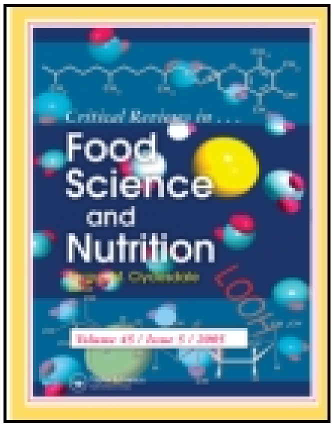

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# The Relationship Between Iron Status and Adiposity in Women from Developing Countries: A Review

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# The Relationship Between Iron Status and Adiposity in Women from Developing Countries: A Review

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*Scientific reports have shown that iron deficiency is positively associated with adiposity. With the high prevalence of iron deficiency and obesity in developing countries and women being particularly affected, this review was carried out with the aim of elucidating the link between iron status and adiposity in women from developing countries and to examine factors influencing this relationship. An extensive literature search was conducted using several search engines. A systematic approach with prespecified inclusion criteria was used in selecting relevant literature. Eight studies that met the inclusion criteria were selected for review. The relationship between iron status indices and adiposity in women in developing countries varied widely. While some studies observed negative relationships, some reported positive relationships, and others no significant relationships. Furthermore, other factors such as infection, alcohol consumption, type of diet, and genes were shown to affect the relationship between iron status and adiposity in women in developing countries. In conclusion, the possibility of iron status playing a role in adiposity in women from developing countries is likely, and it may be influenced by several other factors as described in the results. Thus, it is recommended that a special research effort should be directed toward this area.*

**Keywords** Iron status, adiposity, women, developing countries, review

## *INTRODUCTION*

Iron deficiency and its associated anemia are among the top 10 contributors to the global burden of disease, affecting billions of people worldwide (WHO, 2001). The majority of iron-deficient or anemic people are in developing countries (United Nations, 2000). Forty percent of the total attribut-able global burden of iron deficiency occurs in the South East Asian Region and almost another quarter in the African Region (Dreyfuss et al., 2000; WHO [World Health Organization], 2008). The greater demand for iron as a result of growth, menstruation, and lactation makes adolescent girls and women of reproductive age a vulnerable group for iron deficiency (Whitfield et al., 2003). The WHO/World Bank ranks iron deficiency anemia as the third leading cause of disability-adjusted life years lost for females aged 15–44 years (Tolentino and Friedman, 2007).

Iron deficiency usually develops in a sequential manner, starting with iron depletion, progressing into iron-deficient erythropoiesis, and finally overt anemia (Cook et al., 1992). Iron deficiency can be detected by measurements of serum iron, total iron binding capacity (TIBC), serum ferritin, blood hemoglobin (Hb), blood hematocrit (Hct), and soluble transferrin receptor (TfR) concentration (Killip et al., 2007). Consequences of iron deficiency include reduced work capacity, impaired cognitive functioning, poor reproductive performance, and reduced immune functioning (Killip et al., 2007).

While dietary iron remains the major determinant of iron status, scientific evidence suggests that adiposity may be an additional determinant of iron status (Seltzer and Mayer, 1963). An inverse association between adiposity and iron status has been described (Chambers et al., 2006). While studies have shown that adiposity might increase the risk of iron deficiency, adiposity has additionally been shown to induce elevation of serum ferritin concentrations (Zafon et al., 2010). This has been attributed to the fact that ferritin is an acute-phase protein that may be elevated by the low-grade inflammation that occurs when adipose tissues are enlarged (Zafon et al., 2010).

Contrary to the conventional knowledge that the obesity epidemic is limited to industrialized nations, the rising impact of obesity is becoming apparent in developing countries.

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Approximately 115 million people in developing countries have become obese leading to a rise in associated diseases such as heart diseases, diabetes, and cancer (WHO, 2000). The prevalence of obesity in adolescents in countries such as Egypt, Brazil, and Mexico is now comparable to that in developed nations (Wang and Lobstein, 2006). African women are generally more obese than men (WHO, 2000). For example, 33% of Gambian women aged 35 years and above are obese compared with 2% of men in the same age group (Prentice, 2006). Additionally, reports have shown that obesity prevalence is rapidly increasing among women in Asian countries (WHO, 2000).

Given the increasing burden of diseases in developing countries as well as the existence of factors such as poor diets (Hurrell, 1997), traditional beer consumption (Kew and Asare, 2007), infection (Di, 2009), and gene mutation (Mcnamara et al., 1998), all known to influence iron status and adiposity, it is important to have a good understanding of the relationship between iron status and adiposity in this setting. Therefore, this review was carried out with the aim of elucidating the link between iron status and adiposity in women from developing countries and to examine the effect of factors in developing countries that may influence this relationship.

## METHODS

### Search Strategy

A comprehensive literature search of all any-time studies reported in the English language was performed in Ebsco host, Google Scholar, Medline, Web of Science, Science Direct, the Cochrane Library, Scisearch, and PubMed. Search words and phrases used included the following: iron, ferritin, anemia, iron deficiency, TfR, Hb, hypoferremia, hyperferritinemia, anthropometry, body fat, adiposity, overweight, obesity, body composition, fat deposition, body mass index (BMI), chronic diseases, developing countries, women, girls, females, and adolescents. These words and phrases were also used in different combinations and looked for in title, abstract, and full text. A secondary search was conducted through the reference lists of identified papers. Although this paper is not a generic systematic review, it employed a systematic approach to select relevant literature that may help in understanding the link between iron status and adiposity in women from developing countries and the effect of factors in developing countries that may play a role in this association.

### Selection Criteria

Studies that were included in this review had to meet certain criteria as detailed as follows:

1. The study must report on the relationship between at least one of the iron indices (Hb, Hct, serum iron, serum ferritin, TIBC, percentage transferrin saturation, and TfR) and any anthropometric variable (weight, BMI, waist circumference [WC], waist-to-hip ratio [WHR], skinfolds, percentage body fat, lean body mass).
2. The study population was restricted to women from developing countries who were at least 12 years of age.
3. The study must have a cross-sectional design or report the cross-sectional baseline data from other types of studies.

