Original Article

Factors Related to Body Mass Index and Body Mass Index Change in Korean Children: Preliminary Results from the Obesity and Metabolic Disorders Cohort in Childhood

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Background: This preliminary study is to assess risk factors associated with children's body mass index (BMI) and their changes over a 2-year period based on the analysis of the Obesity and Metabolic Disorders Cohort in Childhood registry.

Methods: A total of 1,504 children comprised of 474 1st graders and 1,030 4th graders were included in the study. Data on physical activity, dietary intake, and socioeconomic status were obtained through self-administered questionnaires, and height and weight were measured annually for 2 years.

Results: In a cross-sectional analysis, BMI of 1st graders was associated with higher parental BMI (both $P < 0.001$) and frequent snack consumption ($P = 0.049$). BMI of 4th graders was additionally associated with shorter sleep duration ($P = 0.001$), lower household income ($P = 0.016$), higher fat intake ($P = 0.017$), and frequent meal skipping ($P = 0.020$). During a 2-year follow-up, BMI increased by 0.8 ± 1.4 kg/m^2 in 1st graders and by 1.3 ± 1.4 kg/m^2 in 4th graders. In a longitudinal analysis, higher exercise frequency ($P = 0.007$), shorter sleep duration ($P = 0.027$), lower household income ($P = 0.002$), and higher paternal BMI ($P = 0.002, 0.043$) were significant predictors of BMI changes in the 1st graders whereas only higher maternal BMI ($P=0.035$), and frequent snack consumption ($P = 0.010$) were predictors for the 4th graders BMI changes.

Conclusion: Our findings indicate that parental obesity, short sleep duration, low socioeconomic status, and frequent snacking are associated with BMI and BMI changes.

Keywords: Body Mass Index; Child; Motor Activity; Diet; Environment

INTRODUCTION

The prevalence of obesity has increased at an alarming rate not only in adults but also in Korean children.[1)] Korea is not an exception, with the proportion of obese children increasing from 5.8% in 1997 to 9.7% in 2005.[2)]

There is now an emerging body of evidence that childhood obesity often persists into adulthood,[3)] underscoring the importance of management, prevention, and treatment of childhood obesity. A higher success rate of obesity treatment

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for children vs. adults and the possibility of long lasting lifestyle modification in children make early intervention aiming at modifying risk factors a top priority.[4]

For these reasons, many longitudinal studies have been conducted overseas to investigate the risk factors for childhood obesity,[5-7] and there are active discussions on effective interventions for confirmed risk factors.[8,9] The awareness of the significance of childhood obesity has risen gradually in Korea as well, with many studies being conducted. However, most of the studies are cross-sectional in nature,[10,11] and more longitudinal studies are needed as cross-sectional studies have limitations in clearly identifying causal and temporal relationships.

In this preliminary study, we show the factors that are associated with children's body mass index (BMI) and its changes over a 2-year period, analyzing the Obesity and Metabolic Disorders Cohort in Childhood registry.

METHODS

1. The Obesity and Metabolic Disorders Cohort in Childhood and Study Participants

The Obesity and Metabolic Disorders Cohort in Childhood is a prospective dynamic cohort study that performs annual follow-ups aimed at determining the prevalence, causes, prevention, and management of childhood obesity. At baseline in 2005, the cohort included all 1st graders of 4 elementary schools in Gwacheon city, a suburb city of Seoul. In 2008, in the 4th year follow-up, 1st and 4th graders from 2 elementary schools in Jung-gu, downtown Seoul, and 5 elementary schools in Gyeonggi province were added to the cohort. Annual physical examinations including anthropometry, blood chemistry, and questionnaires on lifestyle habits including diet were administered (Figure 1). This study was approved by the institutional review board of Inje University Seoul Paik Hospital. A detailed description on this cohort is given elsewhere.[12]

An analytic sample included in total 1,504 children who participated in both of the 4th (2008) and 6th (2010) annual follow-ups. Baseline characteristics including age, height, weight, BMI, and household income were not significantly different between participants in our analytic sample who underwent both of the 4th and 6th follow-ups and participants who underwent only the 4th follow-up. However, there were more girls (62.3%) who were followed up on compared to boys (56.0%) in 4th

