Nutrition 32 (2016) 332–337

Contents lists available at ScienceDirect

Nutrition

journal homepage: www.nutritionjrnl.com

Applied nutritional investigation

Association between serum zinc level and body composition: The Korean National Health and Nutrition Examination Survey

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ARTICLE INFO

Article history:
Received 3 June 2015
Accepted 14 September 2015

Keywords:
Zinc
Body composition
Body fat percentage
Waist circumference
Lean body mass

ABSTRACT

Objective: The aim of this study was to examine the association between serum zinc levels and several body composition factors in Korean adults.
Methods: We used data from the Korean National Health and Nutrition Examination Survey, a cross-sectional survey of Korean civilians. Data from 1896 adults were analyzed.
Results: Serum zinc levels in men with elevated waist circumference were higher than in those with normal waist circumference (152.1 ± 3.7 μg/dL versus 137.8 ± 2.2 μg/dL; $P < 0.001$) and serum zinc levels increased with increasing tertiles of total body fat percentage (134.2 ± 2.8 μg/dL, 142 ± 2.9 μg/dL, and 148 ± 2.7 μg/dL; $P = 0.001$). Among men with a normal waist circumference, serum zinc levels of those with the highest total body fat percentage were higher than in those with the lowest or medium total body fat percentage values (145.4 μg/dL versus 135.2 μg/dL; $P = 0.029$). In contrast, in men with an elevated waist circumference, no difference in serum zinc levels according to total body fat percentage was detected. There was no relationship between serum zinc levels and body composition factors in women.
Conclusions: Body zinc status might be associated with the quantity and distribution of body fat in Korean men. Additional sex-specific studies are needed to determine whether the relationship of body zinc status with abdominal obesity and total body fat affects metabolic disorders and cardiovascular diseases.

Introduction

Body composition is important not only for physiological functioning but also in relation to metabolic disorders, cardiovascular disease (CVD), and mortality. Obesity, which is the excess accumulation of body fat, is an important public health problem because it is associated with an increased risk for type 2 diabetes mellitus, dyslipidemia, hypertension, and CVD, and its prevalence is increasing worldwide [1]. Furthermore, abdominal obesity, presenting as an increase in visceral adiposity, plays a vital role in the development of insulin resistance and the associated metabolic abnormalities [2]. In contrast, a reduction in muscle mass, known as sarcopenia, is associated with physical and functional impairment [3] and negative metabolic outcomes [4]; therefore, sarcopenia is a major global health issue.

Zinc is the second most abundant trace element in the body and plays catalytic, structural, and regulatory roles in various cellular processes as an essential micronutrient. Additionally, zinc not only plays critical roles in cellular proliferation and differentiation [5], it also has an insulinomimetic effect on energy metabolism [6,7].

The association between zinc status and body composition such as body weight, body fat percentage, and lean body mass has been assessed in experimental studies. One study reported that zinc supplementation increased the body fat percentage in both genetic and diet-induced obese mice [8], and another showed that *Znt7*-deficient mice, which show dysfunctional incorporation of zinc in the Golgi apparatus, were lean due to a significant reduction in body fat composition [9]. In another study, maternal zinc

H-NK and W-SC conceived the study. H-NK, S-WS, and W-SC analyzed and interpreted the data. H-NK and W-SC wrote the manuscript. S-WS supervised the writing of the paper and provided critical revisions. All authors read and approved the final manuscript. The authors have no conflicts of interest to report.

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http://dx.doi.org/10.1016/j.nut.2015.09.006
0899-9007/

restriction in rats increased body fat percentage and decreased lean and fat-free mass (FFM) in offspring [10].

In several studies conducted in children or adolescents, body zinc status was found to affect body composition. Zinc supplementation in Peruvian children with mild to moderate growth stunting induced an increase in the FFM [11], whereas in a study of children ages <2 y, zinc supplementation increased height but had no effect on weight gain [12]. Recent meta-analyses revealed that zinc supplementation increased linear growth and weight gain in children [13,14].