### Definition of Terms

1. Adiposity: refers to a state of being fat. This includes total body fat as indicated by BMI $\geq$ 25 kg/m$^2$, central fat as indicated by WHR $>$ 0.8 or WC $>$ 88 cm, and fatness in other regions of the body such as arm, chest, hip, thigh, etc. (WHO, 1998; Methot et al., 2010).
2. Obesity: BMI $\geq$ 30 kg/m (Kasdan, 2000; United Nations, 2000).
3. Iron deficiency: serum ferritin concentration $<$12 $\mu$g/l (Kasdan, 2000, Yip and Ramakrishnan, 2002).
4. Iron deficiency anemia: serum ferritin concentration $<$ 12 $\mu$g/l and Hb $<$12 g/dl (Kasdan, 2000, Yip and Ramakrishnan, 2002).

## RESULTS

Eight studies met the inclusion criteria (Ettyang et al., 2003; Nemati et al., 2007; Eckhardt et al., 2008; Paknahad et al., 2008; Eftekhari et al., 2009; Famodu and Awodu, 2009; Aderibigbe et al., 2011a, 2011b). The publication year ranged from 2003 to 2010. The number of female participants examined in the selected studies ranged from 76 to 6841. Two of the studies were conducted in adolescent girls (Nemati et al., 2007; Eftekhari et al., 2009), five in adult women who were neither pregnant nor lactating (Eckhardt et al., 2008; Paknahad et al., 2008; Famodu and Awodu, 2009; Aderibigbe et al., 2011a, 2011b), and one in lactating women (Ettyang et al., 2003). Five of the studies included ferritin as a measure of iron status (Ettyang et al., 2003; Nemati et al., 2007; Eftekhari et al., 2009; Aderibigbe et al., 2011a, 2011b). Paknahad et al. (2008) and Nemati et al. (2007) only used Hb and Hct, while Famodu and Awodu (2009) used Hct only. One of the studies did not include BMI as an anthropometric index (Nemati et al., 2007). Only three studies examined WHR as an indicator of adiposity (Famodu and Awodu, 2009; Aderibigbe et al., 2011a, 2011b. The detailed description of the papers is illustrated in Table 1.

Eftekhari et al. (2009) found a negative association between ferritin and BMI ($r = -0.38$, $p < 0.01$) in iron-deficient Iranian girls aged 13–20 years, while Nemati et al. (2007) observed a positive association between ferritin and body weight ($r = 0.158$, $p < 0.05$) in adolescent Iranian girls aged 12 years. In addition, there was no significant difference ($p > 0.05$) between the weight and height of anemic and nonanemic

**Table 1** Description of studies examining the link between iron status and adiposity in women from developing countries

| Reference | Objective of study | Study population | No. of subjects | Results | Observed trends | Statistical significance | Factors implicated in iron and adiposity link | Factors corrected for in the study |
|---|---|---|---|---|---|---|---|---|
| Eftekhari et al., 2009 (Iran) | To investigate the association between iron deficiency and weight status | Iron-deficient adolescent Iranian girls aged 13–20 | 431 | Ferritin and BMI associated negatively | ↑Ferritin<br>↓BMI | $r = -0.38$<br>$p < 0.001$ | Urbanization, Diet, Low physical activity | Systemic diseases |
| Nemati et al., 2007 (Iran) | To determine the prevalence of iron deficiency anemia and its relation to height, weight, and school success | School girls aged 12 in Ardebil, Iran | 170 | Ferritin and weight associated positively | ↑Ferritin<br>↑ weight | $r = 0.158$<br>$p < 0.05$ | — | — |
| Paknahad et al., 2008 (Iran) | To assess the BMI status in premenopausal women and its relationship with iron biochemical indices | Nonpregnant, nonlactating 15–49 years old Iranian women | 1049 | Hb increased across BMI quartile<br>Hct increased across BMI quartiles | ↑Hb/Hct<br>↑BMI | $p < 0.05$ | Industrialization<br>Low physical activity<br>Parity | Infection |
| Ettyang et al., 2003 (Kenya) | To establish the prevalence and the relationship of vitamin A and iron to maternal body composition | Lactating Kenyan women aged 15–45 years | 88 | As ferritin concentration decreases, BMI, % body fat, and fat-free mass did not vary significantly among lactating mothers | ↓Ferritin<br>—BMI, % body fat, and fat-free mass | $p > 0.05$ | — | Age<br>Parity<br>Child's age<br>Child's birth weight<br>Lactation period |
| Eckhardt et al., 2008, (Egypt and Peru) | To compare the odds of anemia in overweight and obese versus nonoverweight women in three countries at different stages of the nutrition transition | Nonpregnant women aged 18–49 years from Mexico, Peru, and Egypt | Mexico: 11,965<br>Egypt: 6841<br>Peru: 5078 | Odds of anemia did not differ by BMI in Mexico<br>Odds of anemia was lower for overweight and obese group than normal weight women in Peru<br>Odds of anemia was lower for overweight and obese group than normal weight women in Egypt | ↑ Odds of anemia—BMI in Mexico<br>↓Odds of anemia<br>↑BMI in Peru<br>↓ Odds of anemia<br>↑BMI in Egypt | $p > 0.05$<br>$p < 0.05$<br>OR = 0.83<br>$p < 0.05$<br>OR = 0.78 | Other micronutrient deficiencies (Zn, folate, and Vit C)<br>Malaria and other chronic parasitic infections<br>Smoking | Socio-demographic characteristic (rural/urban)<br>Education level<br>Parity<br>Age<br>Altitude<br>Socioeconomic status |
| Famodu and Awodu, 2009 (Nigeria) | To study the relationship of fibrinogen, plasma viscosity, and Hct with measures of obesity | Nigerians women (average age 59 years) | 76 | Hct increased across BMI percentile up until the 75th percentile | ↑ Hct<br>↑WHR | $p = 0.0074$ | — | Diseases |
| Aderibigbe et al., 2011a (South Africa) | To examine relationship between iron indices and selected anthropometric CVD risk factors | South African women aged between 15 years and older | 952 | WC and WHR increased with increasing ferritin concentration<br>Serum iron decreased with increasing BMI<br>Ferritin associated positively with BMI, WC, WHR, body fat, and SSF | ↑ Ferritin<br>↑WC and WHR<br>↓ Serum iron<br>↑ BMI | $p < 0.05$ | — | Age<br>BMI<br>Smoking |
| Aderibigbe et al., 2011b (South Africa) | This study examined the associations between iron stores and CVD risk factors in black South African women | South African women aged between 35 years and older | 1262 | WC and WHR increased across ferritin quartiles | ↑ Ferritin<br>↑WC and WHR | $p < 0.05$ | — | Age<br>BMI<br>Smoking<br>Alcohol |

*Note*: CVD: cardiovascular disease.

