*International Blood Research & Reviews*
*2(1): 8-22, 2014, Article no. IBRR.2014.002*

**SCIENCEDOMAIN** *international*
www.sciencedomain.org

# Iron Status and Red Cell Parameters in Pregnant and Non-pregnant Adolescents in Côte d'Ivoire (West Africa)

**Mathieu Nahounou Bleyere[1*], Anthelme Semi Néné-Bi[2], Mama Kone[1], Duni Sawadogo[3], Paul Angoué Yapo[1]**

*[1]Laboratory of Physiology, Pharmacology and Phytotherapy, UFR des Sciences de la nature, Nangui Abrogoua University, 02 BP 801 Abidjan 02, Côte d'Ivoire.*
*[2]Laboratory of animal physiology (Unit Training and Research of Biosciences)/Félix Houphouët-Boigny University; 22 BP 582 Abidjan 22, Côte d'Ivoire.*
*[3]Laboratoire of haematology (Training and Research Unit of the Biological and Pharmaceutical Sciences)/Félix Houphouët-Boigny University; 21 BP 632 Abidjan 21. Côte d'Ivoire.*

***Authors' contributions***

*Authors MNB, ASNB, MK, DS, PAY contributed equally in the study. They made substantial contributions to the design of the study, the collection of the data as well as the preparation and analysis of the data. They also drafted the manuscript and gave final approval for its submission to the journal for consideration of publication.*

***Original Research Article***

***Received 3rd June 2013***
***Accepted 26th September 2013***
***Published 28th October 2013***

## ABSTRACT

**Aims:** The objective of this study was to evaluate iron metabolism and compare iron stores between pregnant and non-pregnant adolescents in Côte d'Ivoire.
**Place and Duration of Study:** The study was undertaken with 187 volunteers adolescents aged from 15 to 19 years. For this study, adolescents were divided into 2 groups with 75 non-pregnant adolescents and 112 pregnant adolescents. Study population was recruited January 2006 to January 2008 in 4 urban community health centers, of Abidjan. Assays of blood samples were performed in Laboratory of Physiology, Pharmacology and Phytotherapy (Nangui Abrogoua University) and in Laboratory of Medical Biochemistry of University Hospital Centre (Cocody, Félix Houphouët-Boigny University).

**Corresponding author: E-mail: bleyere@yahoo.fr;*

**Methodology:** In each pregnant adolescent a blood sample was collected by venipuncture on a dry and EDTA tubes of 5 ml. With these blood samples, haematological and biochemical parameters were determined.
**Results:** Haematological parameters were decreased in pregnant adolescents at the third trimester of pregnancy compared with control adolescents. Pregnant adolescents were more anaemic during pregnancy (77.7 %) compared with non-pregnant adolescents (42.7 %). Iron stores were greatly decreased in 72.3 %, 83.9 % and 95.6 % of adolescents respectively during the 3 trimesters of pregnancy compared with non-pregnant adolescents (34.7 %). In addition, high prevalence of iron deficiency anaemia was recorded throughout pregnancy in adolescents. Therefore, iron status was more altered in pregnant adolescents (11.6 %, 9.8 % and 0.0 % respectively) compared with non-pregnant adolescents (13.3 %). The results of this study show that the causes of pronounced degradation in iron status are insufficient in size of iron stores in pregnant adolescents and non-pregnant adolescents.
**Conclusion:** Iron metabolism alteration is important in pregnant adolescents in Côte d'Ivoire, causing severe anaemia in this group of population.

*Keywords: Pregnant adolescents, Non-pregnant adolescents, Iron stores, Iron deficiency Anaemia, Côte d'Ivoire.*

## 1. INTRODUCTION

Iron is a key component of hemoglobin and myoglobin which transport gases in organism. This micronutrient is also an essential element of many enzymes that carry out oxidation-reduction reactions necessary to generate energy and produce various metabolic for host defense [1, 2, 3]. Its deficiency is a widespread problem, affecting an estimated two billion people worldwide [4, 5]. Iron deficiency is the most common and prevalent nutritional disorder in the world in both developing and developed countries [6]. It occurs when iron stores, mostly found in the liver, start to become depleted. Thereafter, iron deficiency anaemia arises when the production of red blood cells starts to diminish once the iron stores have been depleted [7]. According to World Health Organization (WHO), the iron deficiency anaemia in pregnancy is a significant problem throughout the world with a prevalence ranging from an average of 14 % of pregnant women in developed countries to 56 % in developing countries [8, 9]. Therefore, anaemia is a public health concern resulting nutritional disorder in the world, affecting mainly women of childbearing age and children under five years of age [10]. It causes developmental delay and cognitive impairment in children and infants, reduced work capacity in adults [11, 12]. Among women, anaemia is primarily prevalent during reproductive age and adversely impacts pregnancy outcomes [13, 14, 15]. In addition, anaemia is more observed in adolescents during pregnancy compared with non-pregnant adolescents in some countries [16, 17, 18].

In Côte d'Ivoire, several studies on iron metabolism were devoted to non-pregnant women, pregnant women, non-pregnant adolescents, adolescents during pregnancy, infants and children [19, 20, 21, 22, 23, 24, 25]. Furthermore, adolescence is a physiological period which recommends a need of iron for organism's growth. Moreover, pregnancy in adolescents is a physiological state that requires a high demand of iron [26, 27].

