



Original Article

Association of overweight with asthma symptoms in Japanese school children

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Abstract *Background:* Most studies regarding the association of obesity with asthma have been performed in the Western countries. This study is a nationwide survey conducted in Japan.

Methods: A cross-sectional and questionnaire-based survey was performed among children aged 6–7, 13–14, and 16–17 years, using the ISAAC questionnaire. Overweight was defined as BMI $\geq$ 90th according to the reference values for Japanese children obtained during 1978–1981.

Results: Of a total of 179 218 children, 149 464 replied to the questionnaire (response rate 83.4%). After omitting incomplete data, 139 117 were analyzed. In all the age groups, being overweight was associated with current asthma after adjustment for confounding factors (adjusted OR: 1.24 in children 6–7 years of age, 1.31 in those 13–14 years, and 1.32 in those 16–17 years). These tendencies were observed in both genders. Overweight was a risk factor for nocturnal cough, independent of current asthma in the older age groups (adjusted OR: 1.21 in children 13–14 years, and 1.17 in those 16–17 years).

Conclusions: There is a clear association between obesity and current asthma in Japanese school-aged children. Mechanisms through which obesity related with nocturnal cough might be different from those of obesity-associated asthma.

Key words asthma, obesity, overweight, school children.

In the past few decades, the prevalence of both asthma and obesity has been increasing dramatically. In Japan, there is a 2.1 times increase in the prevalence of asthma¹ and a 2.5–2.6 times increase in the prevalence of obesity² in school-aged children during the past 20 years. Recently there have been a lot of studies evaluating the association between both disorders, but these data are inconsistent. Furthermore, most of them were reported from the Western countries, and little data have been reported from Asian countries. It has been known that there are ethnic differences in body composition including body mass index (BMI), body fat mass and fat distribution between Asian and Caucasian children.^{3,4} These differences might affect the association between obesity and asthma. Age and gender are other factors that influence the relationship between obesity and asthma.⁵ Therefore, we conducted a nationwide survey to evaluate the relationship between asthma and obesity in Japanese children of three different age groups: 6–7 years, 13–14 years, and 16–17 years of age.

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Methods

Study population

This study was a cross-sectional, questionnaire-based survey among 6–7-year-old, 13–14-year-old, and 16–17-year-old school children in Japan, and was carried out from April to July 2008. In order to perform a nationwide survey schools were randomly selected from all the prefectures, and the total number of children recruited was 179 218, corresponding to approximately 2% of the population, according to the data of the National Institute of Population and Social Security Research. Because the mainlands of Japan run from northeast to southwest, the climate varies between regions. In this study, Japan was geographically divided into two regions: northeast and southwest.

Questionnaire

The survey used a Japanese version of the International Study of Asthma and Allergies in Childhood (ISAAC) questionnaire,^{6,7} which was distributed through teachers of the participating schools. The questionnaires for 6–7-year-old children were completed by their parents, and those for older children were answered by the children. The questionnaire also included questions regarding demographics, height and weight.

Current asthma was defined as answering positively to the question "Have you (or your child) had wheezing or whistling in the chest during the past 12 months?". Exercise-induced wheezing (EIW) was defined when the question "In the past 12 months, have you (or your child's) chest sounded wheezy during or after exercise?" was answered "yes". Night cough was defined as a positive response to the question "In the past 12 months, have you (or your child) had a dry cough at night, apart from a cough associated with a cold or chest infection?"

Definition of underweight and overweight

The child's weight and height were requested in the questionnaire. BMI was calculated as body weight in kilograms divided by height squared in meters (kg/m^2). The subjects were categorized into three groups based on the 10th and 90th percentiles, according to the reference values of BMI for Japanese children, which were obtained in 1978–1981 period.⁸ Children who were at the 10th percentile and less were defined as underweight, those at the greater than 10th to less than the 90th percentile were assigned to normoweight, and those at the 90th percentile and more were defined as overweight.

Statistical analyses

The χ^2 test was used to evaluate differences in BMI distribution for the regions and genders. Multivariate logistic regression analysis was performed to estimate the effects of BMI and other covariates on respiratory symptoms (current asthma, exercise-induced wheezing, and night cough) in subjects with current asthma. Kappa statistics were used to compare the level of inter-individual agreement between current asthma and respiratory symptoms (EIW and nocturnal cough). Kappa scores >0.41 are considered to show moderate agreement: >0.61 , good agreement, and >0.81 , very good agreement.⁹ A value of $P < 0.05$ was

considered to be statistically significant. All analysis was performed using the statistical package of SPSS for Windows version 17.0J.