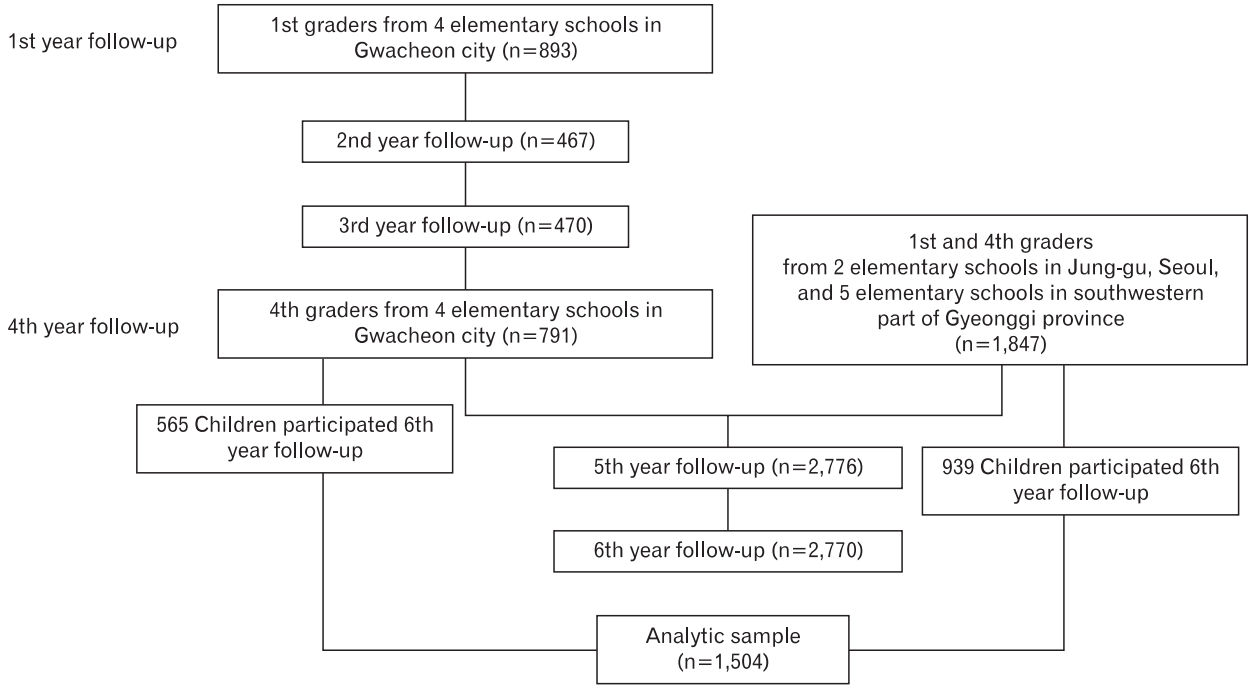

Figure 1. The flow chart of the Obesity and Metabolic Disorders Cohort in Childhood. This study included in total 1,504 children who participated in both of the 4th (2008) and 6th (2010) annual follow-ups.

graders (P = 0.007).

2. Anthropometric Measurement and Obesity Definition

Height and weight of the participants were measured by trained researchers using a manual height scale (DS-102; Jenix, Seoul, Korea) and bioelectrical body composition analyzer (BC-418; Tanita Co., Tokyo, Japan). BMI was calculated by weight (kg) divided by height, squared (m^2). The BMI percentile was estimated based on the age and sex-specific 2007 growth chart for Korean children.[13] Pubertal stages were assessed by the Tanner stages. Children and their parents were asked to select the pubertal rating that best indicated his or her own development by self-assessment.

3. Physical Activity Measurement

Data on physical activity were obtained through self-administered questionnaires. Children and their parents were asked to fill out the questionnaires together. Exercise frequency per week was calculated by summing up days with moderate physical activity of more than 30-minute duration or vigorous physical activity of more than 20-minute duration. Moderate physical activity was defined as activity that increased respiratory rate noticeably, while vigorous physical activity was defined as activity associated with shortness of breath or increased perspiration. Sleep duration was calculated as the mean of reported sleep time per day over one week. Screen time was defined as duration spent watching television plus using the computer per day.