However, no investigation was concerned with comparison of iron metabolism between adolescents according to their physiological state in Côte d'Ivoire. In view of this, the aim of this study was to determine the group of adolescents in Côte d'Ivoire which is exposed to nutritional anaemia by comparing changes of iron metabolism. In this same way, non-

pregnant and pregnant subjects aged 15 to 19 years from Abidjan were selected to evaluate and characterize the iron stores through their haematological and iron metabolism parameters.

## 2. MATERIALS AND METHODS

### 2.1 Study Population

The investigation was a longitudinal, analytic and descriptive study in pregnant adolescents. In addition, study design was a cross sectional analytic study for non-pregnant adolescents. Subjects in this study aged 15 to 19 years, were recruited January 2006 to January 2008 in 4 urban community health centers, of Abidjan (Côte d'Ivoire). These are urban and health centers of Abobo south, south Cocody, urban community health centers "Les Hortensias" Port-Bouet and Municipal Hospital of Port-Bouet. A total of 187 adolescents in consultation in these 4 urban community health centers were selected based on clinical data to exclude those with complications of health like blood transfusion, hypertension, diabetes rheumatism and other infections. Theses adolescents were divided into 2 groups with 75 non-pregnant adolescents regarded as a control group and 112 pregnant adolescents followed from first trimester to third trimester of pregnancy. The characteristics of study population were summarized in Table 1.

**Table 1. General characteristics of study population**

| **Characteristics** | **Non-pregnant adolescents N=75** | **adolescents during pregnancy (N=112)** |
|---|---|---|
| | **n (%)** | **n (%)** |
| Age (years) | 17.04 ± 0.2 | 17.6 ± 0.1 |
| 15 - 17 | 46 (61.3) | 48 (42.9) |
| 18 - 19 | 29 (38.7) | 64 (57.1) |
| Body mass index ($kg.m^{-2}$)$^{\alpha}$ | 20.6 ± 0.9 | 21.5 ± 0.4/24.2 ± 0.4/26.1 ± 0.4 |
| < 18.5 | 20 (26.7) | 26 (23.2)/30 (26.8)/17 (15.2) |
| 18.5 – 26 | 54 (72) | 72 (64.3)/60 (53.6)/87 (77.7) |
| > 26 | | 14 (12.5)/22 (19.6)/8 (7.1) |
| Gravidity | 1.7 ± 0.1 | 3 ± 0.2 |
| Primigravidae | 60 (80) | 27 (24.1) |
| Multigravidae | 15 (20) | 85 (75.9) |
| Parity | 1 ± 0.1 | 0.6 ± 0.1 |
| Nulliparous | 47 (62.7) | 80 (71.4) |
| Primiparous | 13 (17.3) | 19 (17) |
| Multiparous | 15 (20) | 13 (11.6) |
| Space between pregnancy (Months) | 52.6 ± 1.9 | 17.8 ± 2 |
| < 36 | 10 (13.3) | 100 (89.3) |
| > 36 | 65 (86.7) | 12 (10.7) |
| Matrimonial status | | |
| Married | 1 (1.3) | 2 (1.8) |
| Single | 73 (97.3) | 105 (93.8) |
| Concubinage | 1 (1.3) | 5 (4.4) |
| Education attainment | | |
| Uneducated | 2 (2.7) | 39 (34.8) |
| Primary school | 3 (4) | 19 (17) |
| Secondary school | 70 (93.3) | 54 (48.2) |

*n: Number of observed subjects in each group; α: Mean values and proportions of Body Mass Index's variation during the three trimesters of pregnancy*

## 2.2 Blood Samples and Assays of Biological Parameters

In each study adolescent, a blood sample was collected by venipuncture on a dry and EDTA tubes of 5 ml. Blood sampling was performed on fasting in elbow in morning and during each trimester of pregnancy (between 8 and 15 weeks of pregnancy in the first trimester, between 16 and 28 weeks of pregnancy for the second trimester and between 28 and 36 weeks for the last trimester of pregnancy). Haematological parameters were immediately measured on samples collected in EDTA tubes by a haematological analyzer “Sysmex automatic Poch-100i” (1-5-1 Wakinohama-Kaigandori, Chuo-Ku, Kobe 651-0073, Japan). Samples collected in dry tubes were centrifuged at 3000 tours/min during 5 minutes and the serum was used for the determination of biochemical parameters. Iron concentrations were determined by the colorimetric method from kit "Iron FerroZine. The rates of transferrin and ferritin were estimated by immunoturbidimetric method according respectively to kits "Transferrin Immunoturbidimetric" and "Ferritin Turbilatex." The reagents of such analyzes have been provided by Spinreact SA company (Ctra-Santa Coloma, Spain). LisaBio 300 (Hycel group, Pouilly en Auxois, France) allowed the reading values serum iron, transferrin and ferritin. Each assay of blood sample from same sample was performed twice to minimize potential manipulation errors. The average of these obtained 2 values was used.

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.

