

SHORT COMMUNICATION

Greater prevalence of iron deficiency in overweight and obese children and adolescents

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OBJECTIVE: To assess whether overweight children and adolescents, who often have poor dietary habits, are at increased risk of iron deficiency (ID).

METHODS: The study sample included 321 children and adolescents followed in two endocrine centers in Israel between 1999 and 2001. The subjects were divided into three groups on the basis of body mass index (BMI) for age and gender as follows: group 1—BMI below 85th percentile (normal weight); group 2—BMI above 85th, but below 97th percentile (overweight); and group 3—BMI above 97th percentile (obese). ID was defined as iron levels $<8\ \mu\text{mol/l}$ (45 mcg/dl), and iron-deficiency anemia (IDA) was defined as ID and hemoglobin level below 2 standard deviation score (SDS) for the mean for age and gender.

RESULTS: Iron levels below $8\ \mu\text{mol/l}$ (45 mcg/dl) were noted in 38.8% of the obese children and 12.1% of the overweight children, compared with 4.4% of the normal-weight group ($P<0.001$). There was a significant negative correlation of low iron levels with BMI SDS ($r=-0.44$, $P<0.001$), but not with age or gender. Among the children with ID, 26.6% also had IDA. Groups 1, 2, and 3 accounted for 6.7%, 35%, and 58.3% of the children with IDA, respectively.

CONCLUSIONS: ID is common in overweight and obese children. A significantly greater proportion of obese than normal-weight children have IDA. Insufficient dietary intake of iron, whether absolute or relative to body mass, and increased iron needs may be a result of unbalanced nutrition or repeated short-term restrictive diets. Because of potentially harmful effects of ID, obese children should be routinely screened and treated as necessary.

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Introduction

Nutrition in childhood has a significant impact on lifelong health. Obesity and iron deficiency (ID) are two of the most common nutritional disorders worldwide. ID has been associated with decreased exercise capacity, impaired cognitive function, developmental delays, and behavioral disturbances.^{1,2} Obese children are at risk of increased morbidity starting already in childhood or adolescence.³ Interestingly, despite their excessive dietary and caloric intake, obese children and adolescents may be at risk of ID because they tend to consume unbalanced meals, particularly rich in carbohydrates and fat. Both obesity and ID are also more prevalent in lower socioeconomic groups, who consume low-cost fast foods, that are low in essential nutrients and rich in fats, sugars and preservatives.

Screening for iron-deficiency anemia (IDA) by a blood count with indices, is recommended only in infants, because of the critical role of iron in brain development, and in menstruating adolescents.⁴ However, we were impressed by the number of children and adolescents, referred to our obesity clinics, who had evidence of microcytic anemia on complete blood count screen. To determine the prevalence of ID in this patient population, we measured serum iron levels as an early sensitive screen. Low serum iron together with low percent iron saturation precede microcytosis and hypochromia, which in turn leads to IDA. Our findings suggest that obese children and adolescents are commonly iron deficient.

Methods

The study sample consisted of 321 children attending two university-affiliated endocrine clinics in Israel between 1999 and 2001. The mean age was 11.3 ± 3.6 y (range 3–19 y), and female-to-male ratio was 1.8:1. A total of 138 children were overweight ($n=33$) or obese ($n=152$) as determined by body mass index (BMI) for age and gender according to the NIH

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data:⁵ overweight—BMI above 85th percentile, but below 97th percentile; obese—BMI above 97th percentile (>1.88 standard deviation score (SDS)). The remaining 136 children were of normal weight (BMI below 85th percentile, <1.036 SDS) attending the endocrine clinics because of precocious or delayed puberty, familial short stature, or hirsutism. Celiac disease was excluded in all these cases.

Iron levels were measured in the morning after an overnight fast using the FerroZine method without depolarization (Roche Diagnostics GmbH, Mannheim, Germany). ID was defined as iron level <8 μmol/l (45 mcg/dl), and IDA was defined as ID with hemoglobin level below 2 SDS for age and gender.

