 30% iron deficiency anaemia, 6% of inflammatory anaemia and 4.7% of inflammatory anaemia associated with iron deficiency. The prevalence of infections and inflammatory disorders is also observed in adolescents. In addition, Pearson coefficients correlation indicated a significantly positive correlation of C Reactive Protein (CRP) with serum ferritin. The main cause of pronounced degradation in iron status is insufficient in the size of iron stores. The problem of the iron metabolism alteration is important in the Côte d'Ivoire in adolescents.

Key words: Iron deficiency; iron deficiency anemia, inflamatories anaemia, C-reactive protein (CRP); adolescents, abidjan (côte d'Ivoire)

INTRODUCTION

The double nutritional burden (nutritional deficiency and nutritional overload) is nowadays a real public health issue in human nutrition (Ara *et al*., 2010; Mustafa *et al*., 2012). Iron deficiency and overload are the most common nutritional disorder throughout the world (DeMaeyer and Adiel, 1985; Black *et al*., 1994). It is the major cause of anaemia from several studies and would concern 4 to 5 billion people according to the age groups. The layers of the most vulnerable are children, adolescents and women of productive age including pregnant women (Adelekan, 2003; WHO/CDCP, 2004; Porniammongkol *et al*., 2011). Iron is an essential micronutrient for many biological functions including the level of oxygen transport, electron transfer and several enzyme activities (mitochondrial chain, cellular functions). It is found in the organism in very small quantities. Its contribution in the body is mainly through diet (Afoakwah and Owusu, 2011). In developing countries (UNICEF/UNU/WHO, 2001; Berger *et al*., 2005; Thurnham *et al*., 2010), the bioavailability of iron and selected factors (infectious and inflammatory syndromes) expose people to iron deficiency (from 60 to 80%). Conversely, iron deficiency (10-20%) is reduced in industrialized countries (Al-Assaf, 2007; Amegor *et al*., 2009). The iron deficiency gets worse with age and physiological status of populations. In adolescents whose high iron needs and growth is still in progress, is a layer of risk. Adolescence is characterized by rapid growth accompanied by profound metabolic, hormonal and psychological changes exposed to nutritional deficiencies. Iron deficiency has a dramatic effect on immunity, resistance to infection, physical capacity during exercise and especially intellectual performance (Dallman, 1986; Hercberg, 1991). The World Health Organization (WHO) has developed programs to identify risk groups and implement iron supplementation through enrichment of products regular use (UNICEF/UNU/WHO, 2005). In Côte d'Ivoire, several studies on iron metabolism were spent to women of reproductive age, infants and children (Asobayire *et al*., 2001; Bleyere *et al*., 2007; Ahiboh *et al*., 2008; Yapo *et al*., 2008; Yapi *et al*., 2010). In contrast, very few works of this nature were carried out in adolescents for early screening of iron deficiency and the types of anaemia. Therefore, this study aims to assess iron status while

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involving the influence of infectious and inflammatory syndromes in this group of population. In this context, consider our works the objective is also to determine the components of iron status in adolescents. Moreover, our study indicates which among adolescents sex is the most exposed to iron deficiency and types of anaemia. In addition, it will reveal a possible influence of infectious and inflammatory syndromes on the iron status in adolescents.

MATERIALS ET METHODS

Locations and study population: The study subjects were adolescents aged 12 to 18 years both sexes. This study was conducted over a period from October 2008 to September 2009. These adolescents were enrolled in primary, secondary and households of three municipalities in Abidjan: Abobo, Adjamé and Yopougon. This group of adolescents volunteers from various social layers. The collection of anthropometric data of this study was done using a questionnaire for adolescents with the informed consent of parents, following an explanation of interest of the study. For the selection of subjects, a set of criteria including clinical and biological signs allowed to exclude and include topics for the need of our investigations. He acted in any pregnancy (female subject) gynecological, digestive, hematological complications and especially of inflammation in the three months preceding the study. All these observations were made by a medical team from the National Institute of Public Health (INSP) of Côte d'Ivoire. Amongst the 943 volunteers included, we selected only 847 divided as follows 436 adolescent males (51.5%) and 411 female (48.5%) after applying the criteria for inclusion and exclusion of subjects. The males predominated with a sex ratio of 1.1. The mean age of the study population was 14.6±0.1 years and ranged from 12 to 18 years. The mean value of body mass index (BMI) was 18.6±0.1 kg/m^2 for the total population. Moreover, the majority of subjects attends school 94.9% against 1.3 and 3.8% of school dropouts in (Table 1).

Blood samples: At each of the adolescents, a blood sample by venipuncture open the elbow was performed fasting in the morning between 7 and 9 hours in two 5 ml tubes each. The first tube contains an anticoagulant, Ethyl Diamine Tetra Acetic Acid (EDTA) and was used to determine the values of the blood count and erythrocyte indices. The second dry tube was been useful for the determination of serum iron by colorimetric method and determination of serum transferrin, ferritin and C-reactive protein by immunoassay method. Each dose of the blood sample from the same collection is duplicated to reduce the errors of manipulation. And the mean of 2 obtained is used for the study.