4. Socioeconomic Factors and Parental Factors

The mean monthly household income was ascertained through a questionnaire. Education level of parents was categorized into three groups: equal or less than 12 years of schooling, between 13 to 16 years of schooling, and equal or more than 17 years of schooling. Data on family structure and maternal job status were collected as well. Parental BMI was calculated by their reported weight and height and was then classified as normal (< 23 kg/m^2), overweight (more than 23 kg/m^2 and under 25 kg/m^2), or obese (≥ 25 kg/m^2), according to the standards of the Korean Society for the Study of Obesity.

Table 1. Baseline characteristics of study participants.

Variables	1st grade (n = 474)	4th grade (n = 1,030)
Sex (male)	226 (47.7)	508 (49.3)
Age (y)	7.3 ± 0.3	10.0 ± 0.4
BMI (kg/m^2)	16.0 ± 2.3	18.1 ± 3.0
BMI percentile		
≤ 10.0	43 (9.1)	35 (3.5)
10.1–84.9	374 (78.9)	816 (79.2)
85–94.9	36 (7.6)	110 (10.6)
≥ 95.0	21 (4.4)	69 (6.7)
Exercise (frequency/wk)		
≤ 1	128 (27.0)	321 (31.2)
2–4	266 (56.1)	576 (55.9)
≥ 5	80 (16.9)	133 (12.9)
Screen time (h/d)	1.4 ± 0.8	1.6 ± 1.0
Sleep hour (h/d)	9.0 ± 0.6	8.7 ± 0.7
Household income > 3 million KRW	372 (78.5)	641 (62.2)
Maternal BMI (kg/m^2)	21.3 ± 2.4	21.7 ± 2.5
< 23	384 (81.0)	781 (75.8)
23–24.9	55 (11.6)	155 (15.0)
≥ 25	35 (7.4)	94 (9.1)
Paternal BMI (kg/m^2)	23.7 ± 2.7	23.8 ± 2.5
< 23	173 (36.5)	380 (36.9)
23–24.9	171 (36.1)	382 (37.1)
≥ 25	130 (27.4)	268 (26.0)
Maternal education (y)		
≤ 12	152 (32.1)	363 (35.2)
13–16	300 (63.3)	602 (58.4)
≥ 17	22 (4.6)	65 (6.3)
Paternal education (y)		
≤ 12	96 (20.3)	265 (25.7)
13–16	323 (68.1)	605 (58.7)
≥ 17	55 (11.6)	160 (15.5)
Working mother	177 (37.3)	441 (42.8)
Family structure, two parents	450 (94.9)	883 (85.7)
Total energy intake (1,000 kcal/d)	1.8 ± 0.3	1.7 ± 0.4
Fat % of energy intake (%)	26.6 ± 4.9	25.2 ± 5.1
Meal skipping during a week	131 (27.6)	287 (27.9)
Snack intake	110 (23.2)	232 (22.5)

Values are presented as number (%) or mean ± SD.
BMI: body mass index, KRW: Korean won.

5. Dietary Habit, Dietary Intake Survey

The frequency of skipping meals and snack intake was reported. Dietary intake was recorded for two weekdays and one day on the weekend by a 24-hour recall method. This information was then converted into nutrient intake by computer aided nutrients analysis program 2006 (CAN-Pro 3.0; Korean Nutrition Society, Seoul, Korea) from the Korean Nutrition Society.

6. Statistical Analysis

A stratified analysis was conducted for 1st graders and 4th graders separately. Continuous variables were expressed as mean and standard deviation and categorical variables were presented as numbers and percentages. The ANOVA test and t-test were used for comparisons of demographic characteristics.

We analyzed data both cross-sectionally and longitudinally. Multiple linear regression modeling was used to estimate coefficients and confidential interval (CI). Predictor variables for the models were environmental factors, parental and lifestyle habits, whereas dependent variables were BMI in the 4th annual follow-up survey for the cross-sectional analysis, and the BMI changes between 4th and 6th year follow-ups for longitudinal analysis. We additionally adjusted the BMI in the 4th survey only for longitudinal analysis. The estimated BMI changes by parental obesity degree were calculated using general linear modeling. All statistical analyses were performed with SPSS ver. 18 (SPSS Inc., Chicago, IL, USA) and values with $P < 0.05$ were considered statistically significant.

Table 2. Anthropometric change during a 2-year follow-up period.

