Association of Phosphorus and Magnesium with Fat Indices in Children with Metabolic Syndrome

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Abstract—Metabolic syndrome (MetS) is a disease associated with obesity. It is a complicated clinical problem possibly affecting body composition as well as macrominerals. These parameters gain further attention particularly in pediatric population. The aim of this study is to investigate the amount of discrete body composition fractions in groups that differ in the severity of obesity. Also, the possible associations with calcium (Ca), phosphorus (P), magnesium (Mg) will be examined. The study population was divided into four groups. 28, 29, 34 and 34 children were involved in Group 1 (healthy), Group 2 (obese), Group 3 (morbid obese) and Group 4 (MetS), respectively. Institutional Ethical Committee approved the study protocol. Informed consent forms were obtained from the parents of the participants. The classification of obese groups was performed based upon the recommendations of World Health Organization. MetS components were defined. Serum Ca, P, Mg concentrations were measured. Within the scope of body composition, fat mass, fat-free mass, protein mass, mineral mass were determined by body composition monitor using bioelectrical impedance analysis technology. Weight, height, waist circumference, hip circumference, head circumference and neck circumference values were recorded. Body mass index, diagnostic obesity notation model assessment index, fat mass index and fat-free mass index values were calculated. Data were statistically evaluated and interpreted. There was no statistically significant difference among the groups in terms of Ca and P concentrations. Magnesium concentrations differed between Group 1 and Group 4. Strong negative correlations were detected between P as well as Mg and fat mass index as well as diagnostic obesity notation model assessment index in Group 4, which comprised morbid obese children with MetS. This study emphasized unique associations of P and Mg minerals with diagnostic obesity notation model assessment index and fat mass index during the evaluation of morbid obese children with MetS. It was also concluded that diagnostic obesity notation model assessment index and fat mass index were more proper indices in comparison with body mass index and fat-free mass index for the purpose of defining body composition in children.

Keywords—Children, fat mass, fat-free mass, macrominerals, obesity.

I. INTRODUCTION

METS is an advanced obesity state characterized by the presence of at least two MetS components (1-elevated blood pressure, 2-elevated fasting blood glucose, 3-elevated triglyceride or reduced high density lipoprotein cholesterol) other than morbid obesity [1]. With elevations in the prevalence of obesity particularly during childhood, MetS prevalence also increases. Within this context, body composition of children is gaining importance [2]-[7]. Fat mass (FM), fat-free mass (FFM), protein mass (PM), mineral mass (MM) are the prominent components, which should be considered.

Macrominerals, particularly, calcium (Ca), phosphorus (P) and magnesium (Mg) are the elements closely related to body compartments. Calcium is the structural component of bone. It is also found in soft tissues as well as in extracellular fluid. Regulation of nerve transmission, muscle contraction, maintenance of blood pressure as well as acid-base balance in the blood, hormonal actions, blood clotting, cellular motility are among the other functions of Ca [8], [9].

Calcium is in close relation with P. Calcium, along with P is stored in bone in the form of a Ca phosphate salt called hydroxyapatite, $Ca_{10}(OH)_2(PO_4)_6$. Phospholipids are basic structural elements of cell membranes. Phosphorylated compounds participate in energy metabolism. Nucleic acids are long chains of phosphate-containing molecules. Some enzymes, hormones, and cell-signaling molecules depend on phosphorylation for their activation. Phosphorus also participates in acid-base balance by acting as one of the body's most important physiological buffers. A P-containing molecule 2,3-diphosphoglyceric acid binds to hemoglobin in red blood cells and regulates oxygen delivery to the tissues of the body [10], [11].

An excess of Ca and P attenuates the absorption of Mg, which regulates nerve transmission and muscle contraction, assists in hundreds of essential cellular reactions. Also, the important role of Mg in modulating transport functions and receptors, signal transduction, enzyme activities, energy metabolism, nucleic acid and protein synthesis, protecting biological membranes makes Mg deficiency a potential health hazard. The use of Mg supplementation is currently being explored in the management of various conditions, including cardiovascular diseases, and metabolic disorders such as MetS, diabetes mellitus [12]-[14].

The aim of this study is to evaluate possible associations between the fractions of body composition as well as fat indices and macrominerals in healthy, obese, morbid obese children and those with MetS.

