Nutrition Research and Practice (*Nutr Res Pract*) 2013;7(2):139-145
http://dx.doi.org/10.4162/nrp.2013.7.2.139
pISSN 1976-1457 eISSN 2005-6168

Gender specific effect of major dietary patterns on the metabolic syndrome risk in Korean pre-pubertal children

Soo Jin Park[1*], Seung Min Lee[2*], Seon Mee Kim[3] and Myoungsook Lee[2§]
[1]*Department of Oriental Medical Food and Nutrition, Semyung University, Jecheon 390-711, Korea*
[2]*Department of Food and Nutrition, Sungshin Women's University, 147 Mia-dong, Gangbuk-gu, Seoul 142-732, Korea*
[3]*Department of Family Medicine, Korea University, Guro-Hospital, Seoul 136-705, Korea*

Abstract

There is a lack of data on metabolic risk factors during pre-puberty, which is important for identifying the subgroups of youth, at whom early interventions should be targeted. In this study, we evaluated the prevalence of metabolic risk factors and its subsequent relations with dietary patterns in Korean pre-pubertal children through a cross-sectional sample (n = 1,008; boys = 513) of pre-pubertal children (aged 8-9 years) from a sub-study of the Korea Metabolic Syndrome Research Initiatives (KMSRI) in Seoul, Korea. Measures of anthropometry and blood pressure as well as fasting blood samples were used in the analysis. A three-day food records were collected. The metabolic syndrome was defined according to the age-adjusted National Cholesterol Education Program Adult Treatment Panel III guidelines. An added metabolic risk score was calculated for each subject by summing the quintile values of the five individual risk factors. Among the 5 risk components of metabolic syndrome, high waist circumference (WC) was the major factor ($P < 0.001$). A significant increasing trend of the added metabolic syndrome risk score was observed with the increase of WC (P (trend) < 0.001) among both genders. The cutoff point for high WC for pre-pubertal children was 61.3 cm for boys and 59.9 cm for girls. The prevalence of high triglyceride (TG) values was significantly higher in girls than it was in boys ($P < 0.01$). Girls in the highest quintile of balanced dietary pattern scores had lower TG values (P (trend) = 0.032) than did those in the lowest quintile. Moreover, girls in the highest quintile of western dietary pattern scores showed increasing trend for the added metabolic risk score (P (trend) = 0.026) compared with those in the lowest quintile. Adverse associations exist between western dietary patterns and the accumulation of metabolic risks among girls, not in boys, even during pre-puberty.

Key Words: Metabolic syndrome, dietary pattern, pre-pubertal children, gender, waist circumference

Introduction

Metabolic syndrome is one of the most frustrating problems in Korean children because of the difficulties facing the clinical definition and prediction. Despite the confusion, an alarming prevalence of metabolic syndrome in Korean adolescents has been suggested; approximately 50% of boys and 40% of girls are obese [1]. A prospective assessment has revealed that metabolic syndrome occurring in the age group of 5-19 years predicts adult metabolic syndrome 25 to 30 years later [2]. These estimations are based on the same definition of adults in children, even though the classification of metabolic syndrome in children depends strongly on the chosen definition [3]. Little consensus has been reached to date in terms of the prerequisite risk factors, cutoff values for various criteria, gender and ethnic differences and the prevalence and clinical implications of pre-pubertal metabolic syndrome on obese children [3-5].

Diet is known to influence body weight and thus is recognized as a potent modifiable risk factor for metabolic syndrome [6,7]. Ecological studies, migration studies and analyses of secular trends suggest that the adoption of a western diet, such as energy-dense, low fiber, high fat, may be adversely associated with the incidence of metabolic syndrome, type 2 diabetes [8] or a higher fat mass [9]. Food grouping analysis revealed that the odds ratio for abdominal obesity in the western diet group was significantly higher than that in the traditional or modified group in the Korean adolescent population [10]. The risk of the dietary pattern shift on the development of metabolic syndrome in pre-puberty has not been previously evaluated.

The objectives of this study are to provide the understanding of metabolic syndrome risk factors at pre-pubescence as well as to evaluate the association between dietary patterns and metabolic risk factors in Korean boys and girls.

This work was supported by grants from National Research Foundation (NRF) (KRF-2008-314-C00422), a grant of the Seoul R & BD Program (10526) and Grant (11162KFDA154) from Korea Food & Drug Administration in Republic of Korea.
§ **Corresponding Author:** Myoungsook Lee, Tel. 82-2-920-7211, Fax. 82-2-920-2078, Email. mlee@sungshin.ac.kr
* These authors contributed equally to this work.
Received: August 15, 2012, Revised: March 13, 2013, Accepted: March 13, 2013

Subjects and Methods

Subjects and measures

Participants (n = 1,054) were a subgroup of the Korea Metabolic syndrome Research Initiatives (KMSRI)-Seoul Study cohort. They were recruited via information published in a school newsletter between April 20, 2007 and June 7, 2007. The study inclusion criteria were as follows: aged 8-9 y; pre-pubertal; and living in Guro-gu, a southwest district of Seoul. The 1,008 subjects chosen (96%)- comprised of 513 boys and 495 girls - completed a questionnaire survey and provided anthropometric and biochemical data.