Ethics

This study protocol was approved by the independent review board (IRB) of the National Center for Child Health and Development.

Results

Of the 179 218 children, 149 464 replied to the questionnaire (response rate 83.4%). After omitting incomplete data, 139 117 were analyzed (Fig. 1). Background characteristics of the study population are shown in Table 1. Approximately 14% of the subjects were categorized as overweight and the prevalence of overweight was higher in the northeast region compared with the southwest region in each age group (Table 1). The youngest age group included more children categorized as underweight than the older age groups. There were gender differences in the prevalence of overweight and underweight in each age group. There was a tendency that boys were more slender than girls in the children aged 6–7 years, but this tendency changed with age. In the children aged 16–17 years, the prevalence of overweight in boys was higher than that in girls, and more girls were categorized as underweight. There were age differences in the prevalence of respiratory symptoms (Table 2). The prevalence of current asthma in the youngest age group was higher (13.6%) than that of the older age groups (9.5% in children aged 13–14 years and 8.3% in children 16–17 years old). In contrast, only a very low percentage of children aged 6–7 years old (4.3%) had current episodes of EIW, while approximately 15% of the older age group had such episodes (16.5% in children aged 13–14

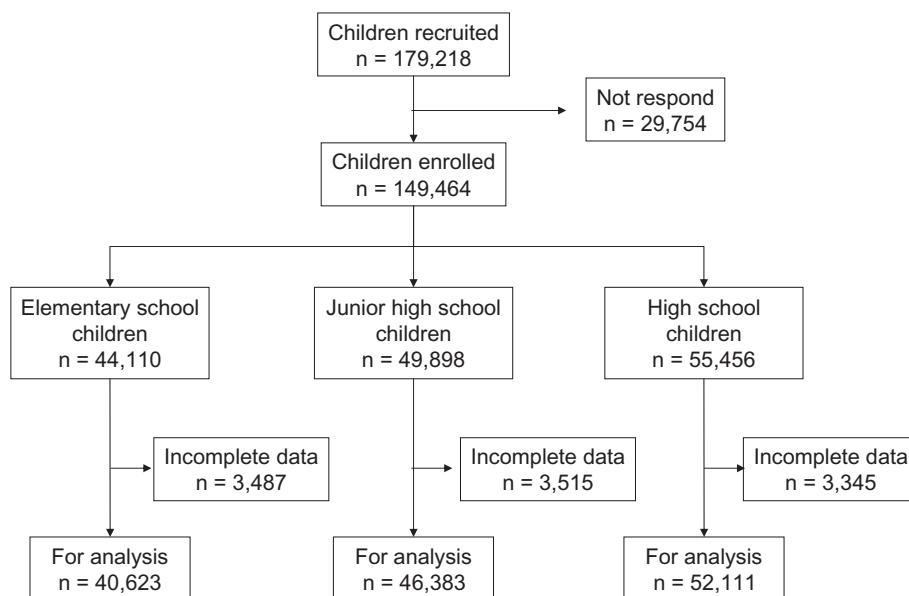


Fig. 1 Participants of the cross-sectional and questionnaire-based survey.

Table 1 Baseline characteristics of the study participants

	Underweight	Normoweight	Overweight	<i>P</i> -value
6–7-year-olds				
Total number	6206 (15.3%)	28 374 (69.8%)	6043 (14.9%)	
Region				
Northeast	2745 (15.2%)	12 462 (69.1%)	2824 (15.7%)	<0.001
Southwest	3461 (15.3%)	15 912 (70.4%)	3219 (14.2%)	
Gender				
Boys	3420 (16.6%)	14 210 (68.7%)	3030 (14.7%)	<0.001
Girls	2786 (14.0%)	14 164 (70.9%)	3013 (15.1%)	
13–14-year-olds				
Total number	3722 (8.0%)	36 073 (77.8%)	6588 (14.2%)	
Region				
Northeast	1491 (7.6%)	15 204 (77.0%)	3053 (15.4%)	<0.001
Southwest	2231 (8.4%)	20 869 (78.3%)	3535 (13.3%)	
Gender				
Boys	1920 (8.4%)	17 681 (77.1%)	3333 (14.5%)	0.002
Girls	1802 (7.7%)	18 392 (78.4%)	3255 (13.9%)	
16–17-year-olds				
Total number	4721 (9.1%)	39 729 (76.2%)	7661 (14.7%)	
Region				
Northeast	1929 (8.5%)	17 000 (75.1%)	3725 (16.4%)	<0.001
Southwest	2792 (9.5%)	22 729 (77.1%)	3936 (13.4%)	
Gender				
Boys	2055 (7.5%)	20 759 (76.0%)	4514 (16.5%)	<0.001
Girls	2666 (10.8%)	18 970 (76.5%)	3147 (12.7%)	

