



Bioavailability

Body mass index, iron absorption and iron status in childbearing age women

María Fernanda Mujica-Coopman^a, Alex Brito^{a,b}, Daniel López de Romaña^{a,c},
Fernando Pizarro^a, Manuel Olivares^{a,*}

^a Micronutrients Laboratory, Institute of Nutrition and Food Technology, University of Chile, Chile

^b United States Department of Agriculture, Western Human Nutrition Research Center, University of California, Davis, USA

^c The Micronutrient Initiative, Ottawa, ON, Canada

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ABSTRACT

Background: The prevalence of obesity has increased at an alarming rate worldwide. Some studies have observed an association between iron (Fe) deficiency (ID) and obesity, however more research is needed. **Objective:** To assess whether body mass index (BMI) is associated with both Fe absorption and Fe status. **Methods:** A cross sectional sample of 318 Chilean childbearing age women was studied. The women received either a single dose of 0.5 mg of Fe ($n = 137$, group 1) or 3 mg of Fe plus ascorbic acid (1:2 molar ratio) ($n = 181$, group 2), both as FeSO₄ with labeled radioisotopes. Fe absorption was assessed through radio Fe erythrocyte incorporation. Fe status was determined by hemoglobin (Hb), mean corpuscular volume, serum Fe, total iron binding capacity, transferrin saturation, erythrocyte Zn protoporphyrin and serum ferritin (SF).

Results: 29%, 47% and 24% of the women were classified as normal, overweight or obese, respectively. Fe absorption was significantly lower in obese women ($p < 0.05$). In group 1, the geometric mean and range ± 1 SD of the percentage of Fe absorption for normal-weight women was 32.9% vs. 19.7% in obese. For group 2, this percentage was 36% vs. 30%, respectively (2-way ANOVA: BMI classification and Fe dose $p < 0.05$; interaction $p = 0.34$). Although Fe absorption was lower in obese women, they had higher SF ($p < 0.01$) and Hb ($p < 0.05$) concentrations.

Conclusion: Although we did not observe a relationship between BMI and Fe status, obese women displayed lower Fe absorption compared with overweight and normal weight women, possibly due to subclinical inflammation associated with obesity.

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Introduction

The nutritional status of populations in countries undergoing economic transition is changing rapidly due to diet and lifestyle changes [1–3]. These populations display a high prevalence of chronic disease associated with obesity, such as cardiovascular disease, type 2 diabetes and cancer. These populations continue to have high rates of micronutrient deficiencies, such as iron deficiency (ID) [4]. Both obesity and ID are independently major disease burdens [5,8]. Obesity is currently considered a global pandemic, while ID continues to be the most prevalent single micronutrient deficiency in the world [6–8]. A connection between obesity and

ID was first reported in obese adolescents, who apparently had lower serum Fe concentrations compared to non-obese adolescents [9,10]. Other studies have described an association between ID and obesity in children and adults [11–13]. The proposed mechanisms that explain this relationship include diminished Fe absorption and decreased Fe mobilization from stores due to inflammation, as well as increased Fe requirements due to high blood volume [14]. Evidence shows elevated inflammatory biomarkers, such as C-reactive protein (CRP), in obese subjects when compared to non-obese subjects and the detrimental effect that pro-inflammatory molecules have on Fe status [15]. To our knowledge, only one study to date has reported an inverse relationship between body mass index (BMI) and Fe absorption, independent of Fe status in childbearing age women [16].

Chile is a country in the advanced stages of nutritional transition. Under-nutrition has virtually disappeared, however, obesity rates and risk factors for chronic diseases are rising. Although anemia

* Corresponding author at: Av. El Líbano 5524, Macul, Santiago, Postal Code: 783 04 90, Chile. Tel.: +56 29781482; fax: +56 22214030.

E-mail address: molivare@inta.uchile.cl (M. Olivares).

is not a public health problem in childbearing age women [17], ID is still highly prevalent. Thus, the objective of the present study is to determine the association between BMI and both Fe absorption and Fe status in Chilean childbearing age women.

Subjects and methods

Design

A cross-sectional study was designed using data from 318 women who participated in previously published [18–27] and non-published Fe absorption studies, between 1997 and 2007 at the Institute of Nutrition and Food Technology (INTA), University of Chile. None of the women were pregnant, confirmed by a negative urine test for human chorionic gonadotropin. All of the women were using a birth control method (e.g., intrauterine device, oral contraceptive, or tube ligation) at the time of the study, were in apparent good health, and none had consumed vitamin or mineral supplements in the 6 months prior to the studies.

BMI classification

Weights and heights were obtained using standardized procedures [18–27]. Body mass index was calculated from bodyweight/height², as defined by the World Health Organization (WHO) [28]. Women were classified as normal (BMI ≥ 18.5 to < 25 kg/m²), overweight (BMI ≥ 25 kg/m² to < 30 kg/m²) or obese (BMI ≥ 30 kg/m²), according to WHO criteria [28].