Assays and calculation of laboratory parameters of iron status: The automated hematology analyzer "Sysmex KX-21N" (Sysmex Corporation 1-5-1, Wakinohama-Kaigandori, Chuo-Ku Kobe 651-0073, Japan) was used to measure the parameters of the blood count. The samples contained in the dry tubes are centrifuged at 3000 g/min for 3 min. The serum was decanted after centrifugation and stored at -20°C in aliquots in cryovials for later determinations of biochemical assessment of iron status and inflammation by the automatic Konelab 20XT (Thermo Electron Oy/Clinical Chemestry of automation, Fi-Vantaa 0121 9515/Cergy-Pontios cedex Finland/France). The kit "FERRITIN latex turbidimetry" Company Chronolab SYS SL (Avenida Diagonal 609, Planta 10, 08028 Barcelona, Spain) was used for the determination of serum ferritin by the immunoturbidimetric method and those provided by Thermo Fisher Scientific Oy (Finland/France) were used for the determination of iron by colorimetric method, transferrin and C-reactive protein serum by immunoassay. The total iron binding capacity (TIBC) and the coefficient saturation of transferrin with iron (SCT)

Table 1: Subject characteristics of study

Parameters	Total population (N = 847)	Boys (N = 436)	Girls (N = 411)
Age (years)	14.6±0.1	14.9±0.1	14.35±0.1
12-17	79.46% (673)	75.23% (328)	83.94% (345)
18	20.54% (174)	24.77% (108)	16.06% (66)
Weight (kg)	46.32±0.47	46.78±0.71	45.82±0.62
Height (m)	1.56±0.004	1.58±0.007	1.54±0.005
Body mass index (kg.m^{-2})	18.58±0.11	18.21±0.15	18.97±0.17
<18.5	11.45% (97)	13.76% (60)	9% (37)
18.5-26	85.13% (721)	83.72% (365)	86.62% (356)
>26	3.42% (29)	2.52% (11)	4.38% (18)
Education			
Educated	94.92% (804)	94.5% (412)	95.38% (392)
Non educated	1.3% (11)	0.92% (4)	1.7% (7)
Dropouts	3.78% (32)	4.58% (20)	2.92% (12)

This table shows the characteristics of the total study population. From the general view, they appear suitable and appropriate to the requirements of our manipulations.

are derived by calculation (Vernet-Nysen, 1981). CTF (mg/l) = 25 x [transferrin (g/l)]; CST (%) = serum iron (mg/l)/CTF (mg/l) x 100.

Assessment of the components of iron status and statistical analyses: Order to better appreciate the parameters of our biological assays, conventional criteria were selected. They combined the recommendations of World Health Organisation (WHO), the French Society of Clinical Biology (SFBC/France), French Society of Hematology (SFH/France-Group of Cellular Hematology), the French Society of Nutrition and Dietetics (France), Centre for Disease Control and Prevention (WHO/CDCP) and the Institute of Medicine (IOM/US) (Vernet-Nyssen, 1981; UNICEF/UNU/WHO, 2001; SNDLF, 2001; WHO/CDCP, 2004).

For the exploitation of different parameters of the study, several statistical tests were performed. The "t" Student test for independent samples for variables and Pearson correlation carried out with the software Statistica version 6 0 windows (StatSoft, data analysis software system) allowed respectively to compare the means of the biological parameters of both sexes and to determine the associations between biochemical indicators and C-reactive protein. For the comparison of different proportions, the test "loglkelihood ratio or G test" is conducted by the statistical program R version 2.1.1 software windows. A significance analysis is defined to a lower probability level p-value 5%. The figures represented in this study were done using the program Prism GaphPad 4 (San Diego, Califormia, United Kingdom). The measurement of haematological and biochemical parameters of samples of subjects was conducted in medical laboratory and Biological Research at the National Institute of Public Health (INSP) of Côte d'Ivoire.

Ethics: Experimental procedures and protocols used in this study were approved by ethical committee of Health Sciences, University of Cocody-Abidjan. These guide line were in accordance with the internationally accepted principles for laboratory use and care. Then, this study was approved by the Ministry of Higher Education and Scientific Research and the Ministry of Health and Public Hygiene in the Republic of Côte d'Ivoire.