All protocols and consent forms were approved by the institutional review board of the participating institution, and the participants provided consent following the recommendations by the attending physicians. Waist circumference (WC) was measured in duplicate at the level of the umbilicus using a non-elastic fiberglass measuring tape (Tech-Med model 4414; Moore Medical Corp., New Britain, CT). The ponderal index (PI) was calculated as weight in kilograms divided by the cube of height in centimeters multiplied by 100. The average blood pressure (BP) value was measured by a juvenile mercury sphygmomanometer read to the nearest 2 mmHg with the subjects in a recumbent position. For biochemistry, 12-hour fasting blood samples were obtained and measured for glucose, lipid profiles and biomarkers for liver damage. Fasting blood sugar (FBS) concentration was measured by a glucose oxidase method using the Vitros analyzer (Ortho Clinical Diagnostics, Rochester, NY). Serum triglycerides (TG) and high-density lipoprotein cholesterol (HDL-c), alanine aminotransferase (ALT), and aspartate aminotransferase (AST) were determined enzymatically using a chemistry analyzer (Hitachi 747, Tokyo, Japan). Atherosclerotic indices, such as total cholesterol (TC)/HDL and TG/HDL, were also calculated.

Dietary intake was assessed by a 3-day food records in a random sample of participants (n = 503) due to practical constraints in the data collection. Considering the participants' young age, a parent or a guardian was asked to co-work on food records with a child. A detailed written direction for food record administration using the semi-quantitative method was provided in advance. Dietary data was rechecked and corrected by a trained nutritionist. A total of 503 subjects' food record data were included in the dietary analysis, after excluding incomplete or unreliable records.

Definitions of metabolic syndrome

To generate a definition appropriate for Korean children aged 8-9 years, we used an age-adjusted National Cholesterol Education Program Adult Treatment Panel (NCEP ATP) III definition [11], i.e., a definition similar to that used in the KMSRI-adult with different cutoff values. We defined abdominal obesity using high WC (64.4 and 62.4 cm for boys and girls, respectively) and a $\geq 75^{th}$ percentile for age and gender based on the 2007 Korean children growth chart [12]. According to the recommendations of the Korea Center for Disease Control (KCDC), high FBS was defined as $\geq$ 100 mg/dl; high TG as fasting TG $\geq$ 110 mg/dl; and low HDL as fasting HDL-c $\leq$ 40 mg/dl [13]. High BP was defined as systolic or diastolic BP $\geq$ 90 percentile for age, gender and height quintile in our sample population due to the methodological difference from KCDC measurements. An added metabolic risk score was calculated for each subject by summing the quintile values of the five individual risk factors.

Statistical analysis

A clustering profile of metabolic syndrome components for each subject was generated in order to explore the major clustering profiles according to the number of metabolic risk factors. The chi-square test was employed to examine the effects of gender on categorical variables, and continuous variables were compared using the t-test. A generalized linear model was used to test the null hypothesis of no trend in the means of the added metabolic syndrome risk score across decile levels of the WC value. We categorized all the food items from the food record data into 24 food groups, according to nutritional composition, natural and conceptual similarity, and dietary habit representation. We, then, calculated the mean daily consumption amount of the 24 food groups for each subject. The principal component analysis was conducted based on the 24 food groups' consumption data in order to identify the major dietary patterns [14]. Orthogonal rotation (varimax method) was employed in order to derive the uncorrelated factors. The number of factors to retain was decided based on the criteria of Eigen value > 1.5 and the natural interpretability. We labeled each factor retained based on factor loadings with absolute values greater than 0.25. The trends in the mean of nutrient intakes across the quintiles of major dietary pattern scores were tested using a generalized linear model. Age, gender and energy intake were included in the model as covariates. Age- and energy intake-adjusted and gender-specific mean values of individual metabolic risk factors and the added risk score across the quintiles of major dietary pattern scores were also examined for a linear trend using a generalized linear model. For testing the trends in systolic blood pressure (SBP) and diastolic blood pressure (DBP), the term of height was also added into the model as a covariate. $P < 0.05$ was considered statistically significant. All analyses were conducted using the SAS software package (Version 9.1, SAS Inc., Cary, NC).

Results

The anthropometric and clinical characteristics of the study subjects are presented in Table 1. The mean age was 8.9 (± 0.3) years for both genders. Anthropometric values, including height, weight, WC and BMI, were all significantly higher in boys than in girls. However, the levels of TG, TC and LDL-c were significantly lower in boys; moreover, a significantly lower level of HDL-c among girls was detected. BP and FBS levels were not significantly different by gender.