Iron absorption

The participants received, after an overnight fast, either a single dose of 0.5 mg of Fe (group 1; $n = 137$) or 3 mg of Fe plus ascorbic acid (1:2 molar ratio) (group 2; $n = 181$) as ferrous sulfate (FeSO₄) labeled with either ⁵⁹Fe (37 kBq) or ⁵⁵Fe (111 kBq), radioisotopes of high specific activity (NEN, Life Science Products, Boston, MA, USA). In addition, venous blood samples were drawn to assess hematological parameters and to measure circulating radioactivity. Blood radioactivity was estimated according to the method described by Eakins and Brown [29]. The percentages of Fe absorption were calculated on the basis of blood volume estimated by height and weight [30], assuming 80% incorporation of the radioisotope into erythrocytes [31].

Iron status and hematological parameters

Hemoglobin (Hb), mean cell volume (MCV) (CELL-DYN 1700, ABBOTT Diagnostics, Abbott Park, IL CELL Dyn), serum Fe, total iron binding capacity (TIBC), transferrin saturation (Sat) [32], erythrocyte Zn protoporphyrin (Zpp) measured by hematofluorometry (hematofluorometer Model 206D, AVIV Biomedical Inc, Lakewood,

NJ), and serum ferritin (SF) were assessed by an enzyme immune assay of double sandwich (INACG) [33].

Anemia was defined as Hb < 12 g/dL and iron deficiency anemia (IDA) was defined as Hb concentrations < 12 g/dL with at least two of the following abnormal indicators of Fe status: Sat $< 15\%$, MCV < 80 fL, SF < 12 μ g/L and Zpp > 70 μ g/dL red blood cells (RBC) [34]. ID without anemia was defined as Hb concentrations > 12 g/dL with at least two abnormal indicators of Fe status. Depleted Fe stores were defined as SF < 12 μ g/L. Fe status was considered to be normal when all of these laboratory indexes were within the reference ranges.

Ethical approval

All studies were performed in accordance with the Helsinki Declaration, and were approved by the Ethics Committee at INTA, University of Chile, before their execution. The doses of radioisotopes used were approved by the Chilean Commission on Nuclear Energy.

Statistical analysis

Normally distributed variables were described by means and standard deviations (SD). Distributions of SF and Zpp concentrations were skewed, therefore the values were log-transformed and the results were then retransformed into antilogarithms to recover the original units. SF results are expressed as geometric means and range ± 1 SD.

The differences between dose groups, classifications of normal, overweight or obese, were assessed by two-way ANOVA with a post hoc Scheffé test. The relationship between Fe absorption, SF and BMI was calculated with a Pearson correlation coefficient. SF was expressed as a natural logarithm.

The statistical significance level was set at $p < 0.05$. All statistical analyses were performed with STATA, version 10.0 (StataCorp, College Station, TX, USA).

Results

The general characteristics of the women are shown in Table 1. The mean age of all the women ($n = 318$) was 40 ± 5 y. There was a statistically significant difference in the age of the women between the groups with different doses of Fe. Of all the women, twenty-nine percent were classified as having normal weight, 47% as overweight and 24% as obese. The mean BMIs were 23 ± 1 kg/m², 27 ± 1 kg/m² and 33 ± 3 kg/m², respectively.

Out of all the women, the prevalence of IDA, ID without anemia, Fe depleted stores, and normal Fe status was 7%, 9%, 18% and 66%, respectively. There were no significant differences in Fe status within each category of BMI classification.

The percentage of Fe absorption was significantly lower in obese women compared to normal-weight ($p < 0.02$) and overweight women ($p < 0.005$) (Table 2).

Table 1
Characteristics of women (mean \pm SD).

	Iron dose (0.5 mg)			Iron dose (3 mg) ^a				
	<i>n</i>	Normal (<i>n</i> = 45)	Overweight (<i>n</i> = 75)	Obese (<i>n</i> = 17)	<i>n</i>	Normal (<i>n</i> = 47)	Overweight (<i>n</i> = 74)	Obese (<i>n</i> = 60)
Age ^b (y)	135	37.6 \pm 4.4	39.7 \pm 4.3	38.9 \pm 4.3	181	40.7 \pm 5.1	40.2 \pm 4.9	40.6 \pm 5
Weight (kg)	137	57.1 \pm 5.4	66.3 \pm 7.0	76.7 \pm 5.8	181	55.5 \pm 5.8	67.0 \pm 6.4	81.1 \pm 10.6
Height (m)	137	1.57 \pm 0.05	1.56 \pm 0.06	1.55 \pm 0.05	181	1.56 \pm 0.07	1.57 \pm 0.06	1.55 \pm 0.06
BMI ^c (kg/m ²)	137	23.1 \pm 1.2	27.2 \pm 1.4	31.8 \pm 1.3	181	22.8 \pm 1.8	27.3 \pm 1.4	33.8 \pm 4.0

2-way ANOVA for repeated measures.

^a 2:1 molar ratio ascorbic acid to iron.

^b There were significant differences between Fe doses groups ($p < 0.05$).

^c There were significant differences between Fe doses ($p < 0.05$) and nutritional status; Sheffé post hoc test: normal vs. overweight, normal vs. obese and overweight vs. obese ($p < 0.0001$).

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