Mean ± SD	1st grade (n = 474)	4th grade (n = 1,030)
Weight (kg)		
Baseline	25.0 ± 4.7	35.6 ± 7.8
Follow-up	30.0 ± 5.9	44.7 ± 9.2
Change	4.9 ± 2.8	9.1 ± 3.7
Height (cm)		
Baseline	124.8 ± 5.0	139.7 ± 6.2
Follow-up	133.2 ± 5.4	151.3 ± 6.6
Change	8.4 ± 1.7	11.6 ± 2.9
BMI (kg/m^2)		
Baseline	16.0 ± 2.3	18.1 ± 3.0
Follow-up	16.8 ± 2.5	19.4 ± 3.2
Change	0.8 ± 1.4	1.3 ± 1.4
BMI percentile		
Baseline		
≤ 10.0	43 (9.1)	42 (8.8)
10.1–84.9	374 (78.9)	380 (80.2)
85.0–94.9	36 (7.6)	29 (6.1)
≥ 95.0	21 (4.4)	23 (4.9)
Follow-up		
≤ 10.0	35 (3.4)	32 (3.1)
10.1–84.9	816 (79.2)	827 (80.3)
85–94.9	110 (10.6)	110 (10.7)
≥ 95.0	69 (6.7)	61 (5.9)

RESULTS

1. Baseline Characteristics of Study Population

Our study cohort included 474 1st graders (31.5%) and 1,030 4th graders (68.5%). Mean ages were 7.3 ± 0.3 years and 10.0 ± 0.4 years, respectively. The mean BMI of the 1st graders was 16.0 ± 2.3 kg/m^2 with 12.0% being over 85 percentile of BMI curve, whereas the mean BMI of the 4th graders was 18.1 ± 3.0 kg/m^2 with 17.3% having the corresponding figure. Data on physical activity, socioeconomic status, family history, dietary habits, and dietary intake of participants are presented in Table 1.

2. Anthropometric Changes over 2 Years

During a 2-year follow-up, the mean weight of the 1st graders increased by 4.9 ± 2.8 kg, and height by 8.4 ± 1.7 cm. 4th graders' weight increased by 9.1 ± 3.7 kg and height by 11.6 ± 2.9 cm. BMI increased by 0.8 ± 1.4 kg/m^2 in 1st graders, and 1.3 ± 1.4 kg/m^2 in 4th graders. At the 6th year follow-up, the proportions of children having BMI percentile over 85 were 17.3% for 1st graders, and 16.6% for 4th graders (Table 2).

3. Factors Influencing BMI at Baseline and BMI Changes over 2 Years for 1st Graders

In a cross-sectional analysis, BMI of children increased by 0.181 kg/m^2 as maternal BMI increased by 1 kg/m^2 ($P < 0.001$) after adjustment of covariates. Higher paternal BMI was also significantly associated with higher BMI in children ($P < 0.001$).

Table 3. Multivariate linear regression modeling for baseline BMI and 2 years BMI change of the 1st graders.