The prevalence of individual components of metabolic syndrome in children was examined (data not shown). The order of these risk factors, according to the prevalence values, was identical between boys and girls, i.e., high WC (25.3% for boys and 23.4% for girls) was the most prevalent, followed by high BP (16.2% for boys and 18.4% for girls), high TG (11.7% for boys and 18.0% for girls), low HDL (3.1% for boys and 4.7% for girls) and high FBS (2.1% for boys and 1.2% for girls). The proportion of high TG values was significantly higher in girls than in boys ($P < 0.01$); yet, the prevalence of the other risk factors was similar between boys and girls.

The major profiles of the metabolic risk factor combination were shown in Fig. 1. We, here, defined the "major profile" as one with a proportion of 20% or more. Approximately 57% of the subjects had none of the five metabolic risk factors. The proportions of those with one, two, three and four or more risk factors were 27.7%, 11.0%, 3.1%, and 0.7%, respectively. Among those with two risk factors, the most prevalent combination was high WC with high BP (42.4%). The other major combination was high WC with high TG (31.5%). Among children with three metabolic risk factors, 46.9% had a combination of high WC, high BP and high TG. The other major combination in our study subjects was high WC, high TG and low HDL (37.5%). The gender-specific analysis did not reveal any significant gender effect in the major clustering profiles of metabolic syndrome risk factors.

Table 1. Anthropometric and clinical characteristics of study participants

Variable	Total (n = 1,008)	Boys (n = 513)	Girls (n = 495)	*P*-value[2)]
Age (yrs)	8.9 ± 0.3[1)]	8.9 ± 0.3	8.9 ± 0.3	0.457
Height (cm)	132.3 ± 5.4	132.6 ± 5.4	131.9 ± 5.3	0.023*
Weight (kg)	31.1 ± 7.0	32.1 ± 8.0	30.1 ± 5.5	< 0.001***
BMI (kg/m^2)	17.6 ± 2.7	18.0 ± 3.0	17.2 ± 2.3	< 0.001***
WC (cm)	59.2 ± 7.1	60.4 ± 7.5	58.1 ± 6.3	< 0.001***
PI (kg/m^3)	13.4 ± 2.0	13.6 ± 2.1	13.0 ± 1.6	< 0.001***
SBP (mmHg)	106.3 ± 13.6	106.8 ± 14.2	105.8 ± 13.1	0.254
DBP (mmHg)	67.9 ± 9.7	67.8 ± 10.3	68.0 ± 9.2	0.754
FBS (mmol/l)	4.6 ± 0.6	4.6 ± 0.7	4.6 ± 0.5	0.406
TG (mmol/l)	0.9 ± 0.5	0.8 ± 0.5	0.9 ± 0.5	< 0.001***
TC (mmol/l)	4.3 ± 0.7	4.3 ± 0.7	4.4 ± 0.7	0.014*
HDL-c (mmol/l)	1.4 ± 0.3	1.5 ± 0.3	1.4 ± 0.2	< 0.001***
LDL-c (mmol/l)	2.5 ± 0.6	2.5 ± 0.6	2.6 ± 0.6	0.004**
AST (U/l)	26.5 ± 6.0	27.1 ± 6.4	25.8 ± 5.6	< 0.001***
ALT (U/l)	24.5 ± 9.3	25.5 ± 10.0	23.3 ± 8.3	< 0.001***

ALT, alanine aminotransferase; AST, aspartate aminotransferase; BMI, body mass index; BP, blood pressure; FBS, fasting blood sugar; HDL-c, high-density lipoprotein cholesterol; LDL-c, low-density lipoprotein cholesterol; PI, ponderal index; TG, triglycerides; TC, total cholesterol; WC, waist circumference.
1) Mean ± SD.
2) *P*-values are for the difference between boys and girls.
* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

To explore the practical usage of WC as a simple screening tool for metabolic syndrome risk and its possible cutoff values for Korean pre-pubertal children, we plotted the mean values of the added risk score after excluding WC, according to WC deciles and gender (Fig. 2). For both genders, a significantly increasing trend of the added metabolic syndrome risk score was observed as WC levels increased (P for trend < 0.001). The observed patterns suggest that the 7th WC decile level (60.3-63.2 cm) for boys and the 5 to 6th decile level (56.0-59.0 cm) for girls may serve as useful screening cut-points for Korean pre-pubertal children with higher metabolic syndrome risk in the future. We also plotted high TG prevalence values by WC deciles and gender. The high TG prevalence significantly increased as WC levels increased in both boys (P for trend < 0.0001) and girls (P for trend < 0.001) (Data not shown). Interestingly, the relationship pattern between high TG prevalence and WC levels resembles that between the added risk score and the WC levels in this study.