years and 14.0% in children 16–17 years old). There were also regional and gender differences in the prevalence of respiratory symptoms. In both the youngest and oldest age groups, the prevalence of current asthma was significantly higher in the northeast region, while it tended to be lower in the 13–14 year-old age

group ($P = 0.055$). In the children aged 6–7 years old, significantly more boys had respiratory symptoms compared with girls. These gender differences became unclear with age. In the oldest age group, there were no differences in the prevalence of respiratory symptoms between genders.

Table 2 Prevalence of respiratory symptoms

	CA	<i>P</i> -value	EIW	<i>P</i> -value	NC	<i>P</i> -value
6–7-year-olds						
Total	13.6		4.3		13.4	
Regions						
Northeast	14.1	0.007	4.4	0.375	13.2	0.159
Southwest	13.2		4.2		13.6	
Gender						
Boys	15.8	<0.001	5.0	<0.001	14.5	<0.001
Girls	11.4		3.5		12.3	
13–14-year-olds						
Total	9.5		16.5		11.8	
Regions						
Northeast	9.2	0.055	16.4	0.825	11.1	<0.001
Southwest	9.7		16.5		12.3	
Gender						
Boys	9.7	0.173	15.8	<0.001	11.2	<0.001
Girls	9.3		17.1		12.3	
16–17-year-olds						
Total	8.3		14.0		11.8	
Regions						
Northeast	8.9	<0.001	15.0	<0.001	12.0	0.289
Southwest	7.8		13.3		11.7	
Gender						
Boys	8.4	0.091	14.1	0.421	11.7	0.428
Girls	8.0		13.9		11.9	

CA, current asthma; EIW, exercise-induced wheezing; NC, nocturnal cough.

From these findings, we evaluated the association of under- or overweight with respiratory symptoms, using a multivariate logistic regression analysis, adjusted for geographic region and gender (Table 3). In all the age groups, there was a significant association of overweight with current asthma (adjusted OR: 1.24, 95% CI: 1.15–1.34, $P < 0.001$ in children 6–7 years of age; adjusted OR: 1.31, 95% CI: 1.21–1.42, $P < 0.001$ in those 13–14 years; and adjusted OR: 1.32, 95% CI: 1.22–1.44, $P < 0.001$ in those 16–17 years). With regard to underweight, in the 13–14-year-old group, underweight was significantly associated with current asthma in boys (adjusted OR: 1.17, 95% CI: 1.00–1.36, $P = 0.049$), while underweight tended to negatively associate with current asthma in girls ($P = 0.085$). Furthermore, a significantly negative association was found in the girls aged 16–17 years (adjusted OR: 0.83, 95% CI: 0.70–0.97, $P = 0.020$).

Being overweight also associated with EIW in all the age groups (adjusted OR: 1.32, 95% CI: 1.16–1.50, $P < 0.001$ in children 6–7 years of age; adjusted OR: 1.37, 95% CI: 1.28–1.47, $P < 0.001$ in those 13–14 years; and adjusted OR: 1.36, 95% CI: 1.27–1.46, $P < 0.001$ in those 16–17 years), but being underweight had no effect on EIW (Table 4). There was moderate inter-individual agreement between current asthma and EIW (kappa value = 0.46), while the inter-individual agreement between current asthma and nocturnal asthma was poor (kappa value = 0.28). Therefore, to examine the association of under- or overweight with nocturnal cough, current asthma was added as a covariate (Table 4). In the children aged 13–14 and 16–17 years obesity was significantly associated with nocturnal cough, independent of current asthma (adjusted OR: 1.21, 95% CI: 1.18–1.31, $P < 0.001$ in those 13–14 years; and adjusted OR: 1.17, 95%

