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Unchanged Iron and Copper and Increased Zinc in the Blood of Obese Children After Two Hypocaloric Diets

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ABSTRACT

Serum iron (sFe), and ferritin (sFert), transferrin saturation index (TSI), plasma zinc and copper (pZn, pCu), and erythrocyte zinc content (eZn) were measured in 55 obese children and adolescents (28 males and 27 females) before and after a 13-wk treatment with a hypocaloric balanced diet (HCBD, 22 subjects) or a 10-wk treatment with a protein sparing modified fast diet (PSMF, 33 subjects). The energy intake provided by the HCBD and PSMF diet was calculated to be 60 and 25%, respectively, of the recommended dietary allowances (RDAs) for age and sex. Neither diet was supplemented with trace elements or calcium.

Using a visual memory system, all subjects had a 24-h dietary intake recall before starting the weight-loss program. Iron, zinc, and copper intakes from the 24-h recall were compared with those from prescribed diets.

Both diets produced a significant ($p < 0.001$) weight reduction with a significant reduction in the arm muscle area of the PSMF group.

After treatment, no significant change was observed in sFe, sFert, and TSI of either group, whereas eZn increased significantly in the HCBD and the PSMF groups ($p = 0.001$ and $p < 0.006$, respectively), with an improvement of the erythrocyte index (E.I.). A significant increase in pZn was also observed in the PSMF group ($p = 0.007$).

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When compared with the usual intakes, HCBD supplied less iron ($p = 0.04$) and more copper ($p = 0.001$), whereas PSMF provided more zinc ($p = 0.026$).

Index Entries: Iron; zinc; copper; childhood obesity; protein-sparing modified fast; hypocaloric diets; very low calorie diets.

INTRODUCTION

In affluent countries, obesity is by far the most common nutritional problem during childhood *(1)*, and dietary restriction remains the cornerstone of weight loss therapy for individuals of any age *(2)*. Although hypocaloric balanced diets (HCBDs) are the most common dietary approach, in the last few years, very low calorie diets (VLCDS) also have been used for the treatment of childhood obesity *(1–4)*. Both have been demonstrated to be safe and effective in producing rapid weight loss in obese children and adolescents without evident side effects *(2,4)*. Some may not provide all micronutrient requirements, so mineral and vitamin supplements are commonly recommended *(1–4)*. The importance of some minerals, like iron, zinc, and copper, during growth is well known, but we are unaware of any reports relating to the safety of weight loss treatments on the nutritional status for these metals in obese children. It is difficult to determine which tissue best represents the body contents of zinc and copper *(5)*. However, serum levels and red and white blood cell contents are the most widely used indexes. The aim of the present study was to evaluate the short-term effects of an HCBD and a VLCD on iron, copper, and zinc blood content in obese children and adolescents.

MATERIALS AND METHODS

Subjects

Sixty-one obese children were managed as outpatients at the III Pediatric Clinic of the Department of Pediatrics, II University of Naples, Italy, from January to June 1994. Children were all above 120% of ideal body weight (IBW) *(6)*. None had other clinical problems.

Fifty-five of the children were enrolled in the study, but six with serum iron (sFe) < 5.4 µmol/L were excluded.

Thirty-three children out of 55 (15 males, 18 females; age 8.8 ± 3.1 yr) were assigned to an HCBD for 13 ± 2 wk and 22 children (13 males, 9 females; age 12.6 ± 2.4 yr) were assigned to a VLCD (protein-sparing modified fast [PSMF]) *(7)* for 10 ± 1 wk. Only children 8 yr old or more were assigned to the PSMF group because of the poor compliance before this age.

While on the diet, all patients received daily multiple vitamin** supplements without iron, copper, and zinc.

**Vit. A 2080 IU, vit. B_1 0.8 mg, vit. B_2 0.4 mg, vit. B_6 0.4 mg, vit. C 20 mg, vit. D_2 410 IU, vit. E 1.2 mg, vit. H 0.4 mg, vit. PP 4 mg, panthenol 4 mg.

Clinical and Biochemical Assessment

A complete physical examination, including anthropometric measurements, was performed at the start of the study and repeated monthly. Weight was measured by a balance-beam scale and height by a Harpenden stadyometer. Tricep skin folds were measured *(8)* using an Holtain–Tanner caliper (Harpenden and Holtain, Anthropometric Instruments, UK). Arm fat area (AFA) and arm muscle area (AMA) were calculated from arm circumference and tricep skin folds *(9,10)*.