Two major dietary patterns were identified by the factor analysis

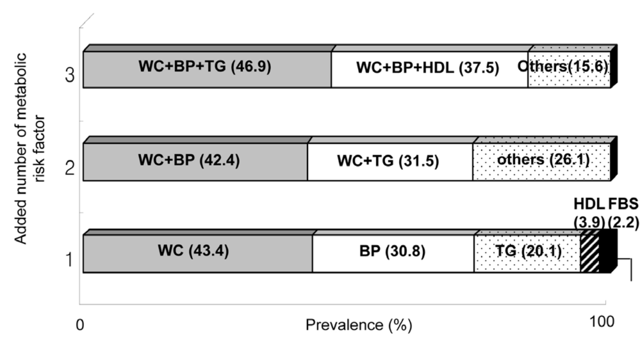

Fig. 1. The prevalence and major clustering profile of the metabolic risk factors in study participants. Metabolic components are defined as follows: high WC, waist circumference ≥ 75th percentile for age and gender, based on the 2007 Korean children and adolescent's growth chart; high BP, systolic or diastolic blood pressure ≥ 90th percentile for age, sex, and height quintile based on the study subjects' data; high FBS, fasting blood sugar ≥ 100 mg/dl; high TG, triglycerides ≥ 110 mg/dl; low HDL, HDL-c ≤ 40 mg/dl.

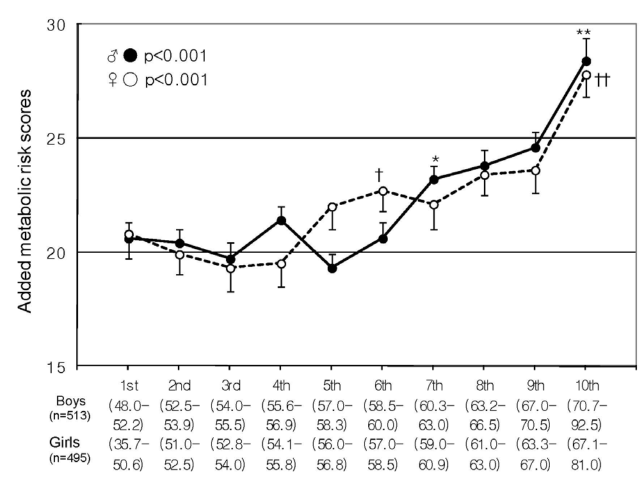

Fig. 2. Added metabolic risk scores according to WC deciles in study participants.

Table 2. Factor loading matrix for 2 major factors extracted, based on food consumption data from a 3-day food record

Food group	Factor 1 Balanced pattern	Factor 2 Western pattern
Other grains	0.35	-0.24
Potatoes	0.44	0.16
Vegetables	0.67	-0.03
Legumes	0.34	-0.13
Red meats	0.44	0.03
Seasonings	0.76	0.07
Plant oil	0.53	-0.22
Fruits	0.26	0.03
Fast foods	-0.29	0.03
Fish	0.27	-0.34
White rice	0.37	-0.47
Breads	0.04	0.32
Cereals	-0.04	0.26
Noodles	-0.02	0.41
Kimchi	0.16	-0.45
Seaweeds	0.24	-0.34
Poultry	0.17	0.32
Eggs	0.05	-0.31
Sweet snacks	0.02	0.37
Animal fat	0.20	0.49
Seafood	0.22	0.26
Rice cake	0.04	0.16
Processed meats & fish	0.20	0.15
Dairy products	0.05	-0.10

based on food consumption information from the 3-day 24-hour dietary record data (Table 2). The first factor was represented by a higher intake of white rice, other grains, vegetables, potatoes, legumes, red meat, seasoning, plant oil, fruits and fish and a lower intake of fast food. The second factor was characterized by a higher intake of bread, cereal, noodles, poultry, sweet snacks and animal fat and a lower intake of fish, white rice, kimchi, seaweed and eggs. We named the first factor "balanced pattern" and the second "western pattern".

Table 3 shows the mean intake values of the selected nutrients across the quintiles of balanced and western dietary pattern scores. Overall, adherence levels to both the balanced and western dietary patterns were associated with consumption profiles of various nutrients. As the balanced dietary pattern scores increased, intake of protein, dietary fiber and different micronutrients, including niacin, vitamin B_6, folate, vitamin C, vitamin A, vitamin E and zinc, significantly increased. The ratios of saturated fatty acids (SFA) to unsaturated fatty acids (UFA) and sodium to potassium significantly decreased as the pattern of the balanced diet scores increased. A generally opposite pattern was observed for the western dietary pattern. Significant decreases in the intake of protein, dietary fiber, riboflavin, folate, vitamin A, vitamin E, calcium and zinc were detected, as the western dietary pattern scores increased. The SFA to UFA ratio significantly increased across quintiles of the western dietary pattern scores.