Iranian girls aged 12 years (Nemati et al., 2007). Hb and Hct increased ($p > 0.05$) across BMI quartiles in adult Iranian women between the ages 15 and 49 years (Paknahad et al., 2008).

Ettyang et al. (2003) reported no significant difference ($p < 0.05$) in BMI among lactating Kenyan women at different levels of iron depletion (as defined by ferritin), but Hb was shown to increase with increasing BMI. In the report by Famodu and Awodu (2009) Hct increased with increasing BMI and WHR in Nigerian women with an average age of 59 years. Aderibigbe et al. (2011a, 2011b) showed that WC and WHR increased with increasing ferritin concentration in South African women, while serum iron decreased with increasing BMI in women. A lower odds ratio of anemia was additionally reported in over-weight and obese women than normal weight women from Egypt (Eckhardt et al., 2008).

No significant difference in odds of anemia was observed in Mexican women in different categories of BMI (Eckhardt et al., 2008). A lower odds ratio of anemia was reported in overweight and obese women than normal weight women from Peru (Eckhardt et al., 2008).

## *DISCUSSION*

With the high prevalence of obesity and iron deficiency in developing countries, this review elucidates the link and factors influencing the associations between iron status parameters and indicators of adiposity in women from developing countries. The literature search resulted in eight studies that examined the relationship between iron status and adiposity in women from developing countries. Assessment indicators used for iron status varied widely, and there was no uniformity in the physiological state of women participants included in the studies who met the inclusion criteria. The results of the studies reviewed varied widely: while some observed positive associations, some reported negative associations, and some did not observe any significant associations.

The negative association between circulating iron and adiposity was first demonstrated in adolescents (Wenzel et al., 1962) and thereafter several studies have confirmed this finding in different populations (Seltzer and Mayer, 1963; Pinhas-Hamiel et al., 2003; Nead et al., 2004; Eftekhari et al., 2009; Tussing-Humphreys et al., 2009). In addition, it has been reported that obese adolescents have increased ferritin concentration despite the deficient serum iron (Nemati et al., 2007; Zafon et al., 2010). However, the study conducted in Iranian adolescent girls contradicts this observation (Eftekhari et al., 2009). A negative association was reported between ferritin and BMI in this population (Eftekhari et al., 2009). The adolescent girls in this study were already iron deficient (Eftekhari et al., 2009). Furthermore, adolescence is the transition period between childhood and adulthood. The overall iron requirements increase from a preadolescent level. The available data on iron intakes in adolescents suggest that adolescent girls are unlikely to acquire substantial iron stores during this time period. Iron stores are further depleted by the growth spurt that occurs during adolescence (Beard, 2000). This could explain the negative association between ferritin and adiposity in adolescent Iranian girls. Moreover, Asian countries have a greater prevalence of iron deficiency than other developing regions; this has been attributed to less care given to girls and women in this region (Osman and Alok, 1998).

Studies conducted in adult premenopausal women have confirmed the presence of iron deficiency in obese adult women. Zimmermann et al. (2008) showed that independent of iron stores, a higher BMI Z-score was associated with decreased iron absorption in Thai women aged 18–50 years. Aderibigbe et al. (2011a) reported a decreasing serum iron concentration with increasing BMI in South African women aged 15 years and above. An increased risk of anemia with increasing prepregnancy BMI has been reported for postpartum women (Bodnar et al., 2004). There is evidence of an increased risk of iron deficiency in menstruating women, pregnant women, and adolescents after bariatric surgery (Flancbaum et al., 2006; Love and Bilett, 2008). On the contrary, reports from Peru and Egypt showed that the odds of anemia decreased with increasing BMI in adult premenopausal women, while in women from Mexico, no significant variation in odds of anemia with change in BMI was found (Eckhardt et al., 2008). Additionally, Hct increased with increasing BMI in Nigerian women (Famodu and Awodu, 2009), and BMI of lactating women from Kenya was not significantly associated with ferritin concentration (Ettyang et al., 2003).

It has been suggested that overweight or obese women from rural areas (for instance in Egypt, Nigeria, and some parts of Mexico) may have higher energy intakes that convey enough additional iron to lower the risk of anemia compared with their nonoverweight counterparts (Lonnerdal, 2000; Lopez and Martos, 2004). The lifestyle changes of the urban poor may have pressurized them to choose only the high-carbohydrate foods, while their rural counterparts have a wider choice from grown and hunted foods from their surroundings. This could bring the iron status of obese rural women at par to that of the normal weight women in the urban areas (Lonnerdal, 2000; Lopez and Martos, 2004).

Studies that examined the relationship between iron indices and adiposity in postmenopausal women were conducted in developed countries (Liu et al., 2003; Lecube et al., 2006; Crist et al., 2008). A moderate degree of iron deficiency in obese postmenopausal women has been reported (Lecube et al., 2006). A positive association between ferritin and central adiposity has been reported in postmenopausal women (Lecube et al., 2006). Increased secretion of serum ferritin occurs at menopause, but reports have shown that the ferritin level in postmenopausal women is still low compared with that found in men of the same age group (Berge et al., 1994; Kato et al., 2000; Zacharski et al., 2000).

