

# Study of the Mineral Element Status in Sick Cell Patients Attending the Mixed Medicine and Sick Cell Anemia Center “Yolo Mabanga” in Kinshasa in Democratic Republic of the Congo

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## Abstract

**Introduction:** Sick cell disease, also called sickle cell anemia, is a genotypic disorder prevalent in the black population; it is characterized by a hemolytic type anemia and can worsen following a deficiency of copper, zinc and serum iron. **Methods:** It was a question of evaluating the plasma status of copper and zinc by the photometric method, serum iron was measured by spectrophotometry, and finally ferritin and transferrin were measured by the immunoenzymatic method; in subjects with sickle cell disease and healthy subjects of all ages followed at the mixed medicine and sickle cell anemia center in Kinshasa (CMMASS). **Results:** A total of 60 subjects participated in this study. The sex ratio was 1.30; the average age of sickle cell patients was 7.4 years  $\pm$  3.8 and 27.4 years  $\pm$  5.1; for the control group, the average age was 8.2 years  $\pm$  4.2 and 29 years  $\pm$  6.7. 13.3% of children with sickle cell disease presented hypocupremia and 13.3% hypercupremia. For adults with sickle cell disease, 26.7% had hypocupremia and 13% had hypercupremia. Regarding zincemia, 67% of children and adults with sickle cell disease presented hypozincemia; 60% of child subjects with sickle cell disease demonstrated hypsideremia; in adults with sickle cell disease 20% have hypsideremia and 13% have hypersideremia. **Conclusion:** Our results demonstrate not only the effective presence of iron overload in adult sickle cell patients, but also an iron deficiency in controls and sickle cell patients, ignoring hemolysis.

## Keywords

Mineral Elements, Sick Cell Disease, CMMASS

## 1. Introduction

Sickle cell disease is an autosomal recessive genetic disease linked to a genetic anomaly (E6V mutation, *i.e.* a substitution of adenine by Thymine) at the 6th codon of the short arm of chromosome 11. This genetic anomaly causes the formation of abnormal hemoglobin called Hemoglobin S having the characteristic of sickling red blood cells (the RBC takes the shape of a sickle) in the presence of certain conditions such as hypoxia, acidosis and fever [1].

It is the most common “hemoglobinopathy” in Africa, with a prevalence of 20% in DR Congo. It constitutes a real public health problem since recent epidemiological data have shown that in the neonatal period, 2% of newborns are homozygous and approximately 40.000 births of children with sickle cell disease are estimated each year, while in the adult population, the Homozygous form affects approximately 2% of individuals [1].

It is characterized by a hemolytic anemia with release of iron into the blood circulation, also with infectious and inflammatory episodes which can worsen following a deficiency of copper, zinc, serum iron, etc [2]-[4]. In addition to hemolysis, blood transfusion constitutes a source of iron intake in sickle cell patients. Indeed, each transfused erythrocyte concentrate provides approximately 200 mg of iron depending on its volume, thereby causing iron overload in poly-transfused sickle cell patients [5]. However, the human body lacks a physiological mechanism for excreting this excess iron. Consequently, this excess iron accumulates and is responsible for cardiac, hepatic and endocrine damage making up a disease called hemochromatosis [6].

The National Heart Lung and Blood Institute’s Sickle Cell Disease Management Guide has established a comprehensive program to monitor and treat iron overload. He also recommends screening for iron overload by analyzing serum ferritin levels from the start of transfusion therapy, and indicates that overload probably becomes detectable after twenty transfusions [7].

In addition, homozygous sickle cell patients are exposed to iron deficiency following a nutritional deficiency during the growth period. As in developing countries, children, adolescents and pregnant women are particularly vulnerable [8].

Depending on its role, copper transports iron in the body, contributes to the proper functioning of the immune system, etc.; High or low iron levels in the body can lower copper levels in adolescents, pregnant women and people with genetic diseases such as sickle cell anemia.

Indeed, several authors have reported that zinc deficiency is much more present during sickle cell disease and is associated with malnutrition which affects the immune system, thus exposing sickle cell patients to multiple infections [9] [10].

This is why our study is based on the dosage of copper, zinc given their essential roles in the regeneration of red blood cells in the body, especially in sickle cell patients, and iron considered as a constituent element of hemoglobin [11].