Gender-specific mean values of individual metabolic syndrome risk factors and the added metabolic syndrome risk score are

Table 3. Nutrient intakes of participants by quintiles of 2 major dietary patterns

Nutrients	Level of balanced pattern			*P* for trend	Level of western pattern			*P* for trend
	Q1 (n = 101)	Q3 (n = 101)	Q5 (n = 101)		Q1 (n = 101)	Q3 (n = 101)	Q5 (n = 101)	
Energy (kcal)[1)]	1665 (22.8)[3)]	1682 (21.7)	1650 (23.0)	0.842	1670 (21.3)	1656 (21.5)	1673 (21.8)	0.763
Carbohydrate (g)[2)]	222.9 (4.0)	225.0 (3.9)	217.6 (4.1)	0.460	221.2 (3.8)	219.0 (3.8)	226.8 (3.9)	0.368
Protein (g)[2)]	66.4 (6.9)	69.9 (6.5)	85.5 (6.9)	0.049*	84.5 (6.4)	67.6 (6.5)	66.8 (6.6)	0.070
Lipid (g)[2)]	59.9 (1.4)	59.2 (1.3)	56.2 (1.4)	0.236	58.2 (1.3)	59.4 (1.3)	57.1 (1.3)	0.810
SFA:UFA[2)]	0.71 (0.016)	0.64 (0.016)	0.58 (0.016)	< 0.001***	0.59 (0.015)	0.64 (0.016)	0.69 (0.016)	< 0.001***
Dietary fiber (g)[2)]	13.2 (0.39)	15.0 (0.37)	18.1 (0.39)	< 0.001***	17.0 (0.37)	14.8 (0.38)	13.7 (0.38)	< 0.001***
Thiamin (mg)[2)]	1.18 (0.032)	1.14 (0.031)	1.29 (0.032)	0.200	1.16 (0.030)	1.14 (0.030)	1.21 (0.031)	0.187
Riboflavin (mg)[2)]	1.27 (0.033)	1.29 (0.031)	1.31 (0.033)	0.288	1.36 (0.030)	1.26 (0.030)	1.18 (0.030)	< 0.001***
Niacin (mg)[2)]	13.0 (0.40)	14.3 (0.38)	16.5 (0.40)	< 0.001***	14.3 (0.39)	13.9 (0.39)	16.2 (0.40)	< 0.001***
Vitamin B_6 (mg)[2)]	1.49 (0.041)	1.71 (0.039)	2.07 (0.041)	< 0.001***	1.69 (0.042)	1.66 (0.042)	1.86 (0.043)	0.010*
Folate (μg)[2)]	206.4 (9.2)	245.8 (8.7)	305.1 (9.2)	< 0.001***	296.5 (8.4)	230.0 (8.5)	215.2 (8.6)	< 0.001***
Vitamin C (mg)[2)]	65.6 (4.2)	81.1 (4.0)	107.2 (4.3)	< 0.001***	86.6 (4.2)	84.9 (4.2)	79.3 (4.3)	0.195
Vitamin A (μg RE)[2)]	693.9 (35.0)	841.5 (33.3)	1091.2 (35.3)	< 0.001***	946.6 (33.9)	854.9 (34.3)	793.0 (34.7)	< 0.001***
Vitamin E (mg)[2)]	12.9 (0.50)	15.4 (0.48)	18.0 (0.51)	< 0.001***	16.9 (0.48)	15.1 (0.49)	13.3 (0.50)	< 0.001***
Calcium (mg)[2)]	558.4 (18.5)	597.4 (17.6)	578.7 (18.6)	0.217	616.2 (16.7)	569.6 (16.9)	498.6 (17.1)	< 0.001***
Iron (mg)[2)]	13.1 (1.49)	12.7 (1.42)	13.9 (1.51)	0.615	12.6 (1.39)	12.7 (1.41)	14.6 (1.43)	0.323
Zinc (mg)[2)]	7.22 (0.17)	8.13 (0.16)	8.39 (0.17)	< 0.001***	8.16 (0.16)	7.67 (0.16)	7.76 (0.16)	0.021*
Sodium / Potassium[2)]	1.60 (0.032)	1.47 (0.030)	1.40 (0.032)	< 0.001***	1.55 (0.031)	1.51 (0.031)	1.41 (0.031)	0.002**
Cholesterol (mg)[2)]	311.7 (12.0)	317.2 (11.4)	329.3 (12.1)	0.414	337.4 (11.0)	326.9 (11.1)	278.9 (11.2)	< 0.001***

SFA, saturated fatty acids; UFA, unsaturated fatty acids.
[1)] Adjusted for age and gender.
[2)] Adjusted for age, gender, and energy intake.
[3)] Mean ± SE.
* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

Table 4. Individual metabolic risk factors and added risk score by quintiles of 2 major dietary patterns