However, studies assessing the association between zinc status and body composition in adult populations are rare, and the results remain controversial [15,16]. Additionally, few studies have assessed the association between zinc status and body composition in a Korean population [17]. Therefore, using data from the Korean National Health and Nutrition Examination Survey (KNHANES), we evaluated whether serum zinc levels are associated with body composition in Korean adults.

Methods

Study population

The present study used data collected from the KNHANES V-1, which was conducted between January and December 2010 [18]. We originally examined the data from 1988 adults, assessing serum zinc levels. Participants with missing information or data for major variables (n = 81), decreased kidney function (estimated glomerular filtration rate [eGFR] <30 mL/min/1.73 m^2; n = 2), or who were pregnant (n = 9) were excluded. Therefore, the present study population consisted of 1896 participants. This study was approved by the Institutional Review Board of the Catholic University of Korea (IRB approval no: VC14 EIME0157).

Measurements of body composition factors

After an overnight fast, specially trained examiners measured participants' height, weight, and waist circumference (WC). WC was measured using a measuring tape in the horizontal plane around the umbilical region after exhaling. Abdominal obesity was defined as WC ≥ 90 cm (≥85 cm for women) [19]. Body mass index (BMI) was calculated as each participant's weight (kg) divided by height squared (m^2) and was classified as underweight, normal weight, overweight, or obese according to BMIs of <18.5 kg/m^2, 18.5 to 22.9 kg/m^2, 23 to 24.9 kg/m^2 and ≥25 kg/m^2, respectively [20].

Body composition factors, including body lean and fat mass were measured using a whole-body dual-energy x-ray absorptiometry scanner (DXA; QDR 4500 A, Hologic, Inc., Waltham, MA, USA). Participants wore a lightweight gown without metal objects during the measurements. Skeletal muscle mass index (SMI) was calculated using the equation: (SMI [%] = total skeletal muscle mass [kg]/body weight [kg] × 100) [3]. Total body fat percentage (TBF) was calculated by the equation: (TBF [%] = total fat mass [kg]/body weight [kg] × 100). SMI and TBF were categorized into tertiles, with tertile 1, representing the lowest values, tertile 2, the medium values, and tertile 3, the highest values.

Laboratory measurements

Blood samples were collected from the antecubital vein of each participant after ≥12 h of fasting, processed, refrigerated immediately, and transported in cold storage to the Central Testing Institute in Seoul, Korea. All blood samples were analyzed within 24 h after arrival at the testing facility. To measure serum zinc concentrations, trace element tubes were used, and levels were determined by inductively coupled plasma mass spectrometry (ICP-MS; ELAN DRC II, PerkinElmer, Waltham, MA, USA). Serum samples were diluted with 2% nitric acid, and zinc concentrations were determined from the linear relationship (r = 0.999) between the concentrations of a standard solution (1000 μg/mL; CLZN2-2 Y, SPEX CertiPrep, Metuchen, NJ, USA) and the absorbance. The accuracy of the analytical methods was assessed using standard reference materials (ClinChek Serum Controls, lyophilised for trace elements, RECIPE, Munich, Germany). The standard deviation index was 0.50, and the inter- and intra-assay coefficients of variation were 2% and 4%, respectively [21]. Serum zinc levels were categorized into tertiles: tertile 1 represented the lowest zinc levels, tertile 2 medium levels, and tertile 3 highest levels. The eGFR was estimated using the re-expressed "Modification of Diet in Renal Disease" study equation with calibrated serum creatinine values and the formula was: 175 × (serum creatinine concentration)$^{-1.154}$ × (age)$^{-0.203}$ for men, and the value was multiplied by a factor of 0.742 for women [22].