II. PATIENTS AND METHODS

A. Patients

The study was conducted on children, who were admitted to Tekirdag Namik Kemal University, Faculty of Medicine, Department of Pediatrics Outpatient Clinic. Within the scope of

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this study, 28 children with normal-body mass index (N-BMI), 29 obese and 68 morbid obese children were evaluated. Of the morbid obese children, 34 were with MetS. Informed consent forms were obtained from the parents of each participant following a proper description concerning the aim of the study.

Children with genetic, endocrine, or syndromic causes of obesity as well as those using calcium supplements or drugs that could predispose to hypomagnesemia were excluded.

The study protocol was approved by the Tekirdag Namik Kemal University, Medical Faculty, Non-Interventional Ethics Committee.

B. Anthropometric Measurements

Body weight, height, waist circumference, hip circumference, head circumference and neck circumference of the study population were measured. Weights of children with light clothes and no shoes were measured to the nearest 0.1 kg using a weighing scale. Heights were measured to the nearest 0.5 cm while each participant was standing on a stadiometer without shoes. BMI values were calculated as weight divided by square of height (kg/m^2).

C. Obesity Classification

For children, age- and sex-adjusted BMI percentile tables prepared by World Health Organization were used to define those with N-BMI, obesity and morbid obesity [15]. Children with 15th-85th percentiles were grouped as Group 1 (N-BMI). Children, whose values were between 95th and 99th percentiles, were included in Group 2 (obese). Those, whose percentile values were above 99, were defined as morbid obese. Morbid obese children were divided into two groups, those without (Group 3) and with MetS (Group 4).

D. Definition of MetS Criteria

Morbid obese children were evaluated [1] for central obesity, blood pressure, fasting blood glucose, triglyceride, high density lipoprotein cholesterol (HDL-C) values. Children with systolic and diastolic blood pressure values higher than 130 mm. Hg and 85 mm. Hg, respectively, fasting blood glucose values above 100 mg/dl, triglyceride values higher than 150 mg/dl or HDL-C values lower than 40 mg/dl were evaluated. Those with at least two of the above criteria were included into Group 4.

E. Preparation of the Samples

Blood samples were collected after an overnight fasting. The serum samples were kept at -80 °C until the analyses were performed.

F. Technical Information and Laboratory Tests

Body FM, FFM, PM, MM values were registered with body composition monitor using bioelectrical impedance analysis technology (Body Composition Analyzer, Tanita Corp., Tokyo, Japan). Diagnostic obesity notation model assessment-II index (D2I), fat-mass index (FMI) as well as fat-free mass index (FFMI) values was calculated. The formulas used to calculate these indices were:
1. D2I = Fat mass (kg)*100/height (cm)
2. FMI = Fat mass (kg)/height (cm) squared
3. FFMI = FFM (kg)/height (cm) squared.

Biochemical parameters including Ca, P and Mg were determined by AutoAnalyzer.

G. Statistical Analysis

The analysis of the data was performed by SPSS software for Windows, version 16. Values were tabulated as mean ± standard deviation (SD). The differences between groups were evaluated by analysis of variance and post hoc Tukey tests at 0.05 level of significance. Bivariate Pearson's correlation analysis was used to estimate correlations between variables. Scatterplot analyses were performed. Graphics were plotted with a linear regression line.

III. RESULTS

Four groups of children were evaluated for BMI and anthropometric measurements. Values were given in Table I.

TABLE I
BMI VALUES AND ANTHROPOMETRIC MEASUREMENTS OF THE GROUPS
(MEAN ± SD)

Parameter		Group 1 N-BMI	Group 2 OB	Group 3 MO	Group 4 MetS
BMI	kg/m²	16.6 ± 2.2	25.0 ± 3.5	28.6 ± 5.6	31.0 ± 5.6
Waist C	cm	60.3 ± 8.3	83.1 ± 12.3	89.6 ± 15.9	95.0 ± 14.8
Hip C	cm	72.0 ± 12.5	95.6 ± 14.2	98.6 ± 16.6	105.8 ± 16.8
Head C	cm	51.8 ± 2.1	54.8 ± 2.1	54.9 ± 2.5	55.5 ± 2.7
Neck C	cm	27.3 ± 3.2	32.5 ± 2.9	34.2 ± 4.0	36.0 ± 4.2

[BMI, waist C, hip C, neck C 1-2 < 0.01, 1-3 < 0.01, 1-4 < 0.01, 2-3 < 0.01, 2-4 < 0.01, head C 1-2 < 0.01, 1-3 < 0.01, 1-4 < 0.01]

Group 3 and Group 4 did not differ in terms of BMI, waist C, hip C, head C and neck C ($p > 0.05$).