Variables	Baseline BMI (kg/m^2)†		BMI change (kg/m^2) during 2 year follow-up‡	
	Coefficients (95% CI)	P-value	Coefficients (95% CI)	P-value
Exercise frequency per week (vs. < 1)				
2–4	−0.056 (−0.508 to 0.396)	0.807	0.354 (0.075 to 0.632)	0.013*
≥ 5	−0.047 (−0.738 to 0.644)	0.893	0.587 (0.161 to 1.014)	0.007**
Weekly screen time per an hour	−0.012 (−0.051 to 0.026)	0.535	0.014 (−0.009 to 0.038)	0.235
Sleep duration (h) per day (vs. ≤ 8.5)				
8.5–9.5	−0.310 (−0.882 to 0.261)	0.286	−0.192 (−0.543 to 0.159)	0.284
≥ 9.5	−0.508 (−1.173 to 0.157)	0.134	−0.463 (−0.871 to −0.054)	0.027*
Household income (≤ 3 million vs. > 3 million KRW)	−0.377 (−1.319 to 0.565)	0.432	−0.854 (−1.402 to −0.307)	0.002**
Maternal BMI per 1 kg/m^2	0.181 (0.096 to 0.265)	< 0.001***	0.083 (0.030 to 0.137)	0.002**
Paternal BMI per 1 kg/m^2	0.169 (0.094 to 0.243)	< 0.001***	0.043 (0.002 to 0.095)	0.043*
Maternal education (vs. < 12 y)				
13–16	−0.004 (−0.522 to 0.513)	0.987	0.015 (−0.303 to 0.334)	0.925
≥ 17	−0.098 (−1.195 to 1.000)	0.861	−0.507 (−1.183 to 0.170)	0.142
Paternal education (vs. < 12 y)				
13–16	−0.448 (−1.053 to 0.156)	0.146	0.113 (−0.260 to 0.485)	0.552
≥ 17	−0.086 (−0.951 to 0.779)	0.844	0.399 (−0.134 to 0.931)	0.142
Maternal job (yes vs. no)	−0.081 (−0.507 to 0.345)	0.708	0.228 (−0.035 to 0.491)	0.089
Family structure (two parents vs. single)	−0.238 (−1.341 to 0.864)	0.671	−0.082 (−0.747 to 0.584)	0.809
Energy intake per a 1,000 kcal	−0.031 (−0.117 to 0.055)	0.481	0.027 (−0.026 to 0.080)	0.322
Fat % of energy intake per a percent	0.017 (−0.023 to 0.057)	0.408	0.021 (−0.004 to 0.046)	0.104
Meal skipping during a week (yes vs. no)	0.038 (−0.017 to 0.093)	0.170	0.021 (−0.013 to 0.055)	0.232
Snack (yes vs. no)	0.467 (0.003 to 0.931)	0.049*	0.189 (−0.098 to 0.476)	0.196

BMI: body mass index, CI: confidential interval, KRW: Korean won.
*P < 0.05. **P < 0.01. ***P < 0.001.
†Adjusted for age (continuous), sex (male or female), sexual maturation at 4th year follow-up (Tanner stage I, II, III, IV, V), and variables in this table. ‡Adjusted for age (continuous), sex (male or female), sexual maturation at 6th year follow-up (Tanner stage I, II, III, IV, V), baseline BMI (continuous), and variables in this table.

Children who had snacks had a higher BMI by 0.467 kg/m^2 as compared with those who didn't (P = 0.049).

In the longitudinal study with BMI change as an outcome variable, exercise (P = 0.013, P = 0.007), sleep duration (P = 0.027), household income (P = 0.002), maternal BMI (P = 0.002), and paternal BMI (P = 0.043) were all significant predictors of BMI increase. In particular, children reporting more than 9.5 hours of sleep per day experienced a lower BMI increase by 0.463 (CI, 0.054 to 0.871) kg/m^2 than children reporting less than 8.5 hours of sleep duration. Monthly household income more than 3,000,000 Korean won (approximately 2,800 US dollar) was a significant protective factor for a BMI increase by 0.854 (CI, 0.307 to 1.402) kg/m^2 (Table 3).

4. Factors Influencing BMI at Baseline and BMI Changes over 2 Years for 4th Graders

In the cross-sectional analysis, for every maternal BMI increase of 1 kg/m^2, children's BMI increased by 0.208 kg/m^2 (P < 0.001). Higher paternal BMI (P < 0.001), shorter sleep duration (P = 0.001), lower household income (P = 0.016),

Table 4. Multivariate linear regression modeling for baseline BMI and 2 years BMI change of the 4th graders.