Table 3 Association of under- or overweight with current asthma

	Prevalence (%)	<i>P</i> -value	Adjusted OR	95% CI
Total [†]				
6–7-year-olds				
Underweight	13.1	0.312	0.96	0.88–1.04
Normoweight	13.2		1	
Overweight	15.9	<0.001	1.24	1.15–1.34
13–14-year-olds				
Underweight	9.3	0.805	1.02	0.90–1.14
Normoweight	9.1		1	
Overweight	11.6	<0.001	1.31	1.21–1.42
16–17-year-olds				
Underweight	7.5	0.323	0.94	0.84–1.06
Normoweight	7.9		1	
Overweight	10.2	<0.001	1.32	1.22–1.44
Boys [‡]				
6–7-year-olds				
Underweight	14.5	0.138	0.92	0.83–1.03
Normoweight	15.5		1	
Overweight	18.2	<0.001	1.21	1.09–1.34
13–14-year-olds				
Underweight	10.7	0.049	1.17	1.00–1.36
Normoweight	9.3		1	
Overweight	11.2	0.001	1.23	1.09–1.39
16–17-year-olds				
Underweight	8.7	0.269	1.10	0.93–1.29
Normoweight	8.0		1	
Overweight	10.3	<0.001	1.31	1.17–1.46
Girls [‡]				
6–7-year-olds				
Underweight	11.2	0.816	1.02	0.89–1.16
Normoweight	10.6		1	
Overweight	13.5	<0.001	1.26	1.12–1.42
13–14-year-olds				
Underweight	7.8	0.085	0.85	0.71–1.02
Normoweight	9.0		1	
Overweight	12.0	<0.001	1.40	1.24–1.57
16–17-year-olds				
Underweight	6.6	0.020	0.83	0.70–0.97
Normoweight	7.9		1	
Overweight	10.3	<0.001	1.32	1.17–1.50

[†]Adjusted for gender and region.

[‡]Adjusted for region.

CI, confidence interval; OR, odds ratio.

Table 4 Association of under- or overweight with exercise-induced wheezing and nocturnal cough

	Prevalence (%)	P-value	Adjusted OR	95% CI
Exercise-induced wheeze [†]				
6–7-year-olds				
Underweight	4.1	0.680	0.97	0.84–1.12
Normoweight	4.1		1	
Overweight	5.3	<0.001	1.32	1.16–1.50
13–14-year-olds				
Underweight	15.3	0.382	0.96	0.87–1.06
Normoweight	15.8		1	
Overweight	20.4	<0.001	1.37	1.28–1.47
16–17-year-olds				
Underweight	12.9	0.308	0.95	0.87–1.05
Normoweight	13.4		1	
Overweight	17.5	<0.001	1.36	1.27–1.46
Nocturnal cough [‡]				
6–7-year-olds				
Underweight	13.5	0.372	1.04	0.95–1.13
Normoweight	13.2		1	
Overweight	14.8	0.077	1.08	0.99–1.18
13–14-year-olds				
Underweight	11.9	0.306	1.06	0.95–1.18
Normoweight	11.4		1	
Overweight	13.9	<0.001	1.21	1.18–1.31
16–17-year-olds				
Underweight	11.2	0.734	0.93	0.89–1.09
Normoweight	11.5		1	
Overweight	13.7	<0.001	1.17	1.08–1.26

[†]Adjusted for gender and region.

[‡]Adjusted for gender, region and current asthma.

CI, confidence interval; OR, odds ratio.

CI: 1.08–1.26, $P < 0.001$ in those 16–17 years), and there was a similar tendency in the children aged 6–7 years ($P = 0.077$).