RESULTS

Changes in biochemical parameters of iron status: The mean values of biochemical parameters of iron status for all adolescents were normal compared to reference values excluding serum ferritin (Table 2). Iron stores were lower in adolescents compared with international standards. In the same vein, the mean values of serum iron, serum transferrin, total iron binding capacity and coefficient saturation of transferrin in adolescent boys and girls were normal relative to reference values established (Fig. 1). As with all subjects, girls and boys adolescents have indicated lower mean values of serum ferritin compared with international standards (Fig. 1). In addition, the mean values of serum ferritin (19.1±0.6 µg/l and 20.4±0.7 µg/l, respectively for boys and girls) have been significantly the same (Fig. 1). Profile compared with mean values of biochemical parameters by sex presented significant differences between boys and girls adolescents for serum iron, serum transferrin, total iron binding capacity and coefficient saturation of transferrin ($p = 0.013$, $p = 0.002$, $p = 0.001$ and $p = 0.0006$ respectively). Similarly, girls have indicated high values of serum transferrin and total iron binding capacity (2.9±0.03 g/l and 2.7±0.03 g/l, 3.6±0, 04 mg/l and 3.4±0.03 mg/l) compared to boys (Fig. 1). In contrast, adolescents boys showed elevated levels of serum iron and coefficients saturation of transferrin (1.02±0.02 mg/l, 0.96±0.02 mg/l, 30.6±0.6%, 28±0.6%) than girls (Fig. 1).

In terms of the mean value of ferritin, no statistical difference ($p>0.05$) was observed between the two sexes (Fig. 1).

Distribution of proportions values of iron status biochemical parameters: The comparison of observed proportions of adolescents by sex showed significant differences for low values of serum iron, high values of serum transferrin, Total Iron Binding Capacity (TIBC) and normal values of serum ferritin (Table 3). In fact, the

Table 2: Mean values of biochemical parameters in total population

Biochemical parameters of iron status	Mean values±SEM	Reference values
Plasma compartment		
Serum iron (mg/l)	1±0, 01	0, 65-1, 75/0, 5-1, 7
Serum transferrin (g/l)	2, 8±0, 02	2-3, 6
Total iron binding capacity (mg/l)	3, 5±0, 02	2, 5-4, 5
Saturation coefficient of Transferrin (%)	29, 4±0, 4	20-40/15-35
Compartment of reserves		
Serum ferritin (µg/l)	19, 7±0, 4	30-220/20-110
Inflammation		
C-reactive protein (mg/l)	3.3±0.2	0-6

The mean values of iron status parameters of all subjects are compared to reference values established by international organizations. Except the serum ferritin, all biochemical parameters of iron status have normal values. About iron stores, we observed that they are low. Data are shown as mean±SEM. n = 847.

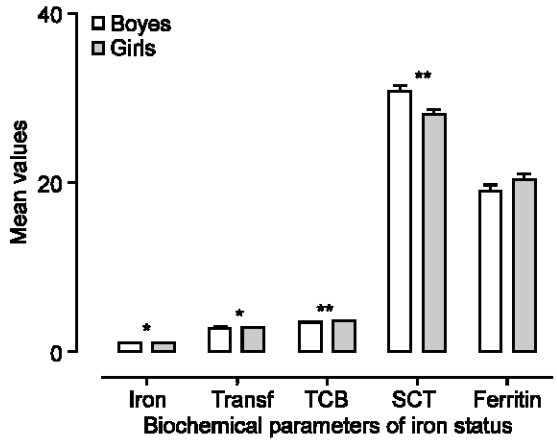

Fig. 1: Profile comparison of mean values of biochemical parameters of iron status by sex. Girls and boys in our study had serum ferritin values approximately equal but below international standards. Regarding other biochemical parameters of iron status, significant differences are observed between the sexes. High values of Serum transferrin (Trans) and Total Iron Binding Capacity (TIBC) are found in girls as in boys, these are high values of Serum iron and Saturation Coefficient of Transferrin (SCT) that are registered. Horizontal scale: Biochemical parameters; Vertical scale: Mean values [Serum iron (mg/l), Transf (g/l), TCB (mg/l), SCT (%), Ferritin (µg/l)]. Data are shown as mean±SEM. *p<0.05, **p<0.01. (Male, n = 436; Female, n = 411)

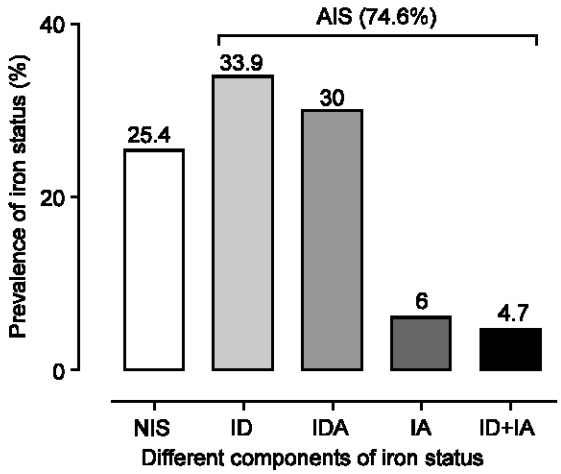

Fig. 2: Prevalence of iron status in adolescents. Abnormal iron status observed in these adolescents is mainly due to Iron Deficiency (ID) and Iron Deficiency Aneamia (IDA) and secondary to Infammatory Aneamia (IA) and Infammatory Aneamia associated with Iron Deficiency (IA+ID). NIS: Normal Iron Status; AIS: Abnormal. Data are shown as mean±SEM. n = 847