Routine biochemical parameters, including total protein, albumin and prealbumin, C_3 factor of complement, creatinin, calcium, phosphorous, alkaline phosphatase, osteocalcin, parathyroid hormone, calcitonin, and urinary calcium excretion, were performed monthly to assure the safety of dietary regimens. sFe and serum ferritin (sFert), transferrin saturation index (TSI), plasma zinc and copper (pZn, pCu), and erythrocyte zinc content (eZn) were measured before starting and at the end of the treatment. After an 8-h fast, 10 mL of venous blood were drawn by a sterile zinc-free syringe with stainless-steel needle. Six milliliters of the sample were used to determine hemoglobin concentration, red blood cell (RBC) count, sFe, transferrin, and sFert levels. Iron was measured by reflexometry (Two-Points Rate Test, Eastman Kodak Company, Rochester, NY), and transferrin and ferritin by immunoturbidimetry (Tina-Quant Ferritina, Boehringer Mannheim, Mannheim, Germany). The remaining 4 mL were collected into a zinc-free tube with heparin and centrifuged at 3000 rpm for 10 min; plasma was then removed for zinc and copper measurements by a Perkin–Elmer 3030 B Atomic Absorption Spectrophotometer (Perkin–Elmer, Uberlingen, Germany). Erythrocytes were washed three times in 0.9% NaCl solution, and 1 mL of RBCs was added to 3 mL of deionized water for lysis. eZn content was measured by the colorimeter *(11)* and reported as pg$\backslash 10^6$ RBC and as the erythrocyte index (EI = $[x - \mathrm{m}]/\mathrm{SD}$; where x is the measured content, and m and SD are the expected value and the standard deviation of the control subjects [12]). This index is useful to normalize values for age and sex.

Diets

Using a visual memory system *(13)*, all subjects had a 24-h dietary intake recall before starting the weight-loss program. This procedure was always carried out by the same physician according to the improved techniques reported by Frank et al. *(14)*. Nutrient intakes provided by the prescribed diets and by dietary recalls were calculated by a food composition computerized code based on available data (Dietosystem, 1985, Milano, Italy) and normalized for the recommended dietary allowances (RDAs) for age and sex *(15)*. Iron, zinc, and copper intakes from the 24-h recall were compared with those from prescribed diets.

The energy intake provided by the HCBD was calculated to be 60% of the RDA with the following distribution: protein 20%, fat 30%, and carbohydrate 50%. The iron and zinc contents in this diet were lower than RDA (68 ± 21 and 69 ± 17% respectively), whereas the copper content was higher (215 ± 149%).

The corresponding values provided by the PSMF diet were calculated to be total energy 25% of the RDA with the following nutrient distribution: protein 60%, fat 20%, and carbohydrate 20%. The iron, zinc, and copper amounts were near the RDA (98 ± 23, 128 ± 43, and 118 ± 45%, respectively).

The amount of calcium furnished by HCBD and PSMF was calculated to be 71 ± 20 and 46 ± 25% of RDA, respectively. The length of treatment was different in the two groups, because 10 wk are enough for a satisfactory weight loss without side effects with the PSMF diet, whereas most children need protracted treatment for a comparable weight loss when managed with HCBD.

Statistical Analysis

Because of the differences in the mean age of groups, treatment length, and trace element content in the diets, we only performed an intragroup comparison. Clinical and biochemical findings were compared before and after treatment by the Wilcoxon matched pairs signed rank test. A p value ≤ 0.05 was considered statistically significant.

RESULTS

Clinical and laboratory data, before and after diets, are reported in Table 1. Both diets led to a significant ($p < 0.001$) reduction in % IBW and AFA, with a significant reduction in the AMA of the PSMF group ($p = 0.01$).

Routine hematological indexes were within normal limits before and after completing the study, except for a significant reduction of C_3 factor of complement observed in both HCBD and PSMF groups (1051 ± 207 vs 897 ± 144 mg/L; $p = 0.001$ and 1083 ± 306 vs 837 ± 129 mg/L, $p < 0.001$, respectively).

After treatment, no significant change was observed in sFe, sFert, and TSI of either group, whereas eZn increased significantly in the HCB and the PSMF groups ($p = 0.001$ and $p < 0.006$, respectively), with an improvement of EI. A significant increase in Zn was also observed in the PSMF group ($p = 0.007$).

Daily intakes of iron, zinc, and copper before treatment were 104 ± 38, 87 ± 56, and 135 ± 83% of RDA in the HCBD group and 110 ± 42, 87 ± 51, and 155 ± 109% of RDA in the PSMF group.

When compared with the usual intakes, HCBD supplied less iron (8 ± 2 vs 11 ± 4 mg/d; $p = 0.04$) and more copper (2.7 ± 1.5 vs 1.4 ± 0.8 mg/d; $p = 0.001$), but PSMF provided more zinc (16 ± 4 vs 11 ± 6.6 mg/d; $p = 0.026$).

Table 1
Clinical and Biochemical Data Before and After Treatments

	PSMF		**HCBD**	
	BEFORE *M±SD*	**AFTER** *M±SD*	**BEFORE** *M±SD*	**AFTER** *M±SD*
IBW *%*	164±22	138±21***	160±20	137±15***
AFA *cm^2*	37.5±9.9	23.8±6.6***	24.7±6.9	17.6±5.0***
AMA *cm^2*	47±12	43±9*	35±12	34±10
sFe *μmol/L*	12.8±4.3	11.3±4.1	10.9±3.2	11.1±4.3
TSI *%*	18±6	16±7	14±5	15±7
sFert *μg/L*	39±28	48±29	37±19	37±19
pZn *μmol/L*	12.8±3.3	15.4±3.3**	13.0±2.3	13.1±13.5
pCu *μmol/L*	14.6±3.9	14.7±3.3	15.5±3.9	14.3±3.6
eZn *pg/10^6 RBC*	881±254	1031±263***	793±144	854±144**
Zn EI	-1.6±0.9	-1.2±0.8**	-2.0±0.7	-1.8±0.6*

*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.