Discussion

In this study, we found that being overweight was associated with current asthma in children of all the three age groups, and this finding remained even after adjusted for other variables such as gender and geographic region. There are three critical periods in the development and persistence of overweight in childhood: the prenatal period, period of adiposity rebound, and adolescence.¹⁰ The youngest age group of this study corresponds to the period of adiposity rebound, and the children of the older age groups are in the middle of adolescence. As the baseline characteristics of the subjects, prevalence rates of overweight were approximately 14%, and the rates were similar in each age group. Our findings are consistent with the results from a 5-year longitudinal cohort study that followed more than 5000 school children, which found that persistent obesity in adolescence was established before age 11, suggesting the need to target efforts to prevent obesity in the early years.¹¹ Although the prevalence rates of overweight were similar between the three age groups as mentioned above, there were some gender differences in the prevalence of overweight. Especially in the older age group, the overweight rate between girls was clearly lower than that between boys. Development of obesity is associated with both biological and behavioral factors, and socially constructed attitudes or beliefs may affect this process. Gender differences for body image concerns emerge

somewhere between the ages of 8 and 10 years, and body dissatisfaction becomes more pronounced with increasing age, particularly in girls.¹² These factors might explain the lower prevalence of overweight in girls of the older age groups in this study.

There are also conflicting data regarding the impact of gender on the obesity–asthma relationship.¹³ Consistent with our results, a cross-sectional study performed in New Zealand showed the associations of BMI with current asthma and inhaled steroid use in children of mean age 11.7 years, and these associations were not significantly different for boys and girls.¹⁴ In contrast, another survey performed in Kyoto, a city in Japan, demonstrated the association of obesity with asthma in girls but not in boys aged 7–15 years.¹⁵ In the Tuscon birth cohort study, girls, but not boys, who became overweight between 6 and 11 years of age were seven times more likely to develop new asthma symptoms at age 11 or 13 years of age.¹⁶ Furthermore, a prospective study in which 4393 US children who were asthma-free during the first 24 months followed up to 14 years showed that boys with high BMI were at increased risk for subsequent asthma.¹⁷ The different outcomes in these studies may be a function of the age at which the children were studied and the duration of follow-up.

In the current study, children who were overweight were more likely to develop wheezing during exercise, as was seen in Belgian children 3–14 years of age.¹⁸ Several studies denied the association between obesity and bronchial hyperresponsiveness.¹⁶ EIW might be caused by reduced lung functions that were found among asthmatic and normal children with high BMI.¹⁹ It

was reported that children with asthma combined with excessive body weight had a low quality of life (QOL) compared with children with asthma and normal weight.²⁰ We previously reported that the presence of EIW among asthmatic children impaired their QOL compared with asthmatics without EIW.⁷ Frequent episodes of EIW could be one of the reasons for the low QOL of asthmatic children with asthma. We also found that overweight was a risk factor for nocturnal cough, independent of current asthma in the older age groups. Mechanisms through which obesity related with nocturnal cough might be different from those of obesity-associated wheezing. Several studies showed the relationship between obesity and gastroesophageal reflux (GER),²¹ suggesting that nocturnal cough in obese children might be due to GER. However, asthma per se was associated with symptoms of GER,²² and the higher prevalence of GER in asthmatic children was not attributable to overweight.²³ Further studies are needed to determine the mechanisms of nocturnal cough in obese asthmatic children. Coughing during night may cause sleep disturbance. Interestingly, an inverted relationship between sleep duration and the risk of obesity was reported in children 5–10 years of age,²⁴ and this phenomenon might be explained by reduced leptin levels due to shorter sleep duration.²⁵ Clinicians should be aware of these symptoms when they see a child with asthma and overweight.

Most of the studies evaluating a BMI–asthma link have focused mainly on obesity. However, underweight has also been shown to be associated with asthma symptoms⁵ and allergen sensitization.¹⁸ In the current study, among children 13–14 years of age, underweight boys had a risk of current asthma, while underweight girls were unlikely to have asthma compared with children with normoweight. These findings are consistent with the previous findings that among children 2–11 years of age in an inner city of the US, a U-shaped association between BMI and the probability of having asthma was observed for boys and a linear trend was observed for girls.⁵ Mechanisms for gender differences among underweight children might be different from those among overweight children.

One of the limitations of this study is that body weights and heights were self-reported. A cross-sectional study showed that when self-reported weights and heights were compared with measured values in children 12–16 years of age, influences of gender and racial biases in reporting of weight and height were relatively small, and concluded that self-reported heights and weights were extremely reliable.²⁶ However, a systematic review showed trends of under-reporting for weight and BMI and over-reporting for height.²⁷ Recently, a correction method to adjust self-reported measures of BMI to more closely approximate measured values was proposed.²⁸ Another limitation is that diagnosis of asthma was based on the questionnaire. Although we used the ISAAC questionnaire which has been proven