## *MECHANISMS*

The etiology of the hypoferremia of obesity is not clear. Among proposed causes are inadequate intake of dietary iron and greater iron requirement in obese individuals because of larger blood volume (Failla et al., 1988; Newman et al., 2003; Pinhas-Hamiel et al., 2003). Kennedy et al. (1986) reported that chronic obesity was negatively associated with iron in the plasma, liver, bone, and muscle of genetically obese mice compared with lean mice. This observation was irrespective of gender and age of the mice (Kennedy et al., 1986).

However, the relationship between adiposity and serum ferritin has been observed to go in an opposite direction compared with that between serum iron and adiposity. A positive association has been demonstrated between ferritin and adiposity (Gillum, 2001). Ferritin, an acute-phase protein, is elevated in inflammatory conditions (Tomkins, 2003). Obesity has been identified as an inflammatory condition (Yanoff et al., 2007). Moreover, recent findings have shown that adipocytes are not just storage organs for fat, they play a regulatory role in body homeostasis as well (Andrew et al., 2006). Hepcidin, a hormone secreted mainly in the liver but also found in adipocytes, is highly expressed in obese individuals (McClung and Karl, 2008). Hepcidin is able to prevent release of iron from the stores and absorption of intracellular iron (McClung and Karl, 2008). This has been speculated as one of the mechanisms that could explain iron deficiency in obese individuals despite optimum or overloaded stores. Liver hepcidin messenger ribonucleic acid (mRNA) expression has been shown to correlate with transferrin saturation, whereas adipose hepcidin mRNA expression did not, but rather correlated positively with markers of inflammation, which indicates that hepcidin may have tissue-specific regulation (Berki et al., 2006). Lipid peroxidation increases during fat deposition as a result of the reactivity of intracellular iron with lipids, sequestration of intracellular iron into the stores could occur in order to reduce lipid peroxidation thereby leading to reduced functional iron and increased iron stores (Festa et al., 2000).

Increased ferritin concentration observed in obese individuals has been argued to be the result of chronic inflammation and not necessarily increased iron stores (Zafon et al., 2010). In the study conducted by Lecube et al. (2006), the increased ferritin concentration found in obese women with metabolic syndrome was not accompanied by any significant changes in other iron status parameters. Additionally, the observation that serum ferritin concentration increased while transferrin saturation decreased in those with excess body fat gave support to the inflammatory cause for hyperferritinemia of obesity (Ford and Cogswell, 1999; Dreyfuss et al., 2000; Gillum, 2001). Some studies have reported elevated amounts of inflammatory cytokines such as tumor necrosis factor and interlukin-6 in patients with obesity and other metabolic syndromes (Hotamisligil, 1999; Pickup et al., 2000). BMI has been positively associated with serum C-reactive protein, another marker of inflammation (Hak, 2002).

Though inflammation is considered to be one of the consequences of obesity, some studies conducted in adults have suggested that inflammation may occur before obesity (Engstrom et al., 2003; Barzilay et al., 2006). It was reported that inflammatory markers were prospectively predictive of weight gain. Although the mechanism of this effect is not fully understood, it has been proposed that inflammation may stimulate hunger and inhibits satiety through interaction with the feeding and satiety center of the brain (Engstrom et al., 2003; Barzilay et al., 2006). There is a growing view that the inflammatory state that characterizes obesity may play a causal role in the development of insulin resistance, type 2 diabetes, and the metabolic syndrome (Grimble, 2002; Weisberg et al., 2003; Xu et al., 2003).

## *OTHER FACTORS THAT COULD AFFECT THE LINK BETWEEN IRON STATUS AND ADIPOSITY IN DEVELOPING COUNTRIES*

Iron status is influenced by the amount of iron present in the diet and other dietary components that may influence iron absorption. The diets in many developing countries are monotonous, composed mainly of cereals and legumes, with minimal amounts of bioavailable iron, and high in inhibitors of nonheme iron absorption such as phytates (Hurrell, 1997). In a study, a cohort of Moroccan children who have been made iron replete by fortification were left to follow their habitual diet (nonfortified cereal and legume); it was reported that the prevalence of iron deficiency increased from 0 to 43% within 15 months among the children (Zimmermann et al., 2005). This finding demonstrated that low iron bioavailability from a legume- and cereal-based diet can be a cause of iron deficiency in developing countries. Furthermore, this diet that is deficient in micronutrient could be energy dense such that it leads to increased adiposity (Quinion, 2010).

Unfortunately, data on the dietary intake of women in developing countries are few. Dietary data from South Africa and Kenya showed that adult women were consuming a diet high in fat and saturated fats but deficient in micronutrients, including iron (Steyn and Nel, 2006). In both the countries, significant differences between the urban and rural women were observed (Steyn and Nel, 2006). Urban women consumed more foods rich in bio-available iron than rural women (Steyn and Nel, 2006). However, distinct difference in nutritional status has been reported between the rich and poor urban women (Hattingh et al., 2008). Urban black South African women were shown to meet $\geq$67% of the recommended daily allowance (RDA) for iron (Hattingh et al., 2008). However, only 54% of these women showed total iron intakes $\geq$67% of the RDA (Hattingh et al., 2008). This report supports others that have showed large discrepancies between the poor and the rich in urban areas of developing countries (Becquey and Martin-Prevel, 2010; Sukchan et al., 2010).

Deficiency of other micronutrients such as folic acid and cobalamin (vitamin $B_{12}$) that are prevalent in developing countries can influence the relationship between iron status and adiposity (Ramakrishnan et al., 1999; Seshadri, 2001). Folic acid deficiency causes disturbance in synthesis of deoxyribonucleic acid (DNA), which leads to damage of red cells (Baynes, 1994). Casanueva et al. (2000) reported that folic acid deficiency was associated with anemia in nonpregnant, nonlactating Mexican women aged 23–40 years. Additionally, folic acid deficiency was associated with obesity in the same population. Menzie et al. (2008) compared the amount of heme iron, nonheme iron, and other dietary factors that influence iron absorption in a sample of obese and nonobese adults. The authors reported that obesity-related hypoferremia cannot be explained by differences in reported dietary iron or vitamin intakes.