Statistics

Data were analyzed with BMDP software.⁶ The following statistical analyses were applied: one- and two-way ANOVA, one-way analysis of covariance, Pearson correlation, stepwise logistic regression; *P*-values <0.05 were considered statistically significant.

Results

Age (mean ± s.d.), gender distribution, and iron levels of the normal-weight (group 1), overweight (group 2), and obese subjects (group 3) are shown in Table 1. Mean serum iron level in the obese children was significantly lower (10.6 μmol/l, 59.4 mcg/dl) than that of the overweight children (13.3 μmol/l, 74.2 mcg/dl) (*P*<0.01), and even more significantly lower than that of the normal-weight children (15.8 μmol/l, 88.4 mcg/dl) (*P*<0.001). Adjustment of the findings for age and gender further strengthened these differences.

Iron levels below 8 μmol/l (45 mcg/dl) were noted in 38.8% of the obese subjects, 12.1% of the overweight subjects, and only 4.4% of the normal-weight group (*P*<0.001). The percentage of males and females with iron levels below this cutoff point was identical (21.2%). When the subjects were reclassified into three groups by age (5–10 y, 10–15 y, and

>15 y), no differences were noted in the percentage of iron-deficient subjects among groups (21.5, 20.1 and 23.5%, respectively).

Iron levels showed a highly significant negative correlation with BMI SDS (*r* = −0.44, *P*<0.001) (Figure 1). For each increase in BMI SDS, there was a concomitant decrease in iron level.

On logistic regression analysis with iron <8 μmol/l (45 mcg/dl) as the dependent variable, and gender, age and BMI SDS as the independent variables, only BMI SDS was a predictor of ID, with an odds ratio of 1.75 (95% CI 1.48–2.06). Receiver operating characteristics (ROC) plot yielded an area under the polygon of 0.79, indicating that BMI alone was sufficient to predict ID.

Pearson correlations showed that iron levels were not gender-dependent. Age was also not associated with an increased risk of ID in either males or females. On ANOVA, the interaction of all three variables (BMI SDS, age, and gender), only BMI SDS had a significant effect on iron level (*P*<0.001).

IDA was noted in 26.6% of the subjects with ID: 6.7% were in normal-weight group compared with 58.3% in obese group (*P*<0.001). As expected, there was a significant positive correlation between iron levels and both delta hemoglobin and delta MCV (*r* = 0.37 and 0.45, respectively, with *P*<0.001 for both).

Discussion

Obesity is increasing worldwide, reaching epidemic proportions.⁷ Poor nutrition is one of the main reasons. It is also one of the main reasons for ID. Recently, the National Health and Nutrition Examination Survey III⁸ demonstrated that ID without anemia is associated with lower standardized math scores in school-aged children and adolescents. ID without anemia in young women impairs adaptation to aerobic exercise.⁹

In the present study, 4.4% of children in the normal-weight group had low iron levels. This rate is consistent with

Table 1 Iron levels according to BMI SDS corrected for age and gender

| | No. pts. | Mean iron μmol/l (mcg/dl) | Age (y) | Mean iron adjusted for age μmol/l (mcg/dl) |
|---------|----------|---------------------------|------------|--|
| Total | 321 | 13.1 (73.2) | 11.4 | |
| Group 1 | 136 | 15.8 ± 5.6 (88.4 ± 31.5) | 10.5 ± 3.2 | 16.1 (89.7) ^{a,b} |
| Females | 93 | 15.4 ± 5.4 (85.9 ± 29.9) | 10.6 ± 3.0 | |
| Males | 43 | 16.8 ± 6.1 (93.9 ± 34.2) | 10.5 ± 3.7 | |
| Group 2 | 33 | 13.3 ± 5.5 (74.2 ± 30.6) | 11.4 ± 2.7 | 13.3 (74.2) ^c |
| Females | 22 | 13.7 ± 5.4 (76.6 ± 30.3) | 11.2 ± 2.6 | |
| Males | 11 | 12.4 ± 5.7 (69.3 ± 32.0) | 11.6 ± 4.2 | |
| Group 3 | 152 | 10.6 ± 5.7 (59.4 ± 28.9) | 12.1 ± 3.9 | 10.4 (58.2) |
| Females | 92 | 9.9 ± 4.9 (55.6 ± 27.4) | 12.0 ± 4.2 | |
| Males | 60 | 11.6 ± 5.7 (65.1 ± 32.0) | 12.1 ± 3.4 | |

^a*P*<0.001 group 1 vs group 3.