A study carried out on the contribution of soluble transferrin receptors in the evaluation of iron status during homozygous sickle cell disease revealed that 17.5% of sickle cell patients and 3.33% of controls (AA) had an increase in iron levels and the receptor transferrin, which demonstrated a severe iron deficiency in sickle cell patients [12]. Theoretically with hemolysis the plasma iron level should be higher.

Thus, it was a question of evaluating the plasma status of copper, zinc, iron (ferritin and transferrin) in the blood of sickle cell patients of all ages followed at the mixed medicine and sickle cell anemia center of Kinshasa (CMASS).

The interest of this study is to allow clinicians to provide the community as well as health professionals with useful information that can help them cope with and prevent vaso-occlusive crises (VOC) and thoracic acute syndrome (TAS).

## 2. Population and Methods

It is an analytical—comparative study, the study concerned subjects with sickle cell disease and controls (non-sickle cell disease) followed at the Mixed Medicine and Sickle Cell Anemia Center in Kinshasa (CMMASS).

Included in the study, thirty polytransfused sickle cell subjects, not being in a state of severe vaso-occlusive crises, not having received a transfusion during the month and thirty non-sickle cell subjects were taken as controls, not recently having a transfusion. Free and informed consent was obtained, either from the subject himself for adults, or through the parent or guardian for children.

The sampling applied is of non-probabilistic convenience because the choice of patients was made according to their attendance at the center and concerned all subjects with homozygous sickle cell disease (SS) whose hemoglobin status was proven by the electrophoresis method of the Cellulose acetate hemoglobin.

The control group consisted of AA and AS people attending the same center and whose hemoglobin status was proven by electrophoresis.

The dosages of mineral elements included:

- Colorimetric determination of copper with dithiocarbamate in an ammoniacal medium pH 9.2 in the presence of EDTA [13].
- The dosage of zinc with potassium ferrocyanide which reacts with zinc to give a colloidal precipitate of zinc ferrocyanide capable of photocolorimetric dosage [13].

The parameters of the martial assessment included:

- Serum iron dosage with spectrophotometry
- The determination of ferritin and immuno enzyme transferrin.

The following reference values were considered:

- For copper: 12 - 36  $\mu\text{mol/l}$  for children and 11 - 24  $\mu\text{mol/l}$  for adults
- For zinc: 9 - 21.5  $\mu\text{mol/l}$  for children, 11.6 - 31.3  $\mu\text{mol/l}$  (men), 9.0 - 30.4  $\mu\text{mol/l}$  (women)
- For ferritin: 15 - 80  $\mu\text{g/l}$  for children and for adults 30 - 300  $\mu\text{g/l}$  for males

and 20 - 200 µg/l for females

- For transferrin: 290 - 830 µg/l

Statistical analysis:

To statistically process our results, we proceeded by calculating the average and the standard deviation as well as the calculated Z test.

All data were entered and analyzed using SPSS 15.0 software. The different variables were compared using the chi-square test, the averages were compared using the Student's T-test. The significance threshold p retained was less than 0.05.

### 3. Results

The sample consists of 60 patients including 30 sickle cell patients and 30 AA controls who consulted CMMASS/Yolo during the work period and who freely agreed to participate in the study. These results will be presented in the form of sociodemographic data and mineral element analysis results.

#### 3.1. Sociodemographic Aspect

The study population included a total of 30 children whose ages ranged from 1 to 17 years with an average of  $7.4 \pm 3.8$  years for SS subjects and  $8.2 \pm 4.2$  years for AA subjects and a total of 30 adults including 1 The age varies between 18 and 40 years old. With an average of  $27.4 \pm 5.1$  for SS subjects and  $29 \pm 6.7$  for AA subjects.

#### 3.2. Mineral Element Content of Study Subjects

##### 1) Blood copper levels in children and adults

- Referring to the normal value of serum copper which is 12 - 36 µmol/l in children and 11 - 24 µmol/l in adults. Of 15 children with sickle cell disease, 2 children had hypocupremia < 12 µmol/l, 2 had hypercupremia and 11 had normal values. Compared to the 15 AA children, 10 were within the normal range and 5 had hypocupremia.
- Concerning adults with sickle cell disease, 4 adults or 26.7% presented hypocupremia and 2 subjects presented hypercupremia, 9 subjects had normal values. Compared to the 15 AA adults, 2 presented hypocupremia, 1 hypercupremia and 12 had normal values.