Risk factors of metabolic syndrome	Level of balanced pattern			P for trend	Level of western pattern			P for trend
	Q1 (n = 38)	Q3 (n = 54)	Q5 (n = 56)		Q1 (n = 54)	Q3 (n = 44)	Q5 (n = 53)	
Boys (n = 251)								
WC (cm)1)	63.2 (1.34)3)	62.0 (1.06)	60.8 (1.11)	0.196	62.2 (1.05)	62.3 (1.18)	62.4 (1.08)	0.921
TG (mg/dl)1)	90.2 (7.15)	72.7 (5.85)	67.9 (6.19)	0.108	69.2 (5.82)	79.3 (6.50)	76.9 (6.22)	0.831
FBS (mg/dl)1)	81.0 (2.96)	82.2 (2.42)	82.6 (2.42)	0.674	79.8 (2.38)	81.8 (2.66)	85.7 (2.55)	0.185
HDL (mg/dl)1)	56.5 (1.72)	56.0 (1.41)	57.0 (1.49)	0.718	55.9 (1.40)	56.7 (1.56)	55.4 (1.49)	0.808
SBP (mmHg)2)	106.5 (2.52)	109.6 (2.03)	107.2 (2.12)	0.549	107.6 (2.03)	106.0 (2.24)	107.7 (2.06)	0.747
DBP (mmHg)2)	68.6 (1.79)	68.7 (1.44)	68.4 (1.51)	0.655	68.7 (1.44)	69.3 (1.59)	68.5 (1.46)	0.676
Added risk scores1)	28.6 (1.51)	28.0 (1.19)	26.4 (1.26)	0.341	27.6 (1.22)	28.4 (1.38)	27.2 (1.49)	0.490
Girls (n = 252)	Q1 (n = 63)	Q3 (n = 47)	Q5 (n = 45)		Q1 (n = 47)	Q3 (n = 57)	Q5 (n = 48)	
WC (cm)1)	59.2 (0.90)	59.7 (0.99)	58.8 (1.09)	0.559	58.7 (0.97)	58.8 (0.89)	60.7 (0.99)	0.088
TG (mg/dl)1)	92.3 (6.68)	84.0 (7.63)	72.6 (8.27)	0.032*	73.1 (7.44)	80.2 (6.67)	88.7 (7.62)	0.074
FBS (mg/dl)1)	83.5 (1.71)	80.5 (1.79)	82.7 (2.11)	0.641	80.8 (1.90)	81.5 (1.71)	83.9 (1.95)	0.347
HDL (mg/dl)1)	54.5 (1.26)	53.9 (1.44)	52.9 (1.56)	0.888	55.9 (1.40)	56.3 (1.26)	53.0 (1.43)	0.103
SBP (mmHg)2)	105.0 (1.78)	107.4 (1.93)	106.4 (2.12)	0.773	105.8 (1.95)	108.4 (1.77)	106.7(1.95)	0.857
DBP (mmHg)2)	67.7 (1.32)	69.9 (1.42)	67.3 (1.56)	0.631	68.0 (1.43)	70.2 (1.30)	67.8 (1.43)	0.536
Added risk scores1)	27.2 (1.19)	28.0 (1.33)	28.9 (1.26)	0.605	25.2 (1.35)	26.8 (1.21)	29.5 (1.37)	0.026*

WC, waist circumference; TG, triglycerides; FBS, fasting blood sugar; HDL, high-density lipoprotein; BP, blood pressure.
1) Adjusted for age and energy intake.
2) Adjusted for age, energy intake, and height.
3) Mean ± SE.
* $P < 0.05$

presented across quintiles of the dietary pattern scores (Table 4). In boys, none of the metabolic syndrome risk factors as well as the added risk score were significantly associated with both dietary pattern scores. However, the mean TG values significantly decreased as the balanced dietary pattern scores increased among girls (P for trend = 0.032). The mean values of WC (P for trend = 0.088) and TG (P for trend = 0.074) tended to increase across quintiles of the western dietary pattern scores. In addition, a significant increasing trend was observed for the added MS risk score across the quintiles of the western dietary pattern scores (P for trend = 0.026).

Discussion

The present results, that girls had higher TG, TC and LDL-c values, but lower HDL-c values, despite lower BMI and WC values than those of boys, were similar to the results obtained by Ong *et al.* [15]. With the increasing BMI, girls showed steeper declines in HDL-c and a steeper increase in TG levels compared to those in boys. Reciprocally, earlier maturation in boys is associated with lower adiposity. Previous studies indicated that the negative associations between adiponectin levels and BMI, WC, central fat and insulin levels were gradually stronger in subjects over the age of 15 [15,16]. We observed that the clustered components of metabolic risk were exactly identical in both genders between the ages 8 and 9. This indicates that gender differences in the risk factors for metabolic syndrome or obesity may differ according to pubertal stages [17].

Within the same age group of 8-9 years, the BMI values in our subjects (18.0, boys; 17.2, girls) were lower than those in Australian children (24.4, boys; 24.1, girls) [18], but similar to those in Chinese children (18.3, boys; 18.2, girls) [19]. It is thus necessary to consider racial and ethnic differences when we diagnose metabolic syndrome in children, as depicted in the studies of adolescents and adults [20,21].