results of the study reported a high hyposideremia significantly (p = 0.002) among boys (15.1%) than girls (5.1%). In addition, several girls (39 representing 9.5%) reported significant high values with respect to international references (p = 0.001, p = 0.001 respectively) of serum transferrin and total iron binding capacity compared to boys of our investigation (Table 3). In addition, the proportion of girls to normal values of serum ferritin was significantly higher (36.7%) than boys (13.1%). In contrast, no significant difference (p>0.05) was observed between the proportions of adolescents by sex from the other values of biochemical indicators of iron status assessment and C-reactive protein compared with the criteria international (Table 3).

Prevalence of iron status components: The assessment of biological indicators of iron status based on haematological and biochemical variables was used to determine the prevalence of iron deficiency and types of anaemia illustrated by Fig. 2. For this purpose 74.6% of subjects achieved an abnormal iron status very highly different ($p = 4.9.10^{-7}$) compared to adolescents in normal iron status (25.4%). The abnormal iron status is composed of 33.9% iron deficiency, 30% of iron deficiency anaemia, 6% of inflammatory anaemia of and 4.7% of inflammatory anaemia associated with iron deficiency. These proportions have indicated very highly significant differences ($p = 3.2.10^{-9}$). In this context, iron deficiency and iron deficiency anaemia have been widely higher compared with inflammatory types of anaemia (Fig. 2). The prevalence of iron status components in adolescents by sex summarized in Fig. 3, showed no significant difference (p>0.05). Between boys and girls, no significant difference was demonstrated even though we observed a little higher prevalence of normal iron status (26.3 vs 24.1%), iron deficiency anaemia (32.1 vs 28%), inflammatory anaemia (7.8 vs 4.4%) and inflammatory anaemia associated with iron deficiency (7.3 vs 2.3%) in girls compared to boys (Fig. 3). In contrast, only the prevalence of iron deficiency occurred somewhat higher among boys (41.3%) than girls (26%).

Correlation between C-reactive protein and parameters of iron status: The relationship between biological indicators assessment of iron status and C-reactive protein, have shown a link between such groups in biological parameters. This relation has been significant (p<0.05) for all adolescents and by sex for serum ferritin. Thus, the iron stores of adolescents are involved in a change (increase or decrease) significantly (p<0.05) in the same sense as the dosed inflammatory

Table 3: Distribution of biochemical parameters proportions of iron status

	Total population N = 847		Boys N = 436		Girls N = 411		
Biological parameters	n	%	n	%	n	%	p-value
Serum iron (mg/l)							
Low	87	10.3	66	15.1	21	5.1	0.002 (S)
Normal	727	85.8	350	80.3	377	91.7	0.4 (NS)
High	33	3.9	20	4.6	13	3.2	0.6 (NS)
Serum transferrin (g/l)							
Low	58	6.9	42	9.6	16	3.9	0.1 (NS)
Normal	749	88.4	393	90.1	356	86.6	0.8 (NS)
High	40	4.7	1	0.3	39	9.5	0.001 (S)
TCB (mg/l)							
Low	58	6.9	42	9.6	16	3.9	0.1 (NS)
Normal	749	88.4	393	90.1	356	86.6	0.8 (NS)
High	40	4.7	1	0.3	39	9.5	0.001 (S)
SCT (%)							
Low	116	13.7	71	16.3	45	11	0.3 (NS)
Normal	562	66.4	287	65.8	275	66.9	0.9 (NS)
High	169	19.9	78	17.9	91	22	0.5 (NS)
Serum ferritin (μg/l)							
Low	639	75.7	379	86.9	260	63.3	0.5 (NS)
Normal	208	24.3	57	13.1	151	36.7	0.0006 (S)
High	0	0	0	0	0	0	-
C-reactive protein (mg/l)							
Low	754	88.9	388	89	366	89.1	0.99 (NS)
Normal							
High	93	11.1	48	11	45	10.9	0.98 (NS)

The proportions of the main parameters of iron status in adolescents are established based on the lower and upper limits of reference values. TCB: Total capacity of binding of transferrin; SCT: Saturation Coefficient of Transferrin; S: Statistically different for p-value<0.05; NS: Not statistically significant for p-value <0.05. Data are shown as mean ± SEM.

Table 4: Correlation coefficients between C-reactive protein and parameters of iron status

	C - reactive Protein		
Biochemical parameters of iron status	Total population N = 847	Boys N = 436	Girls N = 411
Plasma compartment			
Serum iron (mg/l)	-0, 04	-0, 02	0, 04
Serum transferrin (g/l)	0, 03	0, 02	-0, 05
Total capacity of binding of transferrin (mg/l)	0, 02	0, 02	0, 03
Saturation coefficient of transferrin (%)	-0, 06	-0, 06	0, 04
Compartment of reserves			
Serum ferritin (µg/l)	0, 09	0, 03	0, 05

This table has assessed the relationship between the parameters of iron status and a variable of inflammation, C-reactive protein. Data are shown as mean ± SEM.

protein (Table 4). However, other parameters of iron status reported no significant relationship (p>0.05) with C-reactive protein (Table 4).