Alcohol consumption has been shown to influence both the iron status (Kew and Asare, 2007; Aderibigbe et al., 2010b) and level of adiposity (Rohrer et al., 2005; Gopane et al., 2010) of an individual. Gopane et al. (2010) reported that the amount of alcohol consumed was a strong predictor of ferritin in a South African study. Alcohol consumption rate is high in sub-Saharan Africa where the consumption of traditional beers that are brewed in iron pots is prevalent (Kew and Asare, 2007). This has been reported to contribute greatly to dietary iron overload in sub-Saharan Africa (Kew and Asare, 2007). However, the effects of alcohol use on the risk of obesity have not been thoroughly explored (Rohrer et al., 2005). Pisa et al. (2010) reported a significant drop in BMI of South African women ($\geq$35 years) with increasing self-reported alcohol consumption. In the same population, increased WC and WHR have been reported to contribute significantly to increased ferritin concentration in black South Africans even after adjusting for self-reported alcohol consumption (Aderibigbe et al., 2010b).

Malnutrition in developing countries is aggravated by the burden of infestations with malaria parasite, intestinal worms, and the human immunodeficiency virus (HIV) (Di, 2009). Microorganisms in need of iron for survival and multiplication compete with the host for the available iron (Di, 2009). It is being speculated that the anemia associated with chronic asymptomatic malaria may be due to an inflammatory-mediated effect on iron redistribution to storage compartments and a resultant deficit in erythropoietin production with or without bone marrow responsiveness (Abdalla et al., 1980). In chronic malaria, the sequestration of iron into the bone marrow coexists with iron-deficient erythropoiesis (Verhoef et al., 2002). HIV-infected persons suffer from iron metabolism disorders. At the advanced stage, anemia can coexist with elevated ferritin and increased bone marrow iron content (De Monge et al., 1999). Obesity as an inflammatory condition coexisting with infection may further deplete the available functional iron while increasing iron stores.

A genetic predisposition to iron overload has been suggested in Africans but the putative gene has not been identified. It is speculated that the gene may be a result of mutation as described in hereditary hemochromatosis gene (HFE) (Mcnamara et al., 1998). The condition was first attributed to excess intake of traditional home made beers. However, not all beer drinkers develop excess iron overload and not everyone who develops iron overload is a traditional beer drinker. Investigators have concluded that heterozygosity for an unidentified iron overloading gene confers susceptibility while homozygous persons may be severely affected (Moyo et al., 1998).

Pregnancy is accompanied by hormonal adaptations, increased dietary intake, and reduced physical activity; all these affect the body composition and iron status of the woman (Harvey, 1999). Repeated pregnancy can lead to long-term obesity and depleted body iron, especially if sufficient time is not allowed in-between pregnancies (Gunderson and Abrams, 2000). It has been shown that it takes an average of 1.5 years for most women to return to their prepregnancy BMI; during this time most of the fluids associated with pregnancy are lost (Quesnel-Valle and Renaly, 2011). Multiple pregnancies (twins, triplets, and more pregnancies) can lead to obesity and iron deficiency as well. Women of African descent are the most likely to have multiple pregnancies, with West African women having the highest rate of 48 in a thousand births (Lyons, 2000). Obesity and iron deficiency in multiple pregnancies could result from an exaggerated physiologic response due to increased placental and fetal mass, and increased blood volume (Montgomery et al., 2005). Anemia has been reported in multiple pregnancies than in singleton pregnancies (Harvey, 1999).

## CONCLUSION

The results of the studies reviewed in this paper showed an inconsistent relationship between iron status parameters and adiposity in women living in developing countries. The likelihood of iron playing a role in adiposity is possible. Besides, factors such as infection, consumption of traditional beer, multiple pregnancies, and poor diet have the potential to affect the iron and adiposity relationship. Further research is, therefore, required in the developing regions in order to understand the link between iron status and adiposity fully. This new research should take into consideration the effect of the factors that have been discussed in this paper.

## REFERENCES


Abdalla, S., Weatherall, D. J., Wickramasinghe, S. N. and Hughes, M. (1980). The anaemia of *P. falciparum* malaria. *Br. J. Haematol.* **46**:171–183.

Aderibigbe, O. R., Pisa, P. T., Ramoteme, L. M., Kruger, H. S. and Vorster, H. H. (2011a). The relationship between indices of iron status and selected anthropometric cardiovascular disease risk factors in an African population: The THUSA study. *Cardiovasc. J. Afri.* **22**(5):249–256.

Aderibigbe, O. R., Pisa, P. T., Ramoteme, L. M., Kruger, H. S. and Vorster, H. H. (2011b). Iron status and cardiovascular disease risk in black South African women: The PURE study. *S. Afr. J. Clin. Nutr.* **22**(4):1–4.

Andrew, S., Greenber, G. and Martin, S. O. (2006). Obesity and the role of adipose tissue in inflammation and metabolism. *Am. J. Clin. Nutr.* **83**(2):S461–S465.

Barzilay, J. I., Forsberg, C., Heckbert, S. R., Cushman, M. and Newman, A. B. (2006). The association of markers of inflammation with weight change in older adults: The Cardiovascular Health Study. *Int. J. Obes.* **302**(9):1362–1367.

Baynes, R. D. (1994). Iron absorption. **In**: Iron Metabolism in Health and Diseases, pp. 150–187. Brock, J. H., Halliday, J. W., Pippard, M. J. and Powell, L.W., eds. W.B. Saunders, London.

Beard, J. L. (2000). Iron requirement in adolescent females. Symposium: Improving adolescent iron status before childbearing. *J. Nutr.* **130**:S440– S 444.

Becquey, E. and Martin-Prevel, Y. (2010). Micronutrient adequacy of women's diet in urban Burkina-Faso is low. *J. Nutr.* **140**:S2079–S2085.

Berge, L. N., Bonzz, K. H. and Nordoy, A. (1994). Serum ferritin, sex hormones and cardiovascular risk factors in healthy women. *Arterioscler. Thromb. and Vasc. Biol*. **14**:857–861.

Berki, S., Gual, P., Anty, R., Luciani, N. and Dahman, M. (2006). Increased adipose tissue expression of hepcidin in severe obesity is independent from diabetes and NASH. *Gastroenterology*. **131**:788–796.