Total iron binding capacity (TIBC), saturation coefficients of transferrin (SCT) and iron stores have been obtained by calculations as follows:

TIBC (µmol/l) = 25. Serum transferrin (g/l) [28].
SCT (%) = [100. Serum iron (µmol/l)]/TIBC (µmol/l) [28].
For Iron stores (mg): 1 µg/l of serum ferritin = 8 mg of iron stores [29]

## 2.3 Statistical Design

The results of study are expressed as averages associated with standard errors of mean (SEM). The determination of iron status components indicated in Table 2, was performed according to recommendations of WHO, French Society of Clinical Biology, French Society of Haematology (Group of Cellular Haematology), Society nutrition and dietetics French (France) and Center of disease control and prevention [10, 28, 30, 31]. Possible changes of haematological and biochemical parameters between various groups of adolescents were evaluated by STUDENT test. The analysis of variance (ANOVA) with repeated measures multivariate tests involving as post hoc Newman-Keuls test were used to compare the means of biological parameters between the different trimesters in pregnant adolescents.

These statistical analyses were performed by computer program Statistica Statsoft Windows version 7.1 [32]. For comparisons of different obtained proportions, Loglikelihood ratio test (Test "G") was conducted by statistical software "R" Windows version 2.0.1 [33]. A probability level (p) of less than 0.05 was chosen for significance in all statistical analyzes.

**Table 2. Assessment of iron status in population [10, 28, 30, 31]**

| Haematological and biochemical parameters | Iron deficiency | Iron deficiency anaemia | Inflammatory anaemia | Iron deficiency + Inflammatory anaemia |
|---|---|---|---|---|
| Hemoglobin | Normal | Low | Low | Low |
| MCV | Normal | Low | Normal | Normal or Low |
| MCH | Normal | Low | Normal or Low | Normal or Low |
| Serum iron | Normal or low | Low | Normal or Low | Low |
| Transferrin | Normal or high | High | Low | Normal or Low |
| SCT | Normal | Low | Normal or Low | Low |
| Serum Ferritin | Low | Very high | Normal or high | Normal |

*SCT: Saturation coefficient of transferrin*

## 3. RESULTS

### 3.1 Changes in Biological Parameters of Iron Status Assessment and Iron Stores

After analyses of data with STUDENT test, all haematological parameters were changed between non-pregnant and adolescents during pregnancy. Indeed, red blood cells, hemoglobin, hematocrit, MCV, MCH were increased in non-pregnant adolescents compared with pregnant adolescents. In addition, the results with ANAVO test indicated that these haematological parameters were decreased in pregnant adolescents at the third trimester of pregnancy compared with control adolescents. However, Mean corpuscular hemoglobin concentration (MCHC) was higher in adolescents throughout pregnancy than in control non-pregnancy adolescents (Fig. 1). For biochemical parameters, serum iron, saturation coefficient of transferrin (SCT) and serum ferritin values were higher in control non-pregnant adolescents compared with values in pregnant adolescents. These different biochemical indicators were decreased in third trimester pregnant adolescents. Conversely, serum transferrin and total iron binding capacity were significantly increased in pregnant adolescents during all trimesters of pregnancy beside control non-pregnant adolescents (Fig. 2).

Furthermore, iron stores were greatly decreased throughout the three trimesters of pregnancy compared with non-pregnant adolescents (Fig. 2).

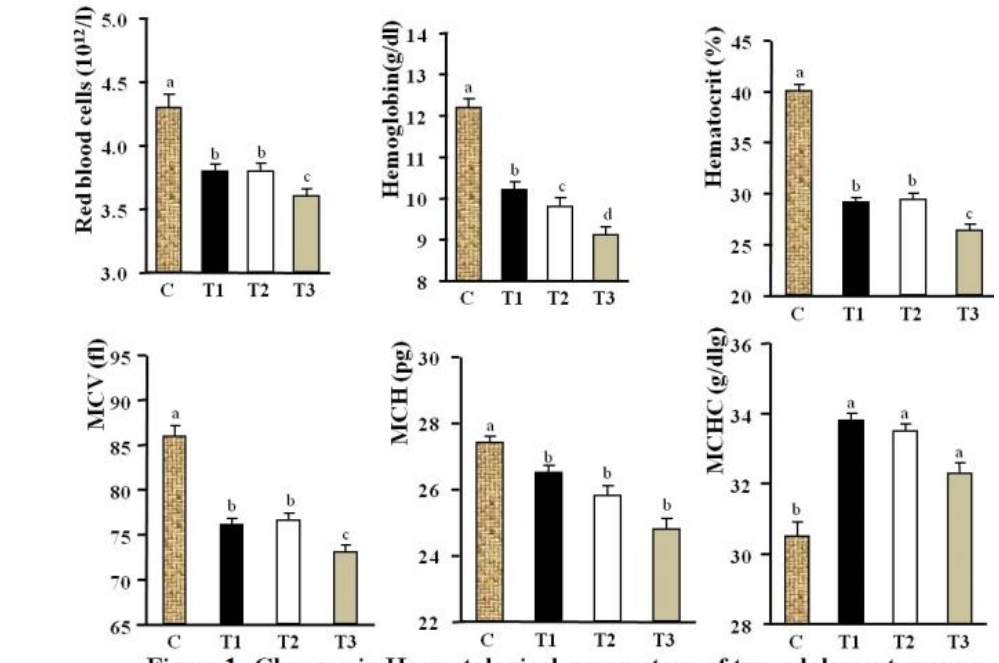


**Figure 1. Changes in Haematological parameters of two adolescent groups**

C: Control Non-Pregnant Adolescents T1: First Trimester T2: Second Trimester T3: Third Trime
MCV: Mean Corpuscular Volume MCH: Mean Corpuscular Hemoglobin
MCHC: Mean Corpuscular Hemoglobin Concentration a, b, c et d: Group statistically signifant for $p < 0.05$