Serum Ca, P, and Mg concentrations measured for the groups were shown in Table II.

TABLE II
SERUM MACROMINERAL CONCENTRATIONS OF THE GROUPS (MEAN ± SD)

Parameter		Group 1 N-BMI	Group 2 OB	Group 3 MO	Group 4 MetS
Calcium	mg/dl	10.1 ± 0.4	9.9 ± 0.3	10.0 ± 0.4	10.0 ± 0.3
Phosphorus	mg/dl	4.8 ± 0.6	4.6 ± 0.6	4.8 ± 0.6	4.6 ± 0.8
Magnesium	mg/dl	2.16 ± 0.16	2.07 ± 0.14	2.12 ± 0.14	2.06 ± 0.14

[Calcium not significant, Phosphorus not significant, Magnesium 1-4 <0.05]

Calcium and P levels of groups did not differ from one another. Magnesium concentrations differed between Group 1 and Group 4 ($p = 0.013$).

Total body FM, FFM, MM, PM, FMI, FFMI and D2I values for groups were shown in Table III.

In all parameters, increasing tendency was observed with the increases in obesity degree.

Correlation analysis has shown that strong correlation existed between P concentrations and D2I (-0.639; 0.001), FMI (-0.596; 0.001) as well as FFMI (-0.462; 0.006) values in MetS group (Fig. 1).

In MetS group, another unique correlation, which did not exist in other groups, between Mg and D2I (-0.414; 0.015) as well as FMI (-0.408; 0.017) was observed (Fig. 2).

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TABLE III
FM, FFM, MM, PM, FAT MASS INDEX, FAT-FREE MASS INDEX AND
DIAGNOSTIC OBESITY NOTATION MODEL ASSESSMENT-II INDEX VALUES OF
THE GROUPS (MEAN ± SD)

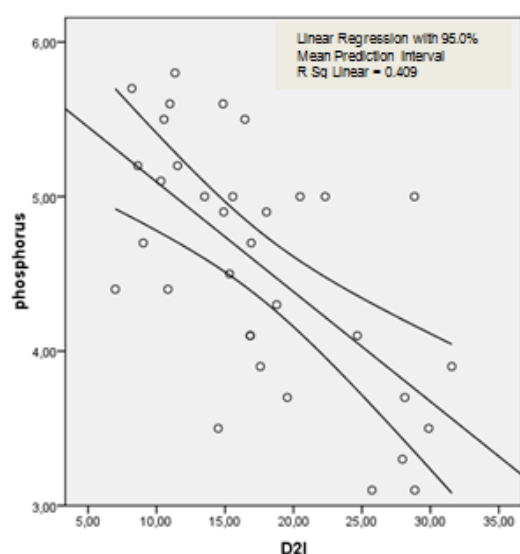| Parameter		N-BMI Group 1	OB Group 2	MO Group 3	MetS Group 4
Fat mass*	kg	5.9 ± 4.4	20.3 ± 8.7	23.0 ± 12.2	27.6 ± 12.5
FMI*	kg/m²	3.0 ± 1.3	8.3 ± 2.5	10.4 ± 3.8	11.3 ± 3.9
FFM *	kg	23.7 ± 10.1	40.0 ± 11.5	39.4 ± 15.6	45.7 ± 13.9
FFMI*	kg/m²	12.9 ± 1.6	16.6 ± 2.0	17.9 ± 2.8	19.1 ± 3.0
MM *	kg	1.23 ± 0.53	2.08 ± 0.60	2.05 ± 0.81	2.37 ± 0.72
PM *	kg	5.12 ± 2.18	8.61 ± 2.48	8.49 ± 3.36	9.86 ± 3.00
D2I	kg/m	4.2 ± 2.4	12.9 ± 4.7	15.4 ± 6.8	17.6 ± 7.0

