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ORIGINAL ARTICLE

Relationship Between being Overweight and Iron Deficiency in Adolescents

Ya-Fang Huang [a], Teck-Siang Tok [b], Chin-Li Lu [c], Hsing-Ching Ko [d], Min-Yu Chen [d,*], Solomon Chih-Cheng Chen [d,e,*]

[a] *Department of Clinical Laboratory, Pingtung Christian Hospital, Pingtung City, Taiwan*
[b] *Department of Pediatrics, Pingtung Christian Hospital, Pingtung City, Taiwan*
[c] *Department of Public Health, College of Medicine, National Cheng Kung University, Tainan, Taiwan*
[d] *Department of Pediatrics, Ditmanson Medical Foundation Chia-Yi Christian Hospital, Chiayi City, Taiwan*
[e] *School of Medicine, Taipei Medical University, Taipei City, Taiwan*

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Key Words
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Objective: Being overweight has been considered to be a risk factor of iron deficiency (ID). The objective of this study was to examine the relationship between being overweight and body iron status among Taiwanese adolescents.
Methods: A total of 2099 adolescents (1327 female) aged 12–19 years from four middle schools and one college in southern Taiwan participated in this study. Data on sex, age, body weight, height, hemoglobin concentration, plasma ferritin (PF), and serum iron (SI) levels were collected. According to the age- and sex-specific body mass index (BMI) percentiles, the participants were divided into four weight groups: underweight ($<5^{th}$ percentile), normal weight ($5–84^{th}$ percentile), overweight ($85–94^{th}$ percentile), and obese ($\geq 95^{th}$ percentile). A multivariate logistic regression model was used to estimate the odds ratio (OR) and the 95% confidence interval (CI) for each factor.
Results: The correlation coefficients of linear regression were positive for BMI–hemoglobin and BMI–PF, but negative for BMI–SI. Compared with the normal-weight group, the obese group had a lower risk of PF level <15 μg/L with an OR (95% CI) of 0.51 (0.30–0.87) but a higher risk of SI <60 μg/dL with an OR (95% CI) of 1.78 (1.34–2.37). The percentages of low PF declined as BMI increased, but the percentages of low SI rose, from underweight to obesity groups.

* Corresponding authors. Department of Pediatrics, Ditmanson Medical Foundation Chia-Yi Christian Hospital, 539 Zhongxiao Road, East District, Chia-Yi City, 60002, Taiwan.
E-mail addresses: cych00026@gmail.com (M.-Y. Chen), solomon.ccc@gmail.com (S.C.-C. Chen).

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Conclusion: The relationship between being overweight and depleted iron store depends on which indicator is used to define the iron deficiency. Being overweight or obese would not be a risk factor of ID in adolescents, if ID were defined by PF rather than SI level.
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1. Introduction

Iron deficiency (ID) may be the most common form of nutritional deficiency worldwide and it is a significant public health problem in both developed and undeveloped countries.[1] In a nationally representative cross-sectional health study in the USA, the prevalence of ID was 9—11% for adolescent girls and women of childbearing age, corresponding to approximately 8 million women with ID.[2] One previous national study in Taiwan showed that the prevalence of ID was 2—6% in adolescent males and 9—10% in adolescent females.[3] ID may cause adverse effects, including reduced work capacity,[4] delayed mental and physical development in children,[5] lower cognitive or behavioral function,[6,7] and impaired sensorimotor function.[8] Since ID is an important public health issue, examining its determinants is important to public health research. Several predisposing factors have been mentioned in the literature, such as female sex, parasite infestation,[9] and *Helicobacter pylori* infection.[10] Some previous studies have suggested being overweight as a risk factor for ID.[11—15]

However, that being overweight may be a risk for ID is contrary to our general understanding, because ID is a micronutrient deficiency that usually occurs in the context of poor nutritional status. For example, the prevalence of ID is often higher in developing countries and it is also associated with lower socioeconomic status.[1,16—19] One study in Indonesia found that thinner adolescents have a five-fold higher risk of suffering from ID anemia compared with nonthin adolescents.[18] Another study in the USA found that children in households with inadequate food had an almost three-fold higher risk of ID than children in households with adequate food.[19] Moreover, the causal mechanism of being overweight for ID still needs further study for clarification.

One challenge to study the risk factor of ID is the diversity of ID diagnosis, for there are many tests but no consensus. Many indicators, such as plasma ferritin (PF), serum iron (SI), soluble transferrin receptor, zinc protoporphyrin, and mean corpuscular volume, have been used to diagnose ID through a single test or a combination of several tests.[20—25] Combining several tests to diagnose ID may be appropriate in academic study, but this is not cost efficient for clinical practice or public health intervention. In practice, SI and PF are the two most frequently used single tests. However, their relationship with being overweight has not been well studied or compared. Thus, the objectives of this study were to examine the relationship between being overweight and body iron status in Taiwanese adolescents by comparing the two tests of SI and PF.

2. Methods

2.1. Ethics statement

The Ethics Review Board of Pingtung Christian Hospital approved the protocol and informed consent prior to the commencement of this study. All participants or their parents provided written informed consent. All data were collected for statistical analysis only, and no personal identification was revealed or compromised.

2.2. Study population

This study was based on routine health checkups that were given to adolescents when they entered school. A total of 2099 adolescents (1327 girls) from one junior high school (786 students, age 12—13 years), three senior high schools (973 students, aged 15—16 years), and one college (340 students, age 18—19 years) in Pingtung County in southern Taiwan participated in this survey in September 2010.

2.3. Laboratory data and definitions

The physical examination and blood sampling were performed after an overnight fast. Bodyweight, height, blood hemoglobin, SI, and PF levels were measured. Venous blood was taken for biochemical analyses, which were performed at the certified clinical laboratory of Pingtung Christian Hospital using a Beckman Coulter LX-20 autoanalyzer (Beckman Coulter, Brea, CA, USA). All technicians were blind to the demographic data and body mass index (BMI) of the participants. We followed the previous studies and World Health Organization recommendations to define anemia as a hemoglobin concentration under 13 g/dL in males or 12 g/dL in females.[25,26] Depleted iron store was defined as either a PF level <15 μg/L[25,27] or SI level <60 μg/dL.[14,28] According to sex- and age-specific BMI criteria,[29] we classified all of the adolescents into four weight groups: underweight ($<5^{th}$ percentile), normal weight (5^{th}—84^{th} percentile), overweight (85^{th}—94^{th} percentile) and obesity ($\geq 95^{th}$ percentile).

2.4. Statistical methods

The statistical analysis was performed using SPSS 21.0 (IBM SPSS Statistics). A p value <0.05 was considered statically significant. The Chi-square test was used to test the association between two categorical variables. The t test was used to examine group differences for continuous variables. Due to the nature of right-skewed distribution, the levels of

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