DISCUSSION

Our investigations in adolescents from Abidjan (Côte d'Ivoire) revealed that 3 in 4 adolescents have a deteriorated iron status. The iron balance indicated nearly all components of iron metabolism that is iron deficiency, iron deficiency anaemia and types of inflammatory anaemia. Amongst these components of the iron status of adolescents, iron deficiency and iron deficiency anaemia (33.9 and 30%, respectively) predominate. The prevalence of iron deficiency and iron deficiency anaemia are the rates established by several studies across developing countries (Dillon, 2000; Leenstra *et al*., 2004). Moreover, the proportions of iron deficiency and iron deficiency anaemia are significantly above the rate of prevalence in industrialized countries. The causes of iron deficiency and iron deficiency anaemia in developing countries are multifactorial. The first reason for the depletion of iron is of order food (Gonzalez-Suarez *et al*., 2009; Afoakwah and Owusu, 2011). It is shown that the reduction of iron is the result of a deficit in the balance of this micronutrient in the body (Al-Assaf, 2007). It is most commonly of insufficient dietary intake deal with more important needs. Iron requirements differ according to age and physiological

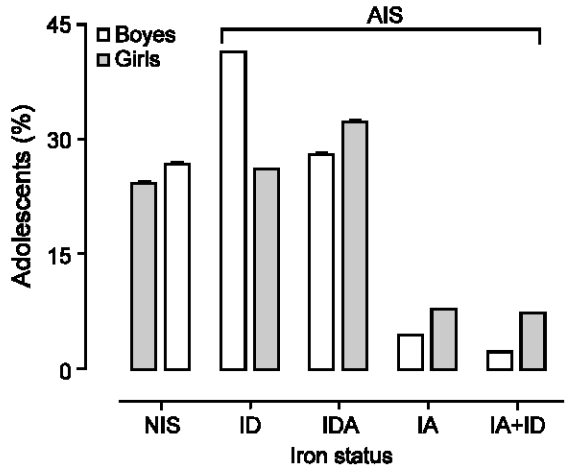

Fig. 3: Prevalence of iron deficiency and aneamias by sex. The prevalence of the components of iron status by sex showed no significant difference except that of Iron Deficiency (ID). It is stronger in boys than in girls. NIS: Normal Iron Status; AIS: Abnormal Iron Status; IDA: Iron Deficiency Aneamia; IA: Inflammatory Aneamia; ID+IA: Inflammatory Anaemia associated with Iron Deficiency. Data are shown as mean ± SEM. (Male, n = 436; Female, n = 411)

status of people. In adolescents, iron requirements are estimated to be 10 and 18 mg daily to perform the most of the metabolism (Beard, 2000; Starkey *et al*., 2001). Adolescents compared to other sections of the population physiologically normal, have a double demand for iron (Maurage, 1999). This is a request in iron to address the growth of the organism and another to correct blood loss hang the period of menstruation (girls). Iron needs advanced during adolescence will participate in the increases in cell mass and blood volume (Ferreira *et al*., 1998). These high prevalences of iron deficiency and iron deficiency anaemia could be explained by the iron quantity and quality in adolescents of their reserves (Butt and Batool, 2010). Our investigations have shown that over 75% of patients have a very low in iron reserves. This large decrease in the size of iron stores in most adolescents and the form of iron consumed by the subjects could explain these high prevalences of iron deficiency and iron deficiency anaemia. The iron in the organism is in two forms namely the haeminic form and the non haeminic form. The first is readily bioavailable compared to the previous form. The haeminic form iron is more abundant in the bodies of animal and non haeminic form is more important in plants. Investigations carried out in developing countries have shown that populations have a diet very low in animal protein (Cournot and Herbecg, 1993; Butt and Batool, 2010). They have a high diet based in vegetables (van der Broek and Letsky, 2000; Oguntona and Akinyele, 2002; El-Hioui *et al*., 2008). This could explain a major alteration of their iron stores. Works in the Côte d'Ivoire reported that the protein profile of the population is considerably below the international standard. They are undernourished (Yapi *et al*., 2005a and 2005b; Yapi *et al*., 2010). In terms of iron stores, no significant difference was observed in subjects while boys have indicated a higher proportion than girls (86.9% vs 63.3%). In fact, adolescents girls are more affected by an alteration of iron metabolism than adolescents boys (Hercberg, 1991). But in the case of our study, boys and girls did not differ from general view. Our results are contrary to those obtained in Kenya in adolescents (Leenstra *et al*., 2004). Iron deficiency is a dynamic concept which results in 3 stages (Hercberg *et al*., 1998): first, the simple depletion of tissue stores in iron deficiency without erythropoiesis which is characterized by an isolated decrease of ferritin serum below the standard (20µg/l in girls and 30µg/l in boys). Then the depletion of reserves with disabilities of erythropoiesis is accompanied by a decrease in the coefficient saturation of transferrin, an increase of the serum transferrin and the total iron binding capacity, a decrease in serum iron and disruption of conventional red cell parameters. Finally, the last stage corresponds to iron deficiency anaemia when the hemoglobin falls below the threshold limit (Duport *et al*., 2003). Works in South Africa and Tanzania respectively, revealed prevalence rates of normal in iron status of 40% and 49% more increased compared to those observed in subjects of our study (Massawe *et al*., 2002; Wolmarans *et al* ., 2003). Besides iron deficiency and iron deficiency anaemia, inflammatory and inflammatory anaemia associated with iron deficiency were observed. Presence of these types of anaemia can be explained by factors such as parasitic, digestive and gynecological infections, infectious and inflammatory symptomes observed in populations of developing countries (Fleming, 1981; Yip and Dallman, 1988; Massawe *et al*., 2002; Amiruddin *et al*., 2012). The changes in C-reactive protein according to serum ferritin in our work further supports the rates of reported inflammatories types of anaemia in our investigations. The results of the Asobayire *et al*. (2001) conducted in Côte d'Ivoire, showed the same observations about the relationship between the inflammatory protein C reaction protein and serum ferritin representing iron stores. The high rate of subjects with low concentrations of C-reactive protein indicates that we are in infectious and inflammatory context. In this environment, the dynamic of iron metabolism is altered (Premji *et al*., 1995; Cottrel *et al*., 2007). That's reason why all the boys and girls adolescents of our study presented high levels of iron deficiency, iron deficiency anaemia and inflammatory