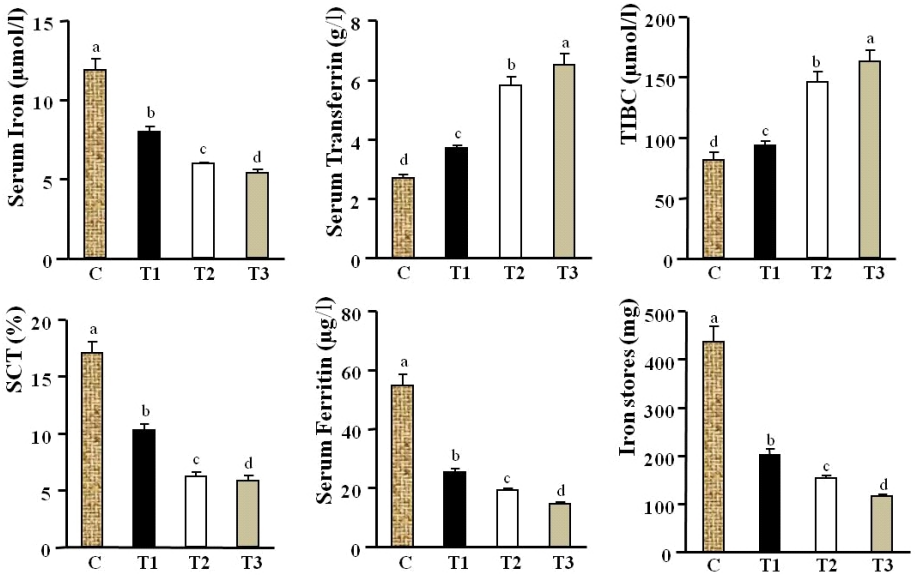


**Figure 2. Evaluation of Biochemical Parameters and Iron Stores in Adolescents groups**

TIBC: Total Iron Binding capacity SCT: Saturation coefficient of Transferrin
a, b, c et d: Group statistically signifant for $p < 0.05$ C: Control Non-Pregnant Adolescents
T1: First Trimester T2: Second Trimester T3: Third Trimester

### 3.2 Frequency of Abnormal Parameters of Iron Status

The findings in Table 3 were reported that pregnant adolescents were more anaemic during pregnancy compared with non-pregnant adolescents. In the same way, severe anaemia was not observed in non-pregnant adolescents. However, this type of anaemia was revealed throughout the three stages of pregnancy in these study adolescents. In addition, in these same subjects, our study was recorded, hypochromic microcytic anaemia, hypochromic normocytic anaemia, normochromic normocytic anaemia and normochromic microcytic anaemia. But, in non-pregnant adolescents only hypochromic microcytic anaemia and hypochromic normocytic anaemia were indicated (Table 3). For low values of hematocrit, microcytosis and hypochromia, different prevalence rates were significantly more high in adolescents during pregnancy beside control non-pregnant adolescents. Moreover, no macrocytosis was observed among pregnant adolescents in contrast to non-pregnant adolescents (8 %). The findings of study were shown that non-pregnant adolescents were indicated proportions of low values of serum iron, saturation coefficient of transferrin and serum ferritin less large relative to those observed in adolescents during pregnancy (Table 4). Conversely, adolescents throughout pregnancy were revealed decreased proportions of low values of serum transferrin and total iron binding capacity compared with control non-pregnant adolescents. However, for high values of serum transferrin and total iron binding capacity, the same pregnant adolescents were recorded increased rates beside non-pregnant adolescents (Table 4). An analysis involving all biological parameters of iron metabolism showed in Table 5 that iron status of all study adolescents was altered. This iron status was more degraded in pregnant adolescents compared with non-pregnant adolescents. In addition, non pregnant adolescent was reported a normal iron status in the third trimester of pregnancy. In the same way, the abnormal iron status was composed of iron deficiency, iron deficiency anaemia, inflammatory anaemia and inflammatory anaemia associated with iron deficiency. Furthermore, pregnant adolescents throughout pregnancy were concerned by high prevalence rates of iron deficiency anaemia. But, non-pregnant adolescents were observed inflammatory anaemia (10.7 %) and inflammatory anaemia associated with iron deficiency compared with pregnant adolescents (Table 5).