Bodnar, L. M., Siega-Riz, A. M. and Cogswell, M. E. (2004). High prepregnancy BMI increases the risk of postpartum anaemia. *Obes. Res*. **12**(6):941–948.

Casanueva, E., Drijanski, A., Fernandez-Gaxiola, A. C., Meza, C. and Pfeffer, E. A. (2000). Folate deficiency is associated with obesity and anaemia in Mexican urban women. *Nutr. Rev.* **20**(10):1389–1394.

Chambers, E. C., Heshka, S., Gallagher, D., Wang, J., Pi-Sunyer, X. and Pierson, R. N. (2006). Serum iron and body fat distribution in a multiethnic cohort of adults living in New York. *J. Am. Dietetic. Assoc*. **106**:680–684.

Cook, J. D., Baynes, D. R. and Skikne, B. S. (1992). Iron deficiency and the measurement of iron status. *Nutr. Res. Rev.* **5**:189–202.

Crist, B. L., Alekel, D. L., Ritland, L. M., Hanson, L. N., Genschel, U. and Reddy, M. B. (2008). Association of oxidative stress, iron and centralized fat mass in healthy postmenopausal women. *J. Women's Hlth*. **18**:795–801.

De Monge, C., Karcher, D. S. and Boelaert, J. R. (1999). Bone marrow macrophage iron grade and survival of HIV-seropositive patients. *AIDS*. **13**:375–380.

Di, P. C. (2009). Burden of non-sexually transmitted infections on adolescent growth and development in the developing world. *Adolesc. Med. State Art. Rev.* **20**(3):930–948.

Dreyfuss, M. L., Stotlzfus, R. J., Shrestha, J. B., Pradhan, E. Z., Leclerg, S. C., Khatry, S. K., Shreshtha, S. R., Katz, J., Albanico, M. and West, K. P. (2000). Hookworms, malaria and vitamin A deficiency contribute to anaemia and iron deficiency among pregnant women in the plane of Nepal. *J. Nutr.* **130**:2527–2536.

Eckhardt, C. L., Torheim, L. E., Monterrubio, E., Barquera, S. and Ruel, M. T. (2008). The overlap of overweight and anaemia among women in three countries undergoing the nutrition transition. *Eur. J. Clin. Nutr.* **62**:238–246.

Eftekhari, M. H., Mozaffari-Khosrav, H. and Shidfar, F. (2009). The relationship between BMI and iron status in iron deficient adolescent Iranian girls. *Publ. Hlth. Nutr.* **12**:2377–2381.

Engstrom, G., Hedblad, B., Stavenow, L., Lind, P., Janzon, L. and Lindgarde, F. (2003). Inflammation-sensitive plasma proteins are associated with future weight gain. *Diabetes*. **52**(8):2097–2101.

Ettyang, G. A., Van Marken Lichtenbelt, W. D., Oloo, A. and Saris, W. H. M. (2003). Serum retinol, iron status and body composition of lactating women in Nandi, Kenya. *Ann. Nutr. Metab.* **47**:276–283.

Failla, M. L., Kennedy, M. L. and Chen, M. L. (1988). Iron metabolism in genetically obese (ob/ob) mice. *J. Nutr.* **118**:46–51.

Famodu, A. A. and Awodu, O. A. (2009). Anthropometric indices as determinants of haemorheological cardiovascular disease risk factors in Nigerian adults living in a semi-urban community. *Clin. Hemorheal. Microcirc.* **43**(4):335–344.

Festa, M., Ricciardelli, G., Mele, G., Pietropaolo, C., Ruffo, A. and Colonna, A. (2000). Overexpression of H ferritin and upregulation of iron regulatory protein gene during differentiation of 3T3-L1 pre-adipocytes. *J. Biol. Chem.* **275**:36708–36712.

Flancbaum, L., Belsley, S., Drake, V., Colarusso, T. and Tayler, E. (2006). Preoperative nutritional status of patients undergoing Roux-en-Y gastric bypass for morbid obesity. *J. Gastrointest. Surg.* **14**:1724–1730.

Ford, E. S. and Cogswell, M. E. (1999). Diabetes and serum ferritin concentration among US adults. *Diabetes Care*. **22**:113–120.

Frison, E., Smith, I. F., Johns, T., Cherfas, J. and Eyzaguirre, P. (2004). Using biodiversity for food, dietary diversity, better nutrition and health. CGIAR. Available from www.bioversityinternational.org/. . ./Using_biodiversity.pdf.

Gillum, R. F. (2001). Association of serum ferritin and indices of body fat distribution and obesity in Mexican American men—The Third National Health and Nutrition Examination Survey. *Int. J. Obes*. **25**:639–645.

Gopane, R. E., Pisa, P. T., Vorster, H. H, Kruger, A. and Margetts, B. M. (2010). Relationships of alcohol intake with biological health outcomes in an African population in transition: The THUSA study. S. *Afr. J. Clin. Nutr.* **23**(3)Supplement 1:S16–21.

Grimble, R. F. (2002). Inflammatory status and insulin resistance. *Curr. Opin. Clin. Nutr. Metab. Care*. **5**:551–559.

Gunderson, E.P. and Abrams, B. (2000). Epidemiology of gestational weight gain and body weight changes after pregnancy. *Epidemiol. Rev.* **22**:261–274.

Hak, E. (2002). Gender difference in cardiovascular disease: an epidemiological study of endocrine factors. PhD thesis, Maastricht University. Rotterdam, Netherlands.

Harvey, M.G. (1999). Physiologic changes during pregnancy. **In**: High Risk and Critical Care Intrapartum Nursing, 2nd ed. Mandeville, L. K. and Troniano, N. H..Lippincott, Philadelphia.

Hattingh, Z., Walsh, C. M., Bester, C. J. and Oguntibeju, O. O. (2008). An analysis of dietary micronutrient intake of two age groups of black South African women. *West Indian Med. J.* **57**(5):431–437.

Hotamisligil, G. S. (1999). The role of TNF alpha and TNF receptors in obesity and insulin resistance. *J. Intern. Med*. **245**:621–625.