Variables	Baseline BMI (kg/m^2)†		BMI change (kg/m^2) during 2 year follow-up‡	
	Coefficients (95% CI)	P-value	Coefficients (95% CI)	P-value
Exercise frequency per week (vs. < 1)				
2–4	0.034 (−0.343 to 0.410)	0.860	0.091 (−0.104 to 0.285)	0.361
≥ 5	−0.138 (−0.812 to 0.536)	0.688	0.199 (−0.150 to 0.547)	0.263
Weekly screen time per an hour	−0.002 (−0.027 to 0.023)	0.876	−0.004 (−0.016 to 0.009)	0.584
Sleep duration (h) per day (vs. ≤ 8.5)				
8–9	−0.143 (−0.612 to 0.326)	0.551	−0.079 (−0.321 to 0.162)	0.520
≥ 9	−0.852 (−1.356 to −0.348)	0.001**	0.024 (−0.236 to 0.285)	0.855
Household income (≤ 3 million vs. > 3 million KRW)	−0.632 (−1.144 to −0.120)	0.016*	−0.018 (−0.283 to 0.247)	0.894
Maternal BMI per 1 kg/m^2	0.208 (0.140 to 0.276)	< 0.001***	0.038 (0.003 to 0.074)	0.035*
Paternal BMI per 1 kg/m^2	0.234 (0.166 to 0.302)	< 0.001***	0.028 (−0.009 to 0.064)	0.135
Maternal education (vs. < 12 y)				
13–16	−0.162 (−0.614 to 0.291)	0.484	−0.167 (−0.401 to 0.067)	0.161
≥ 17	−0.020 (−0.832 to 0.791)	0.961	−0.077 (−0.496 to 0.342)	0.718
Paternal education (vs. < 12 y)				
13–16	−0.016 (−0.505 to 0.473)	0.946	−0.048 (−0.300 to 0.205)	0.711
≥ 17	0.117 (−0.540 to 0.774)	0.727	0.055 (−0.284 to 0.394)	0.752
Maternal job (yes vs. no)	0.182 (−0.164 to 0.529)	0.302	0.089 (−0.090 to 0.268)	0.331
Family structure (two parents vs. single)	0.270 (−0.307 to 0.846)	0.359	0.132 (−0.166 to 0.430)	0.386
Energy intake per a 1,000 kcal	0.135 (−0.355 to 0.625)	0.588	0.136 (−0.117 to 0.389)	0.292
Fat % of energy intake per a percent	0.041 (0.007 to 0.075)	0.017*	−0.007 (−0.024 to 0.011)	0.449
Meal skipping during a week (yes vs. no)	−0.071 (−0.131 to −0.011)	0.020*	0.002 (−0.029 to 0.033)	0.884
Snack (yes vs. no)	0.988 (0.582 to 1.393)	< 0.001***	0.278 (0.066 to 0.490)	0.010**

BMI: body mass index, CI: confidential interval, KRW: Korean won.
*P < 0.05. **P < 0.01. ***P < 0.001.
†Adjusted for age (continuous), sex (male or female), sexual maturation at 4th year follow-up (Tanner stage I, II, III, IV, V), and variables in this table. ‡Adjusted for age (continuous), sex (male or female), sexual maturation at 6th year follow-up (Tanner stage I, II, III, IV, V), baseline BMI (continuous), and variables in this table.

higher fat proportion of energy intake (P = 0.017), regular meal consumption (P = 0.020), and snack intake (P < 0.001) were all significantly associated with a higher BMI of children (P < 0.001). In the longitudinal analysis, higher maternal BMI (P = 0.035), and frequent snack intake (P = 0.010) were significant predictors of BMI increase during the 2-year follow-up (Table 4).

5. Children's Body Mass Index Changes by Parental Obesity

BMI increase over 2 years in 1st grader group was 0.721 kg/m^2 in children with normal weight mothers, 0.989 kg/m^2 in those with overweight mothers, and 1,256 kg/m^2 in those with obese mothers. For the 4th grader group, BMI increases were 1.284 kg/m^2, 1.135 kg/m^2, and 1.639 kg/m^2, respectively. There was no significant association between the degree of paternal obesity and children's BMI changes (Figure 2).