**Table 3. Compared proportions of main haematological parameters between two groups of adolescents**

| Haematological parameters[a] | Non-pregnant adolescents N=75 n (%) | Pregnant adolescents (N=112) | | | *P* values |
|---|---|---|---|---|---|
| | | First trimester n (%) | Second trimester n (%) | Third trimester n (%) | |
| Hemoglobin (g/dl)[b] | | | | | |
| Anaemia (< 10.5 or 11 or 12) | 32 (42.7) | 76 (67.9) | 60 (53.6) | 87 (77.7) | < 0.001 |
| Normal (10.5-14 or 12-16) | 43 (57.3) | 36 (32.1) | 52 (46.4) | 25 (22.3) | < 0.001 |
| Types of anaemia | | | | | |
| Mild (10.5 or 11 or 12-9) | 16 (21.3) | 10 (8.9) | 33 (29.5) | 64 (57.1) | < 0.001 |
| Moderate (8-9) | 16 (21.3) | 40 (35.7) | 10 (8.9) | 24 (21.4) | < 0.001 |
| Severe (< 8) | 0 (0) | 26 (23.2) | 17 (15.2) | 9 (8) | < 0.001 |
| HMA | 29 (38.7) | 40 (35.7) | 38 (33.9) | 59 (52.7) | < 0.001 |
| HNA | 3 (4) | 9 (8) | 7 (6.3) | 4 (3.6) | > 0.05 |
| NNA | 0 (0) | 21 (18.8) | 12 (10.7) | 21 (18.8) | < 0.001 |
| NMA | 0 (0) | 6 (5.4) | 3 (2.7) | 3 (2.7) | > 0.05 |
| Hematocrit (%)[b] | | | | | |
| Low (< 32 or 33) | 36 (48) | 88 (78.6) | 65 (58) | 87 (77.7) | < 0.01 |
| Normal (32-42 or 36-47) | 39 (52) | 24 (21.4) | 47 (42) | 25 (22.3) | < 0.01 |
| MCV (fl) | | | | | |
| Microcytosis (< 80) | 29 (38.7) | 85 (75.9) | 76 (67.9) | 90 (80.4) | < 0.001 |
| Normal (80-100) | 40 (53.3) | 30 (24.1) | 36 (32.1) | 22 (19.6) | < 0.01 |
| Macrocytosis (> 100) | 6 (8) | 0 (0) | 0 (0) | 0 (0) | < 0.001 |
| MCH (pg) | | | | | |
| Hypochromia (< 27 and >31) | 35 (46.7) | 69 (61.6) | 74 (66.1) | 94 (83.9) | < 0.01 |
| Normal (27-31) | 40 (53.3) | 43 (38.4) | 38 (33.9) | 18 (16.1) | < 0.001 |

*n: Number of observed subjects in each group; a: Haemotological reference parameters according to French Society of haematology [21], [52]; b: for these two haematological parameters, the reference values were defined according to the stage of pregnancy to obtain prevalences of types' anaemia and hemodilution; hemoglobin levels are similar in the first and third trimesters of pregnancy, it is the same for hematocrit. MCV: Mean corpuscular volume; MCH: Mean corpuscular hemoglobin; HMA: Hypochromic Microcytic Anaemia; HNA: Hypochromic Normocytic Anaemia; NNA: Normochromic Normocytic Anaemia; NMA: Normochromic Microcytic Anaemia.*

**Table 4. Iron stores parameters in non-pregnant and pregnant subjects**

| Biochemical indicators[α] | Non-pregnant adolescents N=75 n (%) | Pregnant adolescents (N=112) | | | *P* values |
|---|---|---|---|---|---|
| | | First trimester n (%) | Second trimester n (%) | Third trimester n (%) | |
| Serum iron (µmol/l) | | | | | |
| Low (< 7.16) | 29 (38.7) | 57 (50.9) | 112 (100) | 79 (70.5) | < 0.001 |
| Normal (7.16-26.85) | 46 (61.3) | 55 (49.1) | 0 (0) | 33 (29.5) | < 0.001 |
| Serum transferrin (g/l) | | | | | |
| Low (< 2) | 23 (30.7) | 14 (12.5) | 9 (8) | 2 (1.8) | < 0.001 |
| Normal (2-3.6) | 40 (53.3) | 44 (39.3) | 35 (31.3) | 31 (27.7) | < 0.05 |
| High (> 3.6) | 12 (16) | 54 (48.2) | 68 (60.7) | 79 (70.5) | < 0.001 |
| TIBC (µmol/l) | | | | | |
| Low (< 50) | 23 (30.7) | 14 (12.5) | 9 (8) | 1 (0.9) | < 0.001 |
| Normal (50-90) | 40 (53.3) | 44 (39.3) | 35 (31.3) | 32 (28.6) | < 0.05 |
| High (> 90) | 12 (16) | 54 (48.2) | 68 (60.7) | 79 (70.5) | < 0.001 |
| SCT (%) | | | | | |
| Low (< 15) | 27 (36) | 84 (75) | 111 (99.1) | 91 (81.6) | < 0.001 |
| Normal (15-35) | 48 (64) | 28 (25) | 1 (0.9) | 21 (18.4) | < 0.001 |
| Serum ferritin (µg/l) | | | | | |
| Low (< 20) | 26 (34.7) | 67 (59.8) | 72 (64.3) | 97 (88.6) | < 0.001 |
| Normal (20-110) | 49 (65.3) | 45 (40.2) | 40 (35.7) | 15 (13.4) | < 0.001 |
| Iron stores (mg) | | | | | |
| Low (< 200) | 26 (34.7) | 81 (72.3) | 94 (83.9) | 107 (95.6) | < 0.001 |
| Normal (200-900) | 49 (65.3) | 31 (27.7) | 18 (16.1) | 05 (4.4) | < 0.001 |