Fig. 1 Linear regression line between phosphorus concentrations and
diagnostic obesity notation model assessment-II index values in
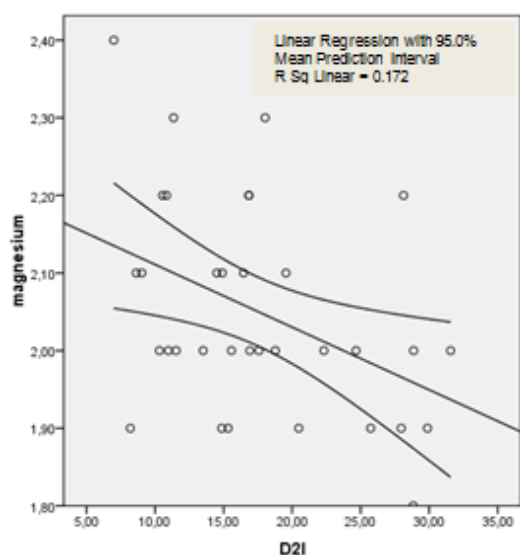morbid obese children with MetS

Fig. 2 Linear regression line between magnesium concentrations and
fat mass index values in morbid obese children with MetS

Negative correlations between P and D2I as well as FMI were found in MetS group. Magnesium was another metal, which exhibits negative correlations with D2I and FMI in the same group. These correlations were confined to children with MetS.

IV. DISCUSSION

This study considers the relations of FM, FFM, MM, PM and related indices (FMI, FFMI, D2I) with macrominerals in children with N-BMI, obesity and MetS.

In this study, FM, FMI, FFM, FFMI and D2I were characterized by increases according to obesity stages. These results were in accordance with the findings of the studies performed on preschool children in Thailand [7] and adolescents in Brazil [5].

Body composition is an issue of increasing interest because of increasing prevalence of obesity in children. FFM is also attracting interest due to the disease-creating potential of childhood obesity during adulthood [2].

BMI does not distinguish fat from lean. In a similar manner, percentage fat is also problematic as an index of fatness because it is affected by relative lean size [2]. Both fat and lean require independent adjustment for size, leading to discrete indices of relative FM and FFM deposition. Adjustment for size is particularly important in children [2]. Therefore, it is plausible to express data also in the form of FMI and FFMI.

Pediatric diseases are extraordinarily diverse. They may exhibit changes in relative fat and lean deposition. In disease states, patients may have either high or low FFM compared with healthy children. A categorization was proposed related to the matter. In some diseases such as anorexia (both FM and FFM are low) and obesity (both FM and FFM are elevated) they act together in the same direction. On the other hand, it is proposed that cancer is associated with low FM and high FFM. In chronic lung disease, high FM is observed with low FFM [2].

Obesity is defined as an excess of body fatness, but remains categorized on the basis of BMI [2]. Therefore, in this study, aside from BMI, we have also considered both FM and FFM fractions as well as FMI and FFMI.

Macrominerals are involved in many vital processes in the body, ranging from energy metabolism to nerve transmission. Calcium, P and Mg are closely related to one another. Therefore, possibly they may be subjected to variation in obesity.

In our study, Ca levels did not differ among the groups. This finding agrees with the results of the study reporting that Ca did not affect fat and lean masses [16].

Phosphorus status was inversely correlated with body weight. Phosphorus supplementation decreased body weight, BMI, waist circumference, which points out a promising role of P in the prevention and management of obesity [17], [18]. In a similar manner, an inverse correlation between P intake and BMI was observed [19]. Low P status may contribute to the development of obesity through its role in the regulation of food intake, thermogenesis and capacity for physical activity. In our study, P was found to be strongly correlated with D2I, FMI and FFMI in morbid obese children with MetS.

Lower serum Mg levels were found in the overweight and obese children compared to the normal weight group. Besides,

a significantly strong inverse relationship was seen between Mg levels and BMI [20]. Women with increased FM in the body composition have significantly lower Mg concentrations. Also, negative correlations were found between serum Mg concentrations and FM [21]. Another negative correlation was reported between Mg and BMI as well as FM in offspring of diabetic parents [22]. In another study, BMI correlated inversely with serum Mg levels in obese adult patients [23]. The results of our study performed on children are consistent with these findings.

V. CONCLUSION

In our study, although there was no difference between the groups, P was strongly correlated with BMI, D2I, FMI and FFMI. Significant correlations were detected also for Mg. These associations were confined to MetS group. The important point was that the strongest correlations were detected between P as well as Mg and D2I as well as FMI upon consideration of all indices. This finding emphasized the preponderance of D2I and FMI upon BMI.

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