##### 2) Blood zinc levels in children and adults

Based on the normal value of serum zinc which is 9 - 21.5 µmol/l for children; for adults, 11.6 - 31.3 µmol/l (Male Sex) and 9.0 - 30.4 µmol/l (Female Sex). The results gave:

- In children: 10 sickle cell patients showed hypozincemia, 5 children had normal zincemia; compared to children without sickle cell disease, 9 have normal zincemia and 6 have hypozincemia;
- In adults: 10 sickle cell patients have hypozincemia and 5 are within the normal range. Unlike normal subjects, 10 had normal zincemia and 5 had

hypozincemia.

### 3) Rates of sideremia in children and adults

With a normal value of 9 - 32  $\mu\text{mol/l}$  for the child,

- We found 9 children with sickle cell disease, or 60%, presenting hyposideremia, unlike the control children, 8 had hypersideremia and 2 children presented hyposideremia. No child presented with hypersideremia in sickle cell patients.
- With a normal value of 10.6 - 28.3  $\mu\text{mol/l}$ , out of 30 adult subjects in the study, 3 or 20% of sickle cell patients presented hyposideremia, however no adult control presented hyposideremia and 2 sickle cell subjects or 13% presented with hypersideremia.

The different averages of mineral elements are shown in **Table 1** and their comparisons are in **Table 3** and **Table 4**. A significant difference was found for copper and iron in children with a lower level in sickle cell patients.

**Table 1.** Average content of mineral elements.

Parameters	Sickle cell patients n/30		Controls n/30	
	Children	Adults	Children	Adults
Age (/yrs)	7.4 $\pm$ 3.8	27.4 $\pm$ 5.1	8.2 $\pm$ 4.2	29 $\pm$ 6.7
Copper	13.1 $\pm$ 4.9	17.4 $\pm$ 4.4	17.4 $\pm$ 5.7	15.3 $\pm$ 5.0
Zinc	8.9 $\pm$ 1.7	9.7 $\pm$ 3.4	9.3 $\pm$ 1	9.9 $\pm$ 1.7
Serum iron	10.9 $\pm$ 8.7	18.2 $\pm$ 7.6	34.1 $\pm$ 19	22.5 $\pm$ 11

### 3.3. Plasma Ferritin Content

#### Ferritin levels in children and adults:

For ferritin and transferrin we used only 40 samples including 20 sickle cell patients (including 10 children and 10 adults) and 20 homozygous AA adults (including 10 children and 10 adults).

- Of the 10 subjects with sickle cell disease, 100% had normal ferritin levels (15 - 80  $\mu\text{g/l}$ ), with an average of 54  $\mu\text{g/l} \pm 5.4$ ; just like in the control subjects, 10 children or 100% presented a normal ferritin level with an average of 48.3  $\mu\text{g/l} \pm 13.4 \mu\text{g/l}$ .
- For ferritinemia in adult sickle cell subjects, we had 10 subjects or 100% whose results were within the normal range with an average of 48.7  $\mu\text{g/l} \pm 15.2 \mu\text{g/l}$ ; just as in the control subjects, 10 adults or 100% are located within the normal range with an average of 52.7  $\mu\text{g/l} \pm 15 \mu\text{g/l}$ .

### 3.4. Plasma Transferrin Content

#### Transferrin levels in children and adults

- For transferrin in children, 1 subject with sickle cell disease, or 10%, presented hypotransferrinemia and 4 subjects with sickle cell disease presented hypertransferrinemia; Unlike the controls, 2 subjects or 20% presented hy-

pertransferrinemia and 1 subject or 10% hypotransferrinemia.

Comparing the results of sickle cell patients and adult controls, 10% of sickle cell subjects presented hypotransferrinemia compared to control subjects; there were 40% of control subjects with hypotransferrinemia. And 20% of sickle cell subjects presented hypertransferrinemia, unlike in control subjects, 1 adult or 10% had hypertransferrinemia.

The averages of ferritin and transferrin are shown in **Table 2** and the comparison of averages in **Table 3** and **Table 4**. No difference was observed for the two groups of subjects.