Many studies have shown that WC seems to be the best predictor for children metabolic syndrome in the clinical setting [19-22]. In the present study, the prevalence of metabolic syndrome in children was 3.9% (3.5%, girls; 4.2%, boys) when high WC was determined as > 75^{th} percentile. However, it declined to 2.4% (2.2%, girls; 2.5%, boys) when high WC was determined as > 90^{th} percentile (data not shown). Golley *et al.* [3] reported that the prevalence of metabolic syndrome was 0-4%, as estimated by the adult definition; however, it was increased by 39-59% when specific cutoff values of metabolic syndrome indicators for children were used. Since the prevalence of childhood metabolic syndrome depends strongly on the definition chosen, the clustering patterns of the risk factors are very important in understanding the development of adult metabolic syndrome.

High WC was the most practical and effective single factor, with 50% prevalence in pre-pubertal Korean children. It was even more predictable for the diagnosis of metabolic syndrome when high WC was clustered with high BP or high TG while WC and TG differed according to gender. Similar to the data between the added risk score and the WC levels, WC values might be characterized in terms of WC risk threshold points clustered with 3 risk factors, such as high TG, high BP and low HDL (Data not shown). The Korean WC cutoff values for pre-pubertal children were almost identical to those of the Chinese (61.3 cm for boys and 59.9 cm for girls) [19]. WC values between the 6th and the 7th decile (60.3-63.0 cm, boys; 59.0-60.9 cm, girls) can be suggested as the border-line for the risk of metabolic syndrome.

Upon multi-factorial involvement of diet in the development of metabolic syndrome, previous study collectively suggested that certain dietary patterns can be predictive of individual metabolic risk factors mostly among adult populations [9,23-25]. The current study contributed to a rather scarce body of literature on such a relation in the pre-pubertal children population. Two distinguished dietary patterns from this study have a thread of connection with the previously identified major dietary patterns among Korean populations of other age groups [26-30]. Interestingly, the gender-specific effect of major dietary patterns on metabolic syndrome risk factors was observed. While both balanced and western dietary patterns did not reveal any significant effects on all of the risk factors in boys, the dietary patterns were related with metabolic risk primarily through mobilizing TG levels. Girls with a balanced dietary pattern tended to have lower TG values. Furthermore, girls with a western dietary pattern had an increasing trend for the added metabolic risk score.

This study has certain limitations, including a cross-sectional sample population from one district of a city within a narrow age range, limiting the effect of age-related differences. It is probable that a known nature of intra-individual variability in diet was not fully overcome by a 3-day food record, which provided the basis of the dietary pattern analysis. This limitation appears to be partly responsible for the rather low variances explained by the identified dietary patterns. Another limitation is that food record data were collected only from half of the participants due to practical constraints. Meanwhile, the strengths of this study include its recent data for scientific evidence regarding clustered metabolic risk factors in children. Future study will present whether this clustered pattern with WC risk factor changes or continues as a predictable marker for metabolic syndrome in a 3-year cohort study.

Conclusively, this study emphasizes the central role of WC in the definition of Korean pre-pubertal metabolic syndrome as well as that of BP and TG in both genders. Moreover, dietary contribution may differ by gender even during early pre-pubertal stage.

References

1. Kim HM, Park J, Kim HS, Kim DH. Prevalence of the metabolic syndrome in Korean adolescents aged 12-19 years from the Korean National Health and Nutrition Examination Survey 1998 and 2001. Diabetes Res Clin Pract 2007;75:111-4.
2. Morrison JA, Friedman LA, Wang P, Glueck CJ. Metabolic syndrome in childhood predicts adult metabolic syndrome and type 2 diabetes mellitus 25 to 30 years later. J Pediatr 2008;152: 201-6.
3. Golley RK, Magarey AM, Steinbeck KS, Baur LA, Daniels LA. Comparison of metabolic syndrome prevalence using six different definitions in overweight pre-pubertal children enrolled in a weight management study. Int J Obes (Lond) 2006;30:853-60.
4. Misra A, Khurana L, Vikram NK, Goel A, Wasir JS. Metabolic syndrome in children: current issues and South Asian perspective. Nutrition 2007;23:895-910.
5. Rolland-Cachera MF, Péneau S, Bellisle F. Metabolic syndrome definition in children: a focus on the different stages of growth. Int J Obes (Lond) 2007;31:1760.
6. Panagiotakos DB, Pitsavos C, Skoumas Y, Stefanadis C. The association between food patterns and the metabolic syndrome using principal components analysis: The ATTICA Study. J Am Diet Assoc 2007;107:979-87.
7. Lutsey PL, Steffen LM, Stevens J. Dietary intake and the development of the metabolic syndrome: the Atherosclerosis Risk in Communities study. Circulation 2008;117:754-61.
8. van Dam RM, Rimm EB, Willett WC, Stampfer MJ, Hu FB. Dietary patterns and risk for type 2 diabetes mellitus in U.S. men. Ann Intern Med 2002;136:201-9.
9. Berg CM, Lappas G, Strandhagen E, Wolk A, Torén K, Rosengren A, Aires N, Thelle DS, Lissner L. Food patterns and cardiovascular disease risk factors: the Swedish INTERGENE research program. Am J Clin Nutr 2008;88:289-97.
10. Kim JA, Kim SM, Lee JS, Oh HJ, Han JH, Song Y, Joung H, Park HS. Dietary patterns and the metabolic syndrome in Korean adolescents: 2001 Korean National Health and Nutrition Survey. Diabetes Care 2007;30:1904-5.
11. National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III) final report. Circulation 2002;106:3143-421.
12. Savva SC, Tornaritis M, Savva ME, Kourides Y, Panagi A, Silikiotou N, Georgiou C, Kafatos A. Waist circumference and waist-to-height ratio are better predictors of cardiovascular disease risk factors in children than body mass index. Int J Obes Relat Metab Disord 2000;24:1453-8.
13. Korea Centers for Disease Control. Korea Centers for Disease Control and Committee on Children and Adolescent Growth Chart, Children and Adolescent Growth Chart Report. Seoul: Seoul Press; 2007. p.4-65.
14. Hu FB, Rimm EB, Stampfer MJ, Ascherio A, Spiegelman D, Willett WC. Prospective study of major dietary patterns and risk of coronary heart disease in men. Am J Clin Nutr 2000;72: 912-21.
15. Ong KK, Frystyk J, Flyvbjerg A, Petry CJ, Ness A, Dunger DB. Sex-discordant associations with adiponectin levels and lipid profiles in children. Diabetes 2006;55:1337-41.
16. Tsou PL, Jiang YD, Chang CC, Wei JN, Sung FC, Lin CC, Chiang CC, Tai TY, Chuang LM. Sex-related differences between adiponectin and insulin resistance in schoolchildren. Diabetes Care 2004;27:308-13.
17. Sartorio A, Agosti F, De Col A, Mornati D, Francescato MP, Lazzer S. Prevalence of the metabolic syndrome in Caucasian obese children and adolescents: comparison between three different definition criteria. Diabetes Res Clin Pract 2007;77:341-2.