*n: Number of observed subjects in each group; TIBC: Total iron binding capacity; SCT: Saturation coefficient of transferrin, α: the proportions of various biochemical parameters were defined according to established references [21], [23], [24], [53].*

**Table 5. Compared components of iron status between two groups of adolescents**

| Components of iron status[β] | Non-pregnant adolescents N=75 | Pregnant adolescents (N=112) | | | *P* values |
|---|---|---|---|---|---|
| | | First trimester | Second trimester | Third trimester | |
| | n (%) | n (%) | n (%) | n (%) | |
| Normal iron status | 10 (13.3) | 13 (11.6) | 11 (9.8) | 0 (0.0) | < 0.001 |
| Abnormal iron status | 65 (86.7) | 99 (88.4) | 101 (90.2) | 112 (100) | > 0.05 |
| Iron deficiency | 20 (26.7) | 27 (24.1) | 40 (35.7) | 25 (22.3) | > 0.05 |
| Iron deficiency anaemia | 12 (16) | 65 (58) | 61 (54.5) | 86 (76.8) | < 0.001 |
| Inflammatory anaemia | 8 (10.7) | 6 (5) | 0 (0.0) | 1 (0.9) | < 0.001 |
| Inflammatory anaemia + Iron deficiency | 25 (33.3) | 1 (1.3) | 0 (0.0) | 0 (0.0 | < 0.001 |

*n: Number of observed subjects in each group; β: The prevalences of the various components of iron status were defined depending on established references [6], [21], [23], [25], [26], [53]*

## 4. DISCUSSION

The results of this study indicate that haematological and biochemical parameters were decreased in pregnant adolescents at the third trimester of pregnancy compared with control adolescents. The findings show that iron stores were greatly decreased throughout pregnancy compared with non-pregnant adolescents. These results are similar to those of some authors who reveal that women of reproductive age require more iron. These demands are indispensable for the growth, menstruation and pregnancy [29, 34]. According to some authors, the low iron status early in pregnant women was found to be inversely related to placental size [35]. The total iron requirement is 1040 mg during pregnancy with 840 mg to the foetus [36]. Other studies have shown that for a adolescent who has not finished growing, competition takes place between fetal growth and maternal growth [37, 38]. This phenomenon and the dilution of plasma (normal pregnancy) cause the depletion of maternal iron throughout the pregnancy [34, 39, 40]. According to Ivorian study, women were presented iron deficiency during pregnancy [20]. In addition, the same authors were reported that, adolescents are exposed to an alteration of iron metabolism in the third trimester of pregnancy. Furthermore, non-pregnant adolescents in this same country were more observed an abnormal iron status (86.7 %) [24]. This comparative study shows more clearly the degradation of iron metabolism through iron stores in adolescents than other previous studies. Iron deficiency anaemia is still a major health problem. WHO estimates that 10.3 % of women in industrialized countries are anaemic, as compared with 42.3 % in non-industrialized countries [10]. Pregnancy is considered an important risk factor for iron deficiency and iron deficiency anaemia [41, 42, 43]. In addition, our study indicated that iron deficiency anaemia was higher in pregnant (76.8 %) than non-pregnant women (10.7 %). These results are similar to those which estimated the prevalence of anaemia in pregnant and non-pregnant women in Latin America [44]. These authors showed that anaemia was 38.5 % in pregnant versus 17.3 % in non-pregnant women. In developing countries, the prevalence of iron deficiency anaemia most often is attributed to nutritional deficiencies worsened by chronic blood loss due to parasitic infections and malaria [34, 45, 46, 47]. This could also explain the collapse of the iron stores of all adolescents in our study.

## 5. CONCLUSION

Our study reports the main changes of haematological parameters in adolescents (pregnant and non-pregnant). In addition, biochemical indicators are modified in the same study population. In this way, iron status of the two adolescent groups is altered with high prevalence of abnormal iron status. This abnormal iron status includes iron deficiency, iron deficiency anaemia, inflammatory anaemia and inflammatory anaemia associated with iron deficiency. However, iron status is more degraded in pregnant adolescent throughout the pregnancy.

This investigation reveals that iron metabolism of pregnant adolescents must be particularly followed during all stages of pregnancy.

## FUNDING

This research did not receive any specific grant from any funding agency in the public, commercial, or not-for-profit sector.

## ACKNOWLEDGEMENT

Authors of this study thank Dr Leonie Clemence KOUONON for her support during the drafting of this manuscript.

### CONSENT

All authors declare that 'written informed consent was obtained from the patient (or other approved parties) for publication of this research paper.

### ETHICAL APPROVAL

All authors hereby declare that "Principles of laboratory animal care" (NIH publication No. 85-23, revised 1985) were followed, as well as specific national laws where applicable. All experiments have been examined and approved by the appropriate ethics committee".

All authors hereby declare that all experiments have been examined and approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki."