anaemia. The investigations in Pakistan are indicated the same results with school children of Dera Ismail Khan (Ramzan *et al*., 2009).

Conclusion: The study of iron status has allowed to observe a high prevalence of abnormal iron status of adolescents in Abidjan. This status includes abnormal high prevalence of iron deficiency and iron deficiency anaemia. The main cause of pronounced degradation of iron status is insufficient in the size of iron stores. This deficiency considerably pronounced is related to low intake of iron in food, the living environment unfavorable of adolescents. In addition, infectious and inflammatory syndromes more common in developing countries justify the presence of inflammatory anaemia among adolescents in our study. This alteration of iron metabolism relates to both boys and girls. It is therefore necessary in future studies, elucidate the overall nutritional status. And that, through more sensitive and specific biological indicators as all the nutritional proteins and indices, the soluble receptor of transferrin, hepcidin and other micronutrients such as zinc and copper to determine the full nutritional status of adolescents in Côte d'Ivoire. In this context, we can estimate among adolescents in our country, the double nutritional burden characterized by nutritional deficiencies and nutritional overload.

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REFERENCES

Adelekan, D.A., 2003. Multiple micronutrient deficiencies in developing countries. Nutr., 19: 473-474.

Afoakwah, A.N. and W.B. Owusu, 2011. The Relationship Between Dietary Intake, Body Composition and Blood Pressure in Male Adult Miners in Ghana. Asian J. Clin. Nutr., 3: 1-13.

Ahiboh, H., A.S. Oga, H.F. Yapi, G. Kouakou, K.D. Boua, N. Edjeme and D. Monnet, 2008. Anémie, métabolisme du fer et protéines de la réaction inflammatoire au cours du paludisme (Abidjan, CI). Bull. Soc. Pathol. Exot., 101: 25-28.

Al-Assaf, A.H., 2007. Anemia and Iron Intake of Adult Saudis in Riyadh City-Saudi Arabia. Pak. J. Nutr., 6: 355-358.

Amegor, O.F., D.A. Bigila, O.A. Oyesola, T.O. Oyesola and S.T. Buseni, 2009. Hematological Changes in HIV Patients Placed on Anti Retroviral Therapy in Markurdi, Benue State of Nigeria. Asian J. Epidemiol., 2: 97-103.

Amiruddin, R., D. Sidik, A. Alwi, N.I. Jumriani, P. Astuti and Syafruddin, 2012. Socioeconomic Factors and Access to Health Services for Malaria Control in Mamuju District, West Sulawesi Indonesia. Asian J. Epidemiol., 5: 56-61.

Ara, G., A. Melse-Boonstra, S.K. Roy, N. Alam, S. Ahmed, UH. F. Khatun and T. Ahmed, 2010. Sub-Clinical Iodine Deficiency Still Prevalent in Bangladeshi Adolescent Girls and Pregnant Women. Asian J. Clin. Nutr., 2: 1-12.