IBW: ideal body weigh; AFA: arm fat area; AMA; arm muscle area; sFe: serum iron; TSI: transferrin saturation index; sFert: serum ferritin; pZn: plasma zinc; pCu: plasma copper; eZn: erythrocyte zinc; Zn EI: zinc erythrocyte index.

DISCUSSION

The HCBDs are more frequently used than the VLCDs because of their good compliance even in younger children; nevertheless, this type of diet provide inadequate Fe and Zn. The PSMF diet, on the contrary, with mostly meat and fish, furnishes adequate iron, zinc, and copper intakes. However, this diet is considered to be a very strict regimen, and it requires caution when used in children because of the risk of protein energy malnutrition and nutrient imbalance. A short-term (10 ± 2 wk) use of VLCDs in prepubertal children has been demonstrated to have no more detrimental effects than an HCBD on growth and nutrient balance *(2,4,16,17)*.

Both these diets are usually employed with multiple vitamin supplements containing small amounts of zinc, iron, and copper. Thus, studies evaluating the safety of these regimens on trace metals status in obese children are lacking. The good compliance and the lack of metal supplements makes our study suitable to determine changes in Fe, Zn, and Cu owing to diet.

The PSMF diet is usually supplemented with calcium *(1–3)* because of its low mineral content. Considering the short treatment length, no calcium supplement was given, because calcium is known to decrease zinc intestinal absorption *(18)*. We still monitored several indexes of calcium metabolism, but saw no impairment.

An improved 24-h dietary recall can be used by a small, well-trained staff to collect reliable data on a large number of children and to provide a reasonable estimate of the quality of the diet *(14,19)*. sFe, sFert, and transferrin are commonly accepted measurements of iron status, but the best indexes of zinc and copper status are still to be determined. The beneficial effect of supplementation is generally accepted as a sign of deficiency. Nevertheless, this is clinically evident only in severe deficiencies. Marginal deficiencies need much more attention. The analysis of mineral content in different pools (e.g., erythrocyte, plasma, and so on) sampled simultaneously is of interest, because these represent differing metabolic pools with varying turnover rates *(5)*. In this study, we simultaneously determined pZn and pCu levels together with RBC zinc content. In these cells, the change occurs after plasma (fast) and before hair (slow).

The literature *(20–23)* reports reduced plasma ferritin and TSI *(20)* and low zinc content in the serum *(20,21)*, hair *(21,23)*, and lymphomonocytes *(22)* of obese children. These are considered indexes of subclinical zinc and iron deficiency.

At baseline, nutritional indexes were unremarkable except for sZn and eZn content. These were at the lower limit of our normal range. In this framework, our obese subjects could be considered to present marginal zinc deficiency.

At the end of the treatment, we observed the following findings in both groups of patients: (1) no significant change in iron status and pCu level and (2) a significant increase in pZn and/or eZn content.

In the PSMF group, these findings reflect the iron, zinc, and copper contents of the diet. When compared to usual intake, the PSMF diet provided similar amounts of iron and copper and more zinc. Moreover, this diet supplied less calcium, and this may increase zinc absorption. The HCBD, on the contrary, provided less iron and zinc, and more copper. Notwithstanding this, the blood metal contents from the subjects after this treatment are similar to the PSMF group. The multiple homeostatic mechanisms that regulate iron and copper body content can maintain blood pools relatively stable regardless of diet. Moreover, the improved balance of macronutrients and the change in micronutrient ratios during the HCBD may have improved the intestinal absorption of some metals. The low amounts of iron in the diet could have increased zinc absorption *(18)*. However, the zinc increase may well have come from a redistribution of the metal in the body compartments after lean tissues breakdown. A significant reduction of arm muscle area and C_3 factor suggested a marginal protein malnutrition in our subjects.

It is noteworthy that the literature reports an inverse correlation between the degree of obesity (e.g., AFA, body mass index, % IBW) and the zinc content in some body compartments, such as lymphomonocytes *(22)*, hair, and plasma *(20,21,23)*. The increase in pZn and eZn content that we observed may be related to weight loss.

CONCLUSION

Our data show how the dietary regimens we used had no short-term detrimental effect on iron, zinc, and copper blood contents in obese children. Nevertheless, because blood levels of zinc and copper may not entirely reflect the body content of these metals, an extensive measurement of trace element contents in the tissues and biological fluids of obese children and adolescents is recommended. This approach warrants micronutrient specific supplementation for subjects with one or more deficiencies recognized before starting treatment. A follow-up of iron status may also be recommended for treatments lasting more than 12 wk. Further investigations are needed to evaluate whether a diet-induced weight loss could improve zinc nutritional status in obese children and adolescents.

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