Hurrell, R. F. (1997). Bioavailability of iron. *Eur. J. Clin. Nutr.* **51**:S4–S8.

Kasdan, T. S. (2000). Medical nutrition therapy for anaemia. **In**: Krause's Food, Nutrition and Diet Therapy, 10th ed., pp. 781–800. Mahan, L. K., Escott-Stump, A. Eds. WB Saunders, London.

Kato, I., Dnistrian, A. M., Schwartz, M., Toniolo, P., Koenig, K., Shore, R. E., Zeleniuch-Jacquotte, A., Akhmedkhanov, A. and Riboli, E. (2000). Risk of iron overload among middle aged women. *Int. J. Vitamin Nutr. Res.* **70**:119–125.

Kennedy, M. L., Failla, M. L. and Smith, J. C. (1986). Influence of genetic obesity on tissue concentrations of zinc, copper, manganese and iron in mice. *J. Nutr.* **116**:1432–1441.

Kew, M. C. and Asare, G. A. (2007). Dietary iron overload in the African and hepatocellular carcinoma. *Liver Int*. **27**:735–741.

Killip, S., Bennett, J. M. and Chambers, M. D. (2007). Iron deficiency anaemia. *Am. Fam. Physician*. **75**:671–678.

Lecube, A., Carrera, A., Losada, A., Hernández, C., Simó, R. and Mesa, J. (2006). Iron deficiency in obese postmenopausal women. *Obesity.* **14**(10):1724–1730.

Liu, J. M., Hankinson, S. E., Stampfer, M. J., Rifai, N., Willett, W. C. and Ma, J. (2003). Body iron stores and their determinant in healthy postmenopausal US women. *Am. J. Clin. Nutr.* **78**:1160–1167.

Lonnerdal, B. (2000). Dietary factors influencing zinc absorption. *J. Nutr.* **130**:S1378–S1383.

Lopez, M. A. and Martos, F. C. (2004). Iron availability: An updated review. *Int. J. Food Sci. Nutr.* **55**:597–606.

Love, A. L. and Bilett, H. H. (2008). Obesity, bariatric surgery and iron deficiency: True, true, true and related. *Am. J. Hematol*. **83**:403–409.

Lyons, D. (2000). The material culture of twins in West Africa. Available from www.sfu.ca/archaeology/museum/ndi/mystudy.html.

McClung, J. P. and Karl, J. P. (2008). Iron deficiency and obesity: The contribution of inflammation and diminished iron absorption. *Nutr. Rev.* **60**(2):100–104.

Mcnamara, L., MacPhail, A. P., Gordeuk, V. R., Hasstedt, S. J. and Rouault, T. (1998). Is there a link between African iron overload and the described mutations of the hereditary haemachromatosis gene? *Br. J. Haematol.* **102**:1176–1178.

Menzie, C. M., Yanoff, L. B., Denkinger, B. I., McHugh, T., Sebring, N. G., Calis, K. A. and Yanovski, J. A. (2008). Obesity-related hypoferremia is not explained by difference in reported intake of heme and nonheme iron or intake of dietary factors that can affect iron absorption. *J. Am. Diet. Assoc.* **108**:145–148.

Methot, J., Houle, J. and Poirier, P. (2010). Obesity: How to define central adiposity. *Expert Rev. Cardiovasc. Ther.* **8**(5):639–644.

Montgomery, K. S., Cubera, S., Belcher, C., Patrick, D., Funderburk, H., Melton, C. and Fastenan, M. (2005). Childbirth education for multiple pregnancy Part 1: Prenatal considerations. *J. Perinatal Edu.* **14**(2):26–35.

Moyo, V. M., Mandishona, E., Hasstedt, S. J., Gangaidzo, I. T., Gomo, Z. A. R., Khumalo, H., Saungweme, T., Kiire, C. F., Paterson, A. C., Bloom, P., MacPhail, A. P., Rouault, T. and Gordeuk, V. R. (1998). Evidence of genetic transmission in African iron overload. *Blood.* **9**:1076–1082.

Nead, K. G., Halterman, J. S., Kaczrorowski, J. M., Auinger, P. and Weitzman, M. (2004). Overweight children and adolescents: A risk group for iron deficiency. *Pediratrics.* **114**:104–108.

Nemati, A., Barak, M., Dehghan, M. H., Alimahammadi, H., Ettehad, G. H., Baghi, N., AliPanah Mogadam, J. A. R. and Abbasgholizadde, N. (2007). Relation between iron deficiency and anemia whit school success, weight and height in schoolgirls aged 12 year old in Ardebil Province of Iran. *Res. J. Biol. Sci.* **2**(3):263–267.

Newman, A. B., Kupelian, V., Visser, M., Simonsick, E., Goodpaster, B., Nevitt, M., Kritchevsky, S. B., Tylavsky, F. A., Rubin, S. M. and Harris, T. B. (2003). Sarcopenia: Alternative definitions and associations with lower extremity function. *J. Am. Geriatr. Soc.* **51**(11):1602–1609.

Osman, S. and Alok, B. (1998). Health and nutrition in emerging Asia. *Asian Devel. Rev.* **16**(1):31–71.

Paknahad, Z., Mahboob, S., Omidvar, N., Ebrahimi, M., Ostadrahimi, A. and Afiatmilani, S. H. (2008). Body mass index and its relationship with hematological indices in Iranian women. *Pakistan J. Nutr.* **7**(92):377–380.

Pickup, J. C., Chusney, G. D., Thomas, S. M. and Burt, D. (2000). Plasma interlukin-6, tumor necrosis factor alpha and blood cytokines production in type 2 diabetes. *Life Sci.* **67**:291–300.

Pinhas-Hamiel, O., Newfield, R. S., Koren, I., Agmon, A., Lilos, P. and Phillip, M. (2003). Greater prevalence of iron deficiency in overweight and obese children and adolescents. *Int. J. Obes.* **27**:416–418.

Pisa, P.T., Kruger, A., Vorster, H. H., Margetts, B. M. and Loots Du, T. (2010). Alcohol consumption and cardiovascular disease risk in an African population in transition: The prospective Urban and Rural Epidemiological (PURE) study. *S. Afri. J. Clin. Nutr.* **23**(3) supplement 1:29–37.