Asobayire, S.F., P. Adou, L. Davidsson, J.D. Cook and R.F. Hurell, 2001. Prevalence of iron deficiency with and without concurrent anemia in population groups with high prevalences of malaria and other infections: A studiy in Côte d'Ivoire. Am. J. Clin. Nutr., 74: 776-782.

Beard, J.L., 2000. Effectiveness and strategies of iron supplementation during pregnancy. Am J. Clin. Nutr., 71: 1288S-1294S.

Berger, J., H.K. Thanh, T. Cavalli-Sforza, S. Suttilak, N.C. Khan, S. Milani, P.T. Hoa, N.D. Quang and F. Viteri, 2005. Community mobilization and social marketing to promote weekly iron-folate supplementation in women of reproductive age in Vietnam: Impact on anemia and iron status. Nutr. Rev., 63: S95-S108.

Black, A.K., L.H. Allen, G.H. Pelto, M.P. de Mata and A. Chávez, 1994. Iron, vitamin B-12 and folate status in Mexico: associated factors on men and women and during pregnancy and lactation. J. Nutr., 124: 1179-1188.

Bléyéré, M.N., D. Joulia-Ekaza, A.P. Yapo, J.D. Yao, B.B. N'guessan, A.M.N. Cathy, M. Vanga, M. Koné and E.E. Ehilé, 2007. Hétérogénéité du statut en fer chez la femme au cours de la grossesse en Côte-d'Ivoire. Ann. Biol. Clin., 65: 525-532.

Butt, M.S. and R. Batool, 2010. Nutritional and Functional Properties of Some Promising Legumes Protein Isolates. Pak. J. Nutr., 9: 373-379.

Cottrell, G., J.Y. Mary, D. Barro and M. Cot, 2007. The importance of the period of malarial infection during pregnancy on birth weight in tropical Africa. Am. J. Trop. Med. Hyg., 76: 849-854.

Cournot, M.P. and S. Hercberg, 1993. Prévention des carences minérales (fer, calcium et magnésium). Rev. Prat. (Paris), 43: 141-145.

Dallman, P.R., 1986. Iron deficiency in the weanling: A nutritional problem on the way to resolution. Acta Paediatr. Scand. Suppl., 323: 59-67.

DeMaeyer, E. and M. Adiels-Tegman, 1985. The prevalence of anaemia in the world. World Health Stat. Q., 38: 302-316.

Dillon, J.C., 2000. Prévention de la carence en fer et des anémies ferriprives en milieu tropical. Méd. Trop., 60: 83-91.

Duport, N., P. Preziosi, M.C. Boutron-Ruanlt, S. Bertrais, P. Galan, A. Favier, J.L. Lafond and S. Hercberg, 2003. Consequences of iron depletion on health in menstruating women. Eur. J. Clin. Nutr., 57: 1169-1175.

El-Hioui, M., A.O.T. Ahami, Y. Aboussaleh, S. Rusinek, K. Dik and A. Soualem, 2008. Iron Deficiency and Anaemia in Rural School Children in a Coastal Area of Morocco. Pak. J. Nutr., 7: 400-403.

Ferreira, M.R., W. Souza, E.P. Perez, T. Lapa, A.B. Carvalho, A. Furtado, H.B. Coutinho and D. Wakelin, 1998. Intestinal helminthiasis and anaemia in youngsters from Matriz da Luz, District of São Lourenco da Mata, State of Pernambuco, Brazil. Mem. Inst. Oswaldo Cruz (Rio de Janeiro), 93: 289-293.

Fleming, A.F., 1981. Haematopogical manifestations of malaria and other parasitic diseases. Clin. Haematol., 10: 983-1011.

Gonzalez-Suarez, C., K. Grimmer-Somers and A. Worley, 2009. Is Food Intake Associated with Pre-Adolescent Obesity? An Observational Study in Metromanila, Philippines. Asian J. Clin. Nutr., 1: 107-119.

Hercberg, S., 1991. La carence en fer du nourrisson à l'adolescent. In: Journées parisiennes de pédiatrie. Paris. Flammarion, Médecine Sci., 283-287.

Herbecg, S., P. Galan, A. Prual and P. Prezioi, 1998. Epidémiologie de la déficience en fer et de l'anémie ferriprive dans la population française. Ann. Biol. Clin. (Paris), 56: 49-52.

Leenstra, T., S.K. Kariuki, J.D. Kurtis, A.J. Oloo, P.A. Kager and F.O. Kuile, 2004. Prevalence and severity of anemia and iron deficiency: cross-sectional studies in adolescent schoolgirls in western Kenya. Eur. J. Clin. Nutr., 58: 681-691.

Massawe, S.N., G. Ronquist, L. Nyström and G. Lindmark, 2002. Iron statut and iron deficiency anaemia in adolescents in a Tanzanian subur aera. Gynecol. Obstetric. Invest., 54: 137-144.

Maurage, C., 1999. Fer et statut martial des adolescents. J. Pediatr. Puériculture., 12: 204-207.