Other variables

Self-reported information regarding age, sex, smoking, alcohol consumption, and the amount of physical activity were obtained. Cigarette smoking was divided into three categories based on current use estimates: nonsmoker, ex-smoker, and current smoker. Alcohol consumption was classified into three categories: abstinence (no alcoholic drinks consumed within the previous year), moderate drinking (<14 standard drinks consumed for men or <7 for women per week), and heavy drinking (>14 standard drinks consumed for men or >7 standard drinks for women per week). Physical activity was assessed as the amount and intensity of physical activity per week, and classified as low, moderate, or high. Low physical activity was defined as ≤150 min of moderate intensity or ≤75 min of vigorous intensity exercise per week [23].

Dietary intake was assessed using single 24-h recall and was estimated from the food composition tables of the Rural Development Administration in combination with the nutrient database of the Korea Health and Industry of Development Institute [24,25]. The nutrition survey was conducted at participants' homes by trained dietitians, and additional tools such as food models, two-dimensional food volumes, and containers were used to help participants recall their nutrient intake. The estimated daily energy and fat intake data of the participants were used in this study.

Statistical analysis

We used the SAS PROC SURVEY module considering strata, clusters, and weights to analyze the data using a complex sampling design [26]. All analyses were performed using the sample weights from KNHANES. The characteristics of the study population were analyzed using analysis of variance for continuous variables and χ^2 tests for dichotomous variables. The data are expressed as means ± standard error or as percentages. The proportions of participants in zinc level tertile 3 according to body composition factors were analyzed using χ^2 tests. The differences in the mean zinc levels according to body composition factors were evaluated using analysis of covariance(ANCOVA). Model 1 was adjusted for age, and model 2 was adjusted for age, smoking, alcohol consumption, physical activity, body weight, total fat and energy intake per day, and eGFR levels as covariates. The associations between serum zinc levels and body composition factors were subjected to a multiple regression analysis. The differences in the mean serum zinc levels according to TBF tertiles and abdominal obesity were analyzed using (ANCOVA) after adjusting for the aforementioned covariates. All statistical analyses were performed using SAS software (ver. 9.2; SAS Institute, Cary, NC, USA). $P < 0.05$ was considered statistically significant.

Results

The present study was conducted using the data from 1896 participants (937 men and 959 women). Table 1 shows the characteristics of the study participants according to serum zinc level tertiles. In men, significant differences in age (45.2, 44.3, and 41.3 y; P = 0.010) and TBF (22.2%, 23.9%, and 23.4%; P = 0.009) were observed according to the tertiles of serum zinc, whereas no differences were seen in women. The proportions of participants with zinc levels in tertile 3 according to body composition factors are shown in Figures 1 and 2. This proportion was lower in men with abdominal obesity than in those without abdominal obesity (27.4% versus 36.1%; P = 0.046; Fig. 1B), and the proportion of men with zinc levels in tertile 3 increased, as the SMI tertiles increased (28.5%, 33.4%, and 39.2%; P_{trend} = 0.035; Fig. 1C). The proportion of participants with zinc levels in tertile 3 decreased as the TBF tertiles increased in both men (43.2%, 34%, and 23.4%; $P_{trend} < 0.001$; Fig. 1D) and women (43.6%, 32.5%, and 30.6%; P_{trend} = 0.031; Fig. 2D).

The mean serum zinc levels according to body composition factors are shown in Table 2. After adjusting for age, smoking, alcohol consumption, physical activity, body weight, total fat and energy intake per day, and eGFR levels, serum zinc levels in men with abdominal obesity were higher than in those without abdominal obesity (152.1 ± 3.7 μg/dL versus 137.8 ± 2.2 μg/dL; $P < 0.001$). Additionally, serum zinc levels increased as TBF tertiles increased (134.2 ± 2.8 μg/dL, 142 ± 2.9 μg/dL, and 148 ± 2.7 μg/dL; P = 0.001). However, in women, serum zinc levels did not differ according to body composition factors.