**Table 2.** Average ferritin and transferrin contents.

Parameters	Sickle cell patients n/20		Controls n/20	
	Children	Adults	Children	Adults
Ferritin	54 ± 5.2	48.7 ± 14.7	48.3 ± 14	52.7 ± 15.8
Transferrin	412 ± 197.4	467 ± 258	397 ± 310.4	609.8 ± 270.3

**Table 3.** Comparison of averages of different study parameters in children.

Parameter	Population/enfant	Sample size	Calculated <i>t</i> value	Theoretical <i>Zα</i> value ( $\alpha = 0.05$ )	Difference
Copper	Sickle cell patients	15	-2.22	1.95	Significant
	Controls	15			
Zinc	Sickle cell patients	15	0.589	1.95	Non significant
	Controls	15			
Serum iron	Sickle cell patients	15	4.196	1.95	Significant
	Controls	15			
Ferritin	Sickle cell patients	10	1.208	1.95	Non significant
	Controls	10			
Transferrin	Sickle cell patients	10	0.129	1.95	Non significant
	Controls	10			

**Table 4.** Comparison of means of different parameters in adults.

Parameter	Adult Population	Sample size	Calculated <i>t</i> value	Theoretical <i>Zα</i> value ( $\alpha = 0.05$ )	Difference
Copper	Sickle cell patients	15	1.355	1.95	Non significant
	Controls	15			
Zinc	Sickle cell patients	15	0.209	1.95	Non significant
	Controls	15			
Serum iron	Sickle cell patients	15	1.178	1.95	Non significant
	Controls	15			
Ferritin	Sickle cell patients	10	0.586	1.95	Non significant
	Controls	10			
Transferrin	Sickle cell patients	10	1.21	1.95	Non significant
	Controls	10			

**Table 1** gives the averages and standard deviations of the mineral elements studied as well as the averages and standard deviations of the ages of the population.

**Table 2** gives the averages and standard deviations of ferritin and transferrin for all subjects who participated in the study.

The comparison of the averages of different parameters were carried out in children and adults in order to determine the significance threshold for each element studied, thus **Table 3** and **Table 4** give the differences found for each group of subjects.

For **Table 3**, The Student's t test with two independent samples shows that there is a significant difference between the average concentration of copper and serum iron in children with sickle cell disease and that of control children. Children with sickle cell disease have on average a lower concentration of copper and iron than control children.

**Table 4** shows that for all parameters measured in adults there were no significant differences between the two groups.

#### 4. Discussion

Mineral elements play an important role in the immune system in humans; their deficiency would favor certain biological variations, notably the occurrence of infections. However, our sickle cell patients are subject to multiple infections, hence the interest in the dosage of certain mineral elements in our study and the dosage of ferritin which is an iron storage protein for good guidance in the management of crises in sickle cell patients.

Our study consists of 60 patients including 30 sickle cell patients and 30 controls who consulted CMMASS/Yolo during the period of our study and who agreed to participate in it after informed consent. For the children, their parents freely agreed to have them participate.

The male gender is in the majority at 56.6% with a sex ratio of 1.30. This predominance is also found in other studies in the DR Congo [14] [15]. In Africa, other studies report the same observation [16] [17]. Finally, others see no predominance between the two sexes [18] [19]. This is the case of Thuilliez and Dreux. These differences would be related to the demographic data of each country because the transmission of sickle cell disease is not linked to sex.

The age of polytransfused sickle cell patients varies between 1 and 40 years. The average is 7.4 years for children and 27.4 for adults. These data seem to corroborate the study of Ilunga K. K. A. *et al.* [1].

The study was limited to the dosages of three mineral elements among others: copper, iron and zinc and another parameter which is ferritin.

Regarding copper, out of 15 children with sickle cell disease, 4 children had abnormal cupraemia, including 2 with hypocupraemia < 12  $\mu\text{mol/l}$ . 2 had hypercupremia and 11 had normal values. Compared to the 15 control children, 10 were within the normal range and 5 had hypocupremia. Concerning adults with

sickle cell disease, 4 adults, 2 of whom had hypocupremia  $< 11 \mu\text{mol/l}$  and 2 others hypercupremia and 9 had normal values. Compared to the 15 adult controls, 2 presented hypocupremia, 1 hypercupremia and 12 had normal values. Copper deficiency can worsen anemia and neurological complications in a sickle cell patient, requiring regular monitoring and supplementation if necessary. And excess copper can lead to liver toxicities and other complications, requiring a reduction in copper intake [20].

Copper is an anti-infectious and anti-allergic, it plays several roles in the body, among other things, it is essential for the production of melanin and stimulates the immune system while having an anti-inflammatory effect. In addition, this trace element contributes to strengthening the immune system and promotes healing and slows the development of bacteria and viruses [20].