Mustafa, M., S.K. Deraman, N.M.M. Noor and Y. Rokhayati, 2012. Diet Problem and Nutrient Requirement using Fuzzy Linear Programming Approach. Asian J. Applied Sci., 5: 52-59.

Oguntona, C.R.B. and I.O. Akinyele, 2002. Food and nutrient intakes by pregnant Nigerian adolescents during the third trimester. Nutr., 18: 673-679.

Porniammongkol, O., U. Yamborisut, T. Intajak and P.P. Sirichakwal, 2011. Iron Status of Hill Tribe Children and Adolescent Boys: A Cross Sectional Study at a Welfare Center in Chiang Mai, Thailand. Pak. J. Nutr., 10: 903-909.

Premji, Z., Y. Hamisi, C. Shiff, J. Minjas, P. Lubega and C. Makwaya, 1995. Anemia and *Plasmodium falciparum* infections among young children in an holoendemic area, Bagamoyo, Tanzania. Acta Trop., 59: 55-64.

Ramzan, M., I. Ali and A. Salam, 2009. Iron Deficiency Anemia in School Children of Dera Ismail Khan, Pakistan. Pak. J. Nutr., 8: 259-263.

Société de Nutrition et de Diététique de Langue Française (S.N.D.L.F.), 2001. Anémies nutritionnelles. Cah. Nutr. Diét., 36: 76-81.

Starkey, L.J., L. Johnson-Down and K. Gray-Donald, 2001. Food habits of Canadians: Comparison of intakes in adults and adolescents to Canada's food guide to healthy eating. Can. J. Diet. Pract. Res., 62: 61-69.

Thurnham, D.I., L.D. McCabe, S. Haldar, F.T. Wieringa, C.A. Northrop-Clewes and G.P. McCabe, 2010. Adjusting plasma ferritin concentrations to remove the effects of subclinical inflammation in the assessment of iron deficiency: a meta-analysis. Am. J. Clin. Nutr., 92: 546-555.

UNICEF/UNU/WHO, 2001. Iron deficiency aneamia: assessment, prevention and control. WHO/NHD/0 1.3 Geneva, Switzerland: WHO/UNICEF/UNU/WHO Iron deficiency aneamia: assessment, prevention and control. WHO/NHD/01.3 Geneva, Switzerland: WHO.

UNICEF/UNU/WHO, 2005. Déclaration conjointe de l'Organisation Mondiale de la Santé et du Fonds de Nations Unies pour l'Enfance: Focaliser sur l'anémie ; vers une approche intégrée pour un contrôle efficace de l'anémie. http://www.who.org/ publications/index.html (accessed 5 april 2005).

WHO/CDCP, 2004. Assessing the iron status of populations. 2nd ed. Geneva: WHO. micronutrients/anaemia_iron_deficiency/978924 http://www.who.int/ nutrition/ publications/ micr 1596107.pdf. (accessed 15 december 2011).

van den Broek, N.R. and E.A. Letsky, 2000. Etiologiy of anemia in south Malawi. Am. J. Clin. Nutr., 72: 247S-256S.

Vernet-Nyssen, M., 1981. Recent findings concerning serum iron, the iron binding capacity of serum and transferring saturation suggested terminology. Ann. Biol. Clin., 39: 301-307.

Wolmarans, P., M.A. Dhansay, E.P.G. Mansvelt, J.A. Laubscher and A.J.S. Benadé, 2003. Iron status of South Africa women working in a fruit-packing factory. Public Health Nutr., 6: 439-445.

Yapi, H.F., H. Ahiboh, D. Monet and A.E. Yapo, 2005. Parasites intestinaux, profil hématologique et statut anthropométrique de l'enfant scolarisé en Côte d'Ivoire. Cah. d'études et de recherches francophone/santé, 15: 17-21.

Yapi, H.F., H. Ahiboh, K. Ago, M. Aké and D. Monnet, 2005. Profil protéique et vitamine A chez l'enfant d'âge scolaire en Côte d'Ivoire. Ann. Biol. Clin., 63: 291-295.

Yapi, H.F., H. Ahiboh, D. Koffi, A. Yapo, K.B. Bla, D. Monnet and A.J. Djaman, 2010. Assessment of inflammatory and immunity proteins during *falciparum* malaria infection in children of Côte d'Ivoire. Am. J. Sci. Ind. Res., 1: 233-237.

Yapo, P.A., M.N. Bléyéré, D. Joulia-Ekaza, J.D. Yao, B.B. N'Guessan and E.E. Ehilé, 2008. Prévalence de carences martiales et d'anémies chez des femmes en âge de procréer, non enceintes et des femmes enceintes. Ann. Biol. Clin Qué., 45: 24-28.

Yip, R. and P.R. Dallman, 1988. The roles of inflammation and iron deficiency as causes of anemia. Am. J. Clin. Nutr., 48: 1295-1300.