18. Olds TS, Tomkinson GR, Ferrar KE, Maher CA. Trends in the prevalence of childhood overweight and obesity in Australia between 1985 and 2008. Int J Obes (Lond) 2010;34:57-66.
19. Sung RY, Yu CC, Choi KC, McManus A, Li AM, Xu SL, Chan D, Lo AF, Chan JC, Fok TF. Waist circumference and body mass index in Chinese children: cutoff values for predicting cardiovascular risk factors. Int J Obes (Lond) 2007;31:550-8.
20. Morimoto A, Nishimura R, Kanda A, Sano H, Matsudaira T, Miyashita Y, Shirasawa T, Takahashi E, Kawaguchi T, Tajima N. Waist circumference estimation from BMI in Japanese children. Diabetes Res Clin Pract 2007;75:96-8.
21. Moreno LA, Pineda I, Rodríguez G, Fleta J, Sarría A, Bueno M. Waist circumference for the screening of the metabolic syndrome in children. Acta Paediatr 2002;91:1307-12.
22. Saland JM. Update on the metabolic syndrome in children. Curr Opin Pediatr 2007;19:183-91.
23. Baxter AJ, Coyne T, McClintock C. Dietary patterns and metabolic syndrome--a review of epidemiologic evidence. Asia Pac J Clin Nutr 2006;15:134-42.
24. Esmaillzadeh A, Kimiagar M, Mehrabi Y, Azadbakht L, Hu FB, Willett WC. Dietary patterns, insulin resistance, and prevalence of the metabolic syndrome in women. Am J Clin Nutr 2007;85:910-8.
25. Sonnenberg L, Pencina M, Kimokoti R, Quatromoni P, Nam BH, D'Agostino R, Meigs JB, Ordovas J, Cobain M, Millen B. Dietary patterns and the metabolic syndrome in obese and non-obese Framingham women. Obes Res 2005;13:153-62.
26. Yoo SY, Song YJ, Joung H, Paik HY. Dietary assessment using dietary pattern analysis of middle school students in Seoul. Korean J Nutr 2004;37:373-84.
27. Song YJ, Joung HJ, Paik HY. Socioeconomic, nutrient, and health risk factors associated with dietary patterns in adult populations from 2001 Korean National Health and Nutrition Survey. Korean J Nutr 2005;38:219-25.
28. Song YJ, Paik HY, Yu CH. Factors affecting bone mineral density by dietary pattern group for some Korean college women. Korean J Nutr 2006;39:460-6.
29. Ahn Y, Park YJ, Park SJ, Min H, Kwak HK, Oh KS, Park C. Dietary patterns and prevalence odds ratio in middle-aged adults of rural and mid-size city in Korean Genome Epidemiology Study. Korean J Nutr 2007;40:259-69.
30. Park SJ, Ahn Y, Kim HM, Joo SE, Oh KS, Park C. The association of dietary patterns with bone mineral density in middle-aged women: a cohort of Korean Genome Epidemiology Study. Korean J Community Nutr 2007;12:352-60.