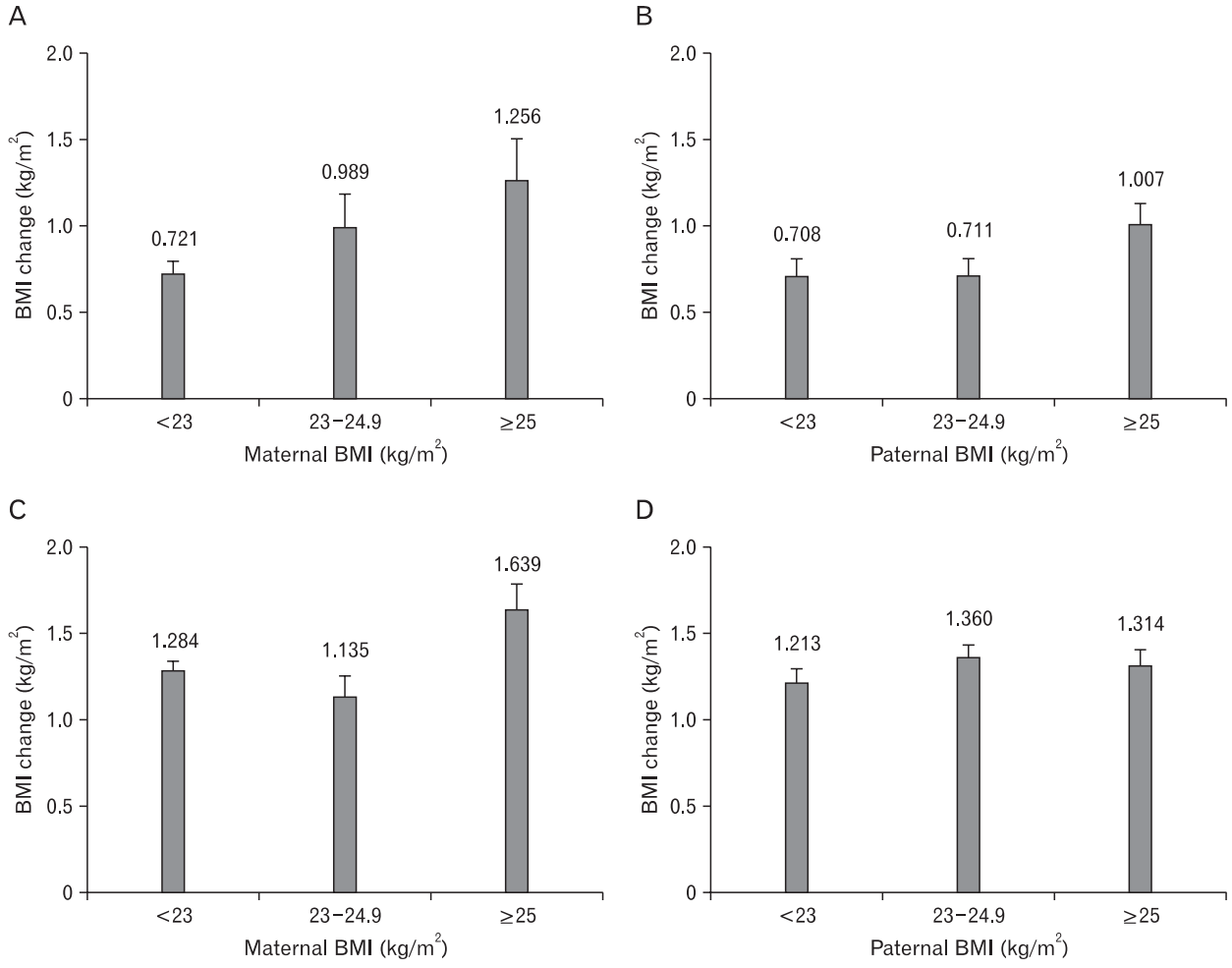

Figure 2. Estimated body mass index (BMI) changes over 2 years by parental BMI categories. The BMI changes were estimated by the general linear modeling controlling for age (continuous), sex (male or female), sexual maturation at 6th year follow-up (Tanner stage I, II, III, IV, V), baseline BMI (continuous), and variables in the Table 3 or Table 4. (A) 1st grader BMI change by maternal BMI categories, P = 0.049. (B) 1st grader BMI change by paternal BMI categories, P = 0.118. (C) 4th grader BMI change by maternal BMI categories, P = 0.025. (D) 4th grader BMI change by paternal BMI categories, P = 0.359. All P-values are by general linear modeling. Error bars represent + SE.

DISCUSSION

Here we assessed the factors associated with BMI of children in the 1st and 4th grade of elementary school in a cross-sectional study and further investigated factors that affect BMI changes in a longitudinal study over a 2-year period. Although there were some differences between the cross-sectional and the longitudinal study, parental BMI, sleep duration, household income, skipping meals, and snack intake were significantly associated with the baseline BMI and BMI changes over time in Korean children.

In particular, high parental BMI was identified as a strong risk factor for the high BMI of both 1st and 4th graders both in the cross-sectional and longitudinal study. This finding is consistent with previous observations from overseas countries that BMI of children positively correlates with BMI of their parents.[14,15] Genome-wide association studies identified variants at several loci associated with BMI, suggesting the influence of genetic predisposition in obesity.[16] Nonetheless, the rapid rise in obesity rate over the past few decades suggests environmental and behavioral factors as key determinants of obesity development over genetic predisposition.[17] Parents and their children are often exposed to similar environments and share similar lifestyles that are mainly determined by parents.[18,19] This is also supported by a recent cross-sectional study in Korea which showed that 2- to 12-year-old children with obese parents (BMI > 25 kg/m^2) were 4 times more likely to be obese themselves,[11] and our observation

emphasizes parental obesity as a high-risk factor for childhood obesity.