Prentice, A. M. (2006). The emerging epidemic of obesity in developing countries. *Int. J. Epidemiol.* **35**:93–99.

Quesnel-Valle, A. and Renaly, E. (2011). Pregnancy: A risk factor for social inequalities in overweight and obesity. Available from Paa2011.princeton.edu/download.aspx?submissionId = 111496.

Quinion, M. (2010). Hidden Hunger. Worldwide words. Available from www.worldwidewords.org/turnsofphrase/tp-hid1.htlm.

Ramakrishnan, U., Manjrekar, R., Rivera, J., Gonzales-Cossio, T. and Martorell, R. (1999). Micronutrients and pregnancy outcome: A review of literature. *Nutr. Res.* **19**(1):103–159.

Rohrer, J. E., Rohland, B. M., Denison, A. and Way, A. (2005). Frequency of alcohol use and obesity in community medicine patients. *B.M.C. Fam. Pract.* **6**:17.

Seltzer, C. C. and Mayer, J. (1963). Serum iron and iron-binding capacity in adolescents. Comparison of obese and non obese subjects. *Am. J. Clin. Nutr.* **13**:354–360.

Seshadri, S. (2001). Prevalence of micronutrient deficiency particularly of iron, zinc and folic acid in pregnant women in South East Asia. *Br. J. Nutr.* **85**:S87–S92.

Steyn, N. P. and Nel, J. H. (2006). Dietary Intake of Adult Women in South Africa and Nigeria with a Focus on the Use of Spreads. Medical Research Council, Tygerberg, South Africa.

Sukchan, P., Liabsuetrakul, T., Chonsuvivatworg, V., Songwathana, P., Sornsrivichai, V. and Kuning, M. (2010). Inadequacy of nutrient intakes among pregnant women in the deep South of Thailand. *B.M.C. Publ. Hlth.* **10**:572.

Tolentino, K. and Friedman, J. F. (2007). An update on anemia in less developed countries. *Am. J. Trop. Med. Hyg.* **77**:44–51.

Tomkins, A. (2003). Assessing micronutrient status in the presence of inflammation. *J Nutr.* **133**(1):S1649–S1655.

Tussing-Humphreys, L. M., Liang, H., Nemeth, E., Freels, S. and Braunschweig, C. A. (2009). Excess adiposity, inflammation, and iron-deficiency in female adolescents. *J. Am. Diet. Assoc.* **109**:297–302.

United Nations. (2000). United Nations Administrative Committee on Coordination, Sub-committee on Nutrition (ACC/SCN). Fourth Report on the World Nutrition Situation: Nutrition throughout the Life Cycle.ACC/SCN in collaboration with International Food Policy Research Institute, Geneva.

Verhoef, H., West, C. E., Kraaijenhagen, R., Nzyuko, S. M., King, R., Mbandi, M. M., Van Laatum, S., Hogervorst, R., Schep, C. and Kok, F. J. (2002). Malarial anemia leads to adequately increased erythropoiesis in asymptomatic Kenyan children. *Blood.* **100**:3489–3494.

Wang, Y. and Lobstein, T. (2006). World trends in childhood overweight and obesity. *Int. J. Pediatr. Obes.* **1**:11–25.

Weisberg, S. P., McCann, D. and Desai, M. (2003). Obesity is associated with macrophage accumulation in adipose tissue. *J. Clin. Invest.* **112**:1796–1808.

Wenzel, B. J., Stults, H. B. and Mayer, J. (1962). Hypoferraemia in obese adolescents. *Lancet.* **13**:354–361.

Whitfield, J. B., Gu Zhu, S. T., Powel, L. W. and Martin, N. G. (2003). Relative importance of female-specific and non-female specific effects on variation in iron stores between women. *Br. J. Haematol.* **120**:860–866.

World Health Organization. (1998). Obesity: Preventing and Managing the Global Epidemic. Report of WHO Consultation on Obesity. June 5–7, 1997. World Health Organization, Geneva.

World Health organization. (2000). The Asia-Pacific Perspective: Redefining Obesity and Its Treatment. Western Pacific Regional Office. World Health Organization, Geneva.

World Health Organization. (2001). Obesity: Preventing and Managing the Global Epidemic. Report of a WHO Consultation, WHO Technical Report Series 894. World Health Organization, Geneva.

World Health Organization. (2008). Worldwide Prevalence of Anaemia 1993–2005. WHO Global Database on Anaemia. World Health Organization, Geneva.

Xu, H., Barnes, G. T. and Yang, Q. (2003). Chronic inflammation in fat play a crucial role in the development of obesity-related insulin resistance. *J. Clin. Invest.* **112**:1821–1830.

Yanoff, L. B., Serbring, N. G., Mchigh, T., Ramaley, A. T. and Yanovski, J. A. (2007). Inflammation and iron deficiency in hypoferrimia of obesity. *Int. J. Obes.* **31**:1412–1417.

Yip, R. and Ramakrishnan, U. (2002). Experiences and challenges in developing countries. *J. Nutr.* **132**:S827–S830.

Zacharski, L. R., Ornstein, D. L., Woloshin, S. and Schwartz, L. M. (2000). Association of age, sex and race with body iron stores in adults: analysis of NHANES III data. *Am. Heart J.* **140**:98–104.

Zafon, C., Lecube, A. and Simo, R. (2010). Iron in obesity. An ancient micronutrient for a modern disease. *Obes. Rev.* **11**(4):322–328.

Zimmermann, M. B., Chaouki, N. and Hurrel, R. F. (2005). Iron deficiency due to consumption of habitual diet low in bioavailable iron: A longitudinal cohort study in Moroccan children. *Am. J. Clin. Nutr.* **81**:115–121.

Zimmermann, M. B., Zeder, C., Muthayya, S., Winichagoon, P., Chaouki, N., Aeberli, I. and Hurrell, R. F. (2008). Adiposity in women and children from transition countries predicts decreased iron absorption, iron deficiency and reduced response to iron fortification. *Int. J. Obes.* **32**:1098–1104.