## COMPETING INTERESTS

The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

## REFERENCES

1. Ganz T. Hepcidin and its role in regulating systemic iron metabolism. Am J Hematol. 2006;1: 29-35.
2. Anderson GJ, Darshan D, Wilkins S J, Frazer DM. Regulation of systemic iron homeostasis: how the body responds to changes in iron demand. Biometals. 2007;20:665-74.
3. Ganz T. Molecular control of iron transport. J Am Soc Nephrol. 2007;18:394-400.
4. Underwood B, Underwood B. The extent and magnitude of iron deficiency and anaemia. In: Verster A, ed. Guidelines for the control of iron deficiency in countries of the Eastern Mediterranean, Middle East and North Africa. Alexandria, World Health Organization Regional Office for the Eastern Mediterranean, 1996:14–8.
5. Zimmermann MB, Hurrell RF. Nutritional iron deficiency. The Lancet. 2007;370(9586): 511-520.
6. DeMaeyer EM, Adiels-Tegman M. The prevalence of anaemia in the world. World Health Stat Q. 1985;38:302-316.
7. Hughes-Jones NC, Wickramasinghe SN, Hatton CSR Lecture Notes: Haematology. Eighth edition. Wiley-Blackwell, Oxford. 2009.
8. World Health Organization (WHO). "The Prevalence of Anaemia in Women: a tabulation of available information," Division of Family Health, Maternal Health and Safe Motherhood Programme, Division of Health Protection and Promotion, Nutrition Programme; WHO, 2nd ed. World Health Organization, Geneva, Switzerland, 1992.
9. ACC/SCN (United Nations Administrative Committee on Coordination/Standing Committee on Nutrition), "Fifth report on the world nutrition situation: Nutrition for improved development outcomes," Geneva, Switzerland, accscn@who.org, 2004.

10. UNICEF/UNU/WHO. Iron deficiency anemia: assessment, prevention, and control. A guide programme managers. WHO/NHD/01.3 Geneva, Switzerland: WHO, 2001. http://www.who.org/publications/index.html consulté le 28/04/2012. Accessed April 28th 2010
11. McCann JC, Ames BN. An overview of evidence for a causal relation between iron deficiency during development and deficits in cognitive or behavioral function. Am J Clin Nutr. 2007;85:931– 45.
12. Haas J, Brownlie T. Iron deficiency and reduced work capacity: a critical review of the research to determine a causal relationship. J Nutr. 2001;131:676S-690S.
13. Allen LH. Anemia and iron deficiency: effects on pregnancy outcome. Am J Clin Nutr. 2000;71(5 Suppl):1280S–1284S.
14. Ronnenberg AG, Wood RJ, Wang X, Xing H, Chen C, Chen D, Guang W, Huang A, Wang L, Xu X. Preconception hemoglobin and ferritin concentrations are associated with pregnancy outcome in a prospective cohort of Chinese women. J Nutr. 2004;134:2586-2591.
15. Lee HS, Kim MS, Kim MH, Kim YJ, Kim WY. Iron status and its association with pregnancy outcome in Korean pregnant women. Eur J Clin Nutr. 2006;60:1130-1135.
16. Halimatou A. évaluation d'une intervention nutritionnelle visant à prévenir l'anémie ferriprive chez des adolescentes pensionnaires au bénin. Thèse présentée à la Faculté des études supérieures de l'Université Laval dans le cadre du programme de doctorat en nutrition pour l'obtention du grade de Philosophiae Doctor (Ph.D.), CANADA, 2008;318p.
17. Moran VH. Nutritional status in pregnant adolescents: a systematic review of biochemical markers. Matern Child Nutr. 2007a;3:74–93.
18. Moran VH. A systematic review of dietary assessments of pregnant adolescents in industrialised countries. Br J Nutr. 2007b;97:411–425.
19. Asobayire SF, Adou P, Davidsson L, Cook JD, Hurell RF. 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. 2001; 74:776-782.
20. Bléyéré MN, Joulia-Ekaza D, Yapo AP, Yao JD, N'guessan BB, Cathy AMN, Vanga OM, Koné M, Ehilé EE. Hétérogénéité du statut en fer chez la femme au cours de la grossesse en Côted'Ivoire. Ann Biol Clin. 2007; 65:525-532.
21. Ahiboh H, Oga AS, Yapi HF, Kouakou G, Boua KD, Edjeme N, Monnet D. Anémie, métabolisme du fer et protéines de la réaction inflammatoire au cours du paludisme (Abidjan, CI). Bull Soc Pathol Exot. 2008;101:25-28.
22. Yapo PA, Bléyéré MN, Joulia-Ekaza D, Yao JD, N'Guessan BB, Ehilé EE. Prévalence de carences martiales et d'anémies chez des femmes en âge de procréer, non enceintes et des femmes enceintes. Ann Biol Clin Qué. 2008;45:24-28
23. Yapi HF, Ahiboh H, Koffi D, Yapo A, Bla KB, Monnet D, AJ Djaman Assessment of inflammatory and immunity proteins during *falciparum* malaria infection in children of Côte d'Ivoire. Am J Sci Ind Res. 2010;1:233-237.
24. Atto V, Bléyéré MN, Konan AB, Datté JY, Yapo PA. Depletion of Iron Stores and Main Associated Parameters in Adolescents of Côte d'Ivoire. Pak J Nutr. 2013;12 (2):188-196.
25. Bleyere MN, Amonkan AK, Kone M, Sawadogo D, YAPO PA. High variability of iron status in adolescent during pregnancy in Côte d'Ivoire. J nutr health. 2013; in press.
26. Leenstra T, Kariuki SK, Kurtis JD, Oloo AJ, Kager PA F.O.Kuile. Prevalence and severity of anemia and iron deficiency: cross-sectional studies in adolescent schoolgirls in western Kenya. Eur J Clin Nutr. 2004;58:681–691.