Interestingly, effects of socioeconomic status (SES) on childhood obesity depend on the economical developmental status of countries. As such, obesity was more prevalent among children from low SES families in developed countries, whereas children of high SES in developing countries tend to be obese.[20,21] A recent domestic study reported a prevalence of obesity among children of lower SES in Korea, similar to developed countries.[22] Here again, both the longitudinal study with 1st graders and the cross-sectional study in 4th graders showed an inverse relationship between household income and baseline BMI or BMI changes over time. The higher obesity rate in children of lower SES is thought to have several causes: 1) parents might be more generous and less controlling of dietary intake and habits of their children; 2) children might have easier access to high-calorie fast foods both within the home and in the local neighborhood; and 3) the access to safe playgrounds for physical activity might be limited.[7] In contrast, high SES with financial freedom allows better access to quality nutrition and environments that encourage healthy physical activity.[23,24]

Short sleep duration per se is associated with obesity in children.[25] A possible explanation is that short sleep duration decreases nocturnal leptin production and increases ghrelin with a net effect of increasing appetite and fatigue, which in turn leads to higher caloric intake and reduced physical activity.[26] In this study, 1st grade children with a sleep duration of more than 9.5 hours per day showed a lower BMI by 0.5 kg/m^2 than children with 8.5 hours of sleep or less per day. The ideal sleep duration related to obesity is hard to define due to its dependence on children's developmental stage and different sociocultural influences. However, a significant linear dose-response relationship could be found in a meta-analysis; the pooled odds ratio for overweight/obesity was 0.91 (CI, 0.84 to 1.00) for each 1-hour increase in sleep duration.[27]

Recent studies showed that snacking contributes to obesity.[28,29] The additional energy content of snacks leads to a positive energy balance as calorie intake with the next meal remains likely unchanged.[29] Interestingly, snacks lead to insulin secretion and suppress the late rise of free fatty acid in plasma that inhibits a feeling of satiety.[26] Our finding supports this, as even after adjusting for total energy intake, fat percent of energy intake, and meal regularity, snack intake was related with an increased BMI.

It is widely accepted that regular exercise is effective in preventing obesity in children and a lower level of physical activity is a risk factor for being overweight or obesity.[30,31] In contrast, our study showed that 1st graders who did more physical exercise had a higher BMI increase during follow-up. This counterintuitive finding might be due to the following; 1) the study participants knew their outcome, obesity status. Hence overweight and obese children actually did more exercise to lose weight; 2) the amount of exercise participants did might not be enough to lose weight; 3) the definition of exercise this study used might be too broad to influence weight status.

This study has several limitations. First, a 2-year follow-up period might be too short to reliably detect the effects of lifestyle on obesity development, as children's anthropometric measures might not change dramatically over such a short period of time. In other studies, participants are followed more than five years.[5,7] As participants in the Obesity and Metabolic Disorders Cohort in Childhood will be followed up into their adulthood, longer follow-up data will be available soon. Second, data collection is mainly based upon unsupervised questionnaires on physical activity, dietary habit, pubertal staging, and nutrient intake, which may lead to information or reporting biases. Future research should incorporate biological markers such as accelerometer data for physical activity and blood nutrient levels to estimate nutrient intake, and actual physical examinations by trained personnel to assess pubertal staging,[32] as more reliable and accurate predictor variables. Third, even if it is a prospective longitudinal study, the predictor variables might be influenced by outcome variables, resulting in biologically implausible relationships such as the inverse correlation between exercise and BMI. Fourth, the number of study participants was relatively small for multivariate analysis and resulted in wide confidence intervals. Four different models showed similar trends but different results with a difficult interpretation. As longer follow-up is available, more concrete results will be expected.

Despite the above limitations, this preliminary study was the first to identify the factors associated with BMI changes in Korean children in a longitudinal study design and was able to identify the predictors of BMI increase in Korean children as parental obesity, short sleep duration, low social economic status, and frequent snacking.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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