^b*P*<0.01 group 1 vs group 2.

^c*P* = 0.05 group 2 vs group 3.

Note: To convert from μmol/l to mcg/dl divide by 0.179.

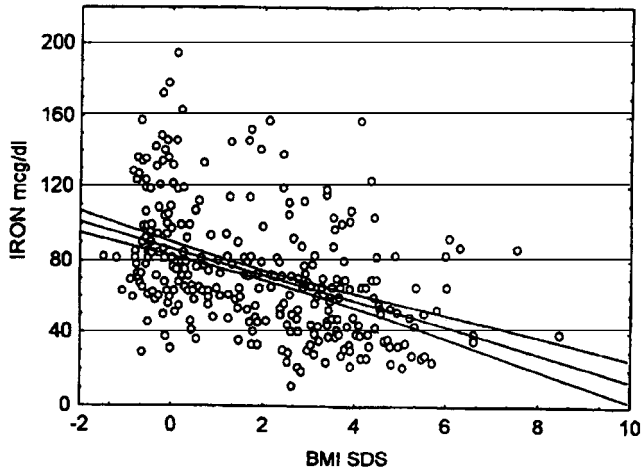


Figure 1. Body mass index SDS vs. iron levels

the estimated prevalence of 3% (1.5–8.7%) of ID in children and adolescents in the USA.¹⁰ However, the high rate of ID in our obese children was surprising, and the precise reason remains unclear. To the best of our knowledge, this is the first report of ID in obese children.

The total amount of iron in the body is determined by its intake, absorption, loss, and storage.¹⁰ In children, risk factors for ID include diet poor in iron, diet poor in enhancers of iron absorption such as vitamin C, and diet rich in inhibitors of iron absorption such as polyphenols (in certain vegetables), tannins (in tea), phytates (in bran), and calcium (in dairy products).¹¹ Dietary intake was not documented in our study and needs further investigation. Moreover, even though the obese patients in the present study were new to our clinic and had not yet started a weight-loss diet, some of them may have tried different unbalanced diets on their own before referral, and had therefore been consuming low iron levels for some time. Even short-term very low-energy diets can cause detectable changes in iron stores.¹²

Iron balance is regulated mainly in the gastrointestinal tract through absorption. As obese children gain weight easily, there is no reason to assume they have a problem with absorption. Furthermore, studies in ob/ob mice have shown that they absorb and retain approximately twice as much iron as wild-type lean mice.¹³ Periods of rapid growth, such as in premature babies, neonates and adolescents,¹⁴ are known to be associated with ID. Similarly, it is possible that obese children have increased iron needs because of their increased growth and body surface area.

Iron loss may be a reason for ID in menstruating adolescents. However, in our study, serum iron levels were low also in males and in prepubertal children. Therefore, iron loss because of menstruation alone is not a sufficient explanation for the observed findings.

ID and IDA are associated with decreased physical endurance and maximal exercise capacity.¹⁵ The extent to which these disorders might affect daily activities that do not

involve maximal exercise capacity is unknown. Nevertheless, we may assume that ID may further contribute to the poor exercise capacity of obese children, who already have difficulties performing even mild physical tasks.

The main limitation of our study is the use of serum iron level, which was selected because it is readily available in many biochemical tests. However, infections and inflammations can decrease serum iron concentration, and there may be day-to-day variations within individuals. Other parameters such as transferrin, transferrin receptor, and ferritin should be studied as well in the future.

In summary, our findings show that obese children and adolescents have a higher than normal rate of ID. We believe that causes may be poor diet content, repeated short-term restrictive diets, and increased iron needs. Because of the potentially harmful effects of ID, obese children should be routinely screened and treated as necessary.

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