Based on the normal value of serum zinc, out of the 15 sickle cell patients evaluated, 10 subjects or 67% of sickle cell patients showed hypozincemia, 5 subjects or 33.3% presented normal zincemia; compared to children without sickle cell disease, 9 subjects or 60% have normal zincemia and 6 subjects or 40% have hypozincemia.

67% of sickle cell patients presented with hypozincemia and 33.3% were within the normal range. Unlike the control subjects, 10 had normal zincemia and 5 had hypozincemia. Zinc deficiency is linked to factors such as increased urinary zinc elimination and chronic intravascular hemolysis [21] [22]. A study confirms that there is a zinc deficiency which is a factor in malnutrition in sickle cell patients [23].

There is also a close correlation between zinc deficiency and impaired immune functions. According to the literature, zinc is an essential trace element that is involved in numerous physiological functions and plays a role in the body's immunity. A sufficient supply of zinc is therefore essential for better protection of sickle cell patients who are prone to multiple infections [20] [24].

Comparing the results of sickle cell children and controls for serum iron, 60% of sickle cell children presented hyposideremia; Unlike the control children, 53.3% had hypersideremia and 13.3% had hyposideremia. A significant difference was found in children. Sickle cell patients presented a low level of serum iron compared to controls as shown in **Table 3**. However, the diagnosis of iron deficiency in sickle cell subjects is not yet well established, due to the lack of specific tests to define their martial condition [25]. Iron deficiency was found in 17.5% of children with sickle cell disease and 20% presented hypersideremia, 3.33% hypersideremia was found in the control group [12].

In adults, 33.3% with sickle cell disease presented hyposideremia, also 13.3% of control adults presented hyposideremia. On the other hand, 2 controls presented hypersideremia.

For transferrin in children, according to the analysis results, 4 sickle cell patients or 40% present hypotransferrinemia and 10% present hypertransferrinemia. Unlike the controls, 2 subjects or 20% presented hypertransferrinemia and 10% of children presented hypotransferrinemia.



In adults, 2 sickle cell subjects, or 20%, presented hyposideremia and 10% hypertransferrinemia, unlike in the controls, 4 adults, or 40%, presented hypersideremia and 10% hypotransferrinemia.

For the level of ferritinemia, 100% of subjects with sickle cell disease and controls have normal ferritinemia, compared to ironemia which increases in 53.3% of control children; and transferrinemia which decreases in 20% of control children and in 40% of children with sickle cell disease. In relation to sideremia, 20% of sickle cell patients presented hyposideremia in adults and 60% hyposideremia in children. 27% of adult controls presented hypersideremia. Thus, the hemochromatosis mentioned by the latter could not be confirmed by the ferritinemia which was normal for all subjects (100%), rather by the transferrinemia which decreased in the controls and increased in the sickle cell patients, which would mean an iron deficiency. The normal values of ferritinemia, with the hyposideremia of iron deficiency anemia, would be related to the disturbances linked to infection and inflammation [26]. Because of chronic hemolysis, which characterizes certain hemoglobinopathies such as sickle cell anemia and thalassemia, is not in itself a cause of iron overload [25]. These results illustrate the limits of the usual parameters in the diagnosis of mineral elements in sickle cell disease.

The reduction in transferrin, specific to hypersideremia, is only noted in 20% of controls, a phenomenon which could be explained by a reduction in its synthesis in favor of ferritin in the inflammatory context and its increase could reflect a tissue deficiency. In iron, no sign of infection or anemia was observed, especially since these receptors are considered an indicator of incipient tissue iron deficiency which has not yet caused anemia [27]-[29] and hyposideremia in 60% of children with sickle cell disease and 20% in adults, due to chronic hemolysis of sickle cell disease, would be at the origin of the correlation between hemoglobin and soluble receptors, since it results in a normal compensatory increase in erythropoietic activity to which the receptors are sensitive[30].

To this end, patients with sickle cell disease should have regular assessments of their copper, zinc and iron levels to detect and treat deficiencies or excesses quickly depending on age and adapted to the specific needs of each patient.

## 5. Conclusions

This work focused on the evaluation of the plasma status of mineral elements such as copper, zinc and iron (ferritin and transferrin) in sickle cell patients. The study was carried out on 60 samples of mixed sex and age, including 30 sickle cell subjects and 30 control subjects followed at the SS mixed medicine and anemia center in Kinshasa.