27. Young MF, Pressman E, Foehr ML, McNanley T, Cooper E et al. Impact of maternal and neonatal iron status on placental transferrin receptor expression in pregnant adolescents. Placenta. 2010;31(11):1010-1014.
28. Vernet M, Corberand J, David V. Algorithmes de prescription recommandés pour le diagnostic d'un déficit et d'une surcharge en fer. Ann Biol Clin. 2001;59:149-55.
29. Beard JL. Iron requirements in adolescent females. J Nutr. 2000; 130:440S-442S.
30. Institute of Medecine (IOM/USA). Comittte on nutritional status during pregnancy and lactation. Nutrition during pregnancy: weight gain and nutrient supplements. Washington DC. National Academy Press. 1990.
31. Société de Nutrition et de Diététique de Langue Française (SNDLF) Anémies nutritionnelles. Cah Nutr Diét. 2001;36 (Hors série):76-81.
32. Statsoft. Statistica (Data Analysis Software System). 2005; Version 7.1 available at www. Statsoft.com. Accessed September 21st 2004.
33. Ihaka R, Gentleman R. R: a language for data analysis and graphics. J Comp Graph Stat. 1996;5:299-314.
34. Wu AC, Lesperance L, Bernstein H. Screening for Iron Deficiency. Pediatr Rev. 2002; 23(5):171-178.
35. Hindmarsh PC, Geary MPP, Rodeck CH, Jackson MR and Kingdom JCP. Effect of early maternal iron stores on placental weight and structure. Lancet. 2000;356:719–723,
36. Hallberg L. Iron balance in pregnancy. In: Berger H (editor). Vitamins and minerals in pregnancy and lactation. Nestle Nutr Workshop Ser. 1988;16:115-27.
37. Gambling L, Danzeisen R, Gair S, Lea RG, Charania Z, Solanky N, Joory KD, Srai SK, McArdle HJ. Effect of iron deficiency on placental transfer of iron and expression of iron transport proteins in vivo and in vitro. Biochem J. 2001;356:883-889.
38. Ayoubi JM, Hirt R, Badiou W, Hininger-Favier I, Favier M, Zraik-Ayoubi F, Berribi, Pons JC. Nutritionet femme enceinte. EMC (ElsevierMasson SAS, Paris) Gynecol/Obstet 2012;5-042A-10.
39. Puolakka J, Jänne O, Vihko R. Evaluation by Serum Ferritin Assay of the Influence of Maternal Iron Stores on the Iron Status of Newborns and Infants. Acta Obstet Gynecol Scand. 1980;59:53–56.
40. Colomer J, Colomer C, Gutierrez D, Jubert A, Nolasco A, Donat J, Fernandez-Delgado R, Donat F, Alvarez-Dardet C. Anaemia during pregnancy as a risk factor for infant iron deficiency: report from the Valencia Infant Anaemia Cohort (VIAC) study. Paediatr Perinat Epidemiol. 1990;4:196–204.
41. Bodnar LM, Cogswell ME, Scanlon K S. Low income postpartum women are at risk of iron deficiency. J Nutr. 2002;132: 2298-2302.
42. Sserunjogi L, Scheutz F, Whyte SR Postnatal anaemia: neglected problems and missed opportunities in Uganda. Health Policy Plann. 2003;18:225-231.
43. Cardenas VM, Mulla ZD, Ortiz M, Graham DY. Iron deficiency and Helicobacter pylori infection in the United States. Am J Epidemiol. 2006;163:127-134.
44. Cook JD, Alvarado J, Gutnisky A, Jamra M, Labardini J, Layrisse M, Linares J, Loría A, Maspes V, Restrepo A, Reynafarje C, Sánchez-Medal L, Vélez H, Viteri F Nutritional Deficiency and Anemia in Latin America: A Collaborative Study. Blood. 1971;38(5):591–603.
45. Yip R, Johnson C, Dallman PR. Age-related changes in laboratory values used in the diagnosis of anemia and iron deficiency. J Am Med Assoc. 1984;39:427-36.

46. Yip R, Dallman P. The role of inflammation and iron deficiency as causes of anemia. J Am Med Assoc 1988;48:1295-1300.
47. Dillon JC. Prévention de la carence en fer et des anémies ferriprives en milieu tropical. Méd Trop. 2000;60:83-91.



*Peer-review history:*
*The peer review history for this paper can be accessed here:*
*http://www.sciencedomain.org/review-history.php?iid=294&id=28&aid=2411*