Our results demonstrate not only the effective presence of hemochromatosis but also an iron deficiency in controls and in sickle cell patients, ignoring hemolysis; this leads us to say, despite the chronic hemolysis that sickle cell patients experience, ferritin is normally compared to other parameters where there have been significant variations following diet and sickle cell disease. Also the

study reveals that sickle cell patients have copper and zinc deficiencies which can have harmful consequences on their health. These results highlight the importance of adequate screening and management of mineral deficiencies in sickle cell patients.

These observations show that sickle cell disease gives rise to multiple biological variations of which our studied parameters are one of them. This demonstrates the benefit of regular, effective medical monitoring leading not only to reducing crises but also to good care.

Thus, we suggest that sickle cell patients eat foods rich in mineral elements to avoid certain deficiencies which would lead to repeated crises.

In perception, this study can be continued on several parameters such as Hb, RBC, WBC, TfR, VGM and TCMH, CRP, stools to provide clinicians with a characteristic hematological and biochemical profile during sickle cell disease.

### Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

### References

- [1] Ilunga, A.K.K., Kabengele, G.K., Kilara, T.K., Inkale, C.B., Woto, I.T., Makoka, S.K., *et al.* (2022) Sociodemographic Profile and Clinic of Polytransfused Sickle Cell Patients in Kinshasa: Case of the Center for Mixed Medicine and SS Anemia. *Open Access Library Journal*, **9**, 1-11. <https://doi.org/10.4236/oalib.1109222>
- [2] Ahluwalia, N. (2009) Diagnostic Utility of Serum Transferrin Receptors Measurement in Assessing Iron Status. *Nutrition Reviews*, **56**, 133-141. <https://doi.org/10.1111/j.1753-4887.1998.tb01738.x>
- [3] Sall-lopez, *et al.* (2002) Limites des paramètres de routine dans le diagnostic de carence martiale au cours de la drépanocytose homozygote. *L'eurobiologiste*, **260**, 26-34.
- [4] Luboya, E., Tshilonda, J.B., Ekila, M.B. and Aloni, M.N. (2014) Répercussions psychosociales de la drépanocytose sur les parents d'enfants vivant à Kinshasa, République Démocratique du Congo: Une étude qualitative. *Pan African Medical Journal*, **19**, Article 5. <https://doi.org/10.11604/pamj.2014.19.5.2830>
- [5] Magne, I. (2006) Quand faut-il transfuser l'enfant drépanocytaire en Afrique? *DevSante*.
- [6] Raghupathy, R., Manwani, D. and Little, J.A. (2010) Iron Overload in Sickle Cell Disease. *Advances in Hematology*, **2010**, Article ID: 272940. <https://doi.org/10.1155/2010/272940>
- [7] National Institute of Health: National Heart, Lung, and Blood Institute (2002) Division of Blood Diseases and Resources: The management of Sickle Cell Disease. NHI Publications.
- [8] WHO (1992) The Prevalence of Anemia in Women: A Tabulation of Available Information. [http://apps.who.int/iris/bitstream/10665/58994/1/WHO\\_MCH\\_MSM\\_92.2.pdf](http://apps.who.int/iris/bitstream/10665/58994/1/WHO_MCH_MSM_92.2.pdf)
- [9] Wajcman, H. and Labie, D. (1985) Facteurs biologiques modulant la gravité de la drépanocytose. *Annals of Pediatrics*, **32**, 813-818.

- [10] Imoberdorf, R., Rühlin, M. and Ballmer, P. (2010) Zinc un oligoélément vital à grand potentiel. *Forum Médical Suisse—Swiss Medical Forum*, **10**, 764-768. <https://doi.org/10.4414/fms.2010.07322>
- [11] Kubab, N., et al. (2009) Guide des examens biologiques. 5ème édition Lamarre, Wolters Kluwer.
- [12] Lopez-Sall, P. (2004) Apport des récepteurs solubles de la transferrine dans l'évaluation du statut en fer au cours de la drépanocytose homozygote. *Annales de Biologie Clinique*, **62**, 415-421.
- [13] Rowe (1973) Food Analysis by Atomic Absorption Spectroscopy. Varian Techtron Pty Ltd., 13-39.
- [14] Abdala, K.A., Mabiala Babela, J.R. and Shindano, M.E. (2018) Aspects épidémiologiques, cliniques et thérapeutiques de la drépanocytose chez l'enfant à l'Hôpital général de référence de Kindu (HGRK). *Revue Africaine de Médecine Interne*, **2**, 81-87.
- [15] Mashako, M.R., Bitwe, R.M., Nsibu, C.N. and Mashako, Y.K. (2019) Profil épidémiologique et clinique de la drépanocytose à l'hôpital provincial du Nord-Kivu. *Revue Malgache Pédiatrie*, **2**, 62-69.
- [16] Diagne, I., Ndiaye, O., Moreira, C., Signate-Sy, H., Camara, B., Diouf, S., et al. (2000) Les syndromes drépanocytaires majeurs en pédiatrie à Dakar (Sénégal). *Archives de Pédiatrie*, **7**, 16-24. [https://doi.org/10.1016/s0929-693x\(00\)88912-5](https://doi.org/10.1016/s0929-693x(00)88912-5)
- [17] Mabiala, B.J.R., Nkanza, K.S.A.T., Ganza, Z.P.S., Nzingoula, S. and Senga, P. (2005) Causes d'hospitalisation des enfants drépanocytaires: influence de l'âge (CHU de Brazza-ville, Congo). *Bulletin de la Société de pathologie exotique*, **98**, 392-393.
- [18] Thuilliez, V. and Vierin, Y. (1997) Le poids de la drepanocytose en milieu pédiatrique au Gabon. *Santé Publique*, **1**, 45-60.
- [19] Dreux, O. (2012) Education thérapeutique pour les enfants drepanocytaires: Justifications à la mise en place et initiation de ce projet au CHU de Grenoble. Ph.D. Thesis, Université Joseph Fournier.
- [20] Dr serge Rafal (2008) L'alimentation antioxydante. Marrabout.
- [21] Finan, A.C. (1988) Nutritional Factors and Growth in Children with Sickle Cell Disease. *Archives of Pediatrics & Adolescent Medicine*, **142**, 237-240. <https://doi.org/10.1001/archpedi.1988.02150020139051>
- [22] Phebus, C.K., Maciak, B.J., Gloninger, M.F. and Paul, H.S. (1988) Zinc Status of Children with Sickle Cell Disease: Relationship to Poor Growth. *American Journal of Hematology*, **29**, 67-73. <https://doi.org/10.1002/ajh.2830290203>
- [23] Beaune, G., Borel Giraud, N. and Tshilolo, L. (2009) Etude du profil protéique de 45 enfants drépanocytaires homozygotes congolais. *Annales de biologie clinique*, **67**, 607-612. <https://doi.org/10.1684/abc.2009.0373>
- [24] Daeschner, C.W., Carpentieri, U., Goldman, A.S. and Haggard, M.E. (1985) Zinc Deficiency and Blood Lymphocyte Function with Sickle Cell Disease. *Scandinavian Journal of Haematology*, **35**, 186-190. <https://doi.org/10.1111/j.1600-0609.1985.tb01569.x>
- [25] Tshilolo, L., Zita, M.N., Ngiyulu, R. and Kayembe Nzongola, D. (2016) Le statut martial chez soixante-douze drépanocytaires homozygotes congolais. *Médecine et Santé Tropicales*, **26**, 83-87. <https://doi.org/10.1684/mst.2016.0535>
- [26] Ngangoue, N., et al. (1996) Bilan martial, anémie et syndromes inflammatoires en milieu hospitalier: Comment interpréter les resultants. *Feuillets de biologie*, **37**, 53-57.
- [27] Bordessoule, D. (1992) Anémies inflammatoires: Physiopathologie, Diagnostic. *Revue*

*du praticien*, **42**, 2094-2095.

- [28] Himes, J., Walker, S., Williams, S., Bennett, F. and Grantham-McGregor, S. (1997) A Method to Estimate Prevalence of Iron Deficiency and Iron Deficiency Anemia in Adolescent Jamaican Girls. *The American Journal of Clinical Nutrition*, **65**, 831-836. <https://doi.org/10.1093/ajcn/65.3.831>
- [29] Kuvibidila, S., Warriar, R., Ode, D. and Yu, L. (1996) Serum Transferrin Receptor Concentrations in Women with Mild Malnutrition. *The American Journal of Clinical Nutrition*, **63**, 596-601. <https://doi.org/10.1093/ajcn/63.4.596>
- [30] Beguin, Y., *et al.* (1991) Le dosage du récepteur circulant de la transferrine: Une nouveauté pour quantifier l'érythropoïèse. *Médecine et Hygiène*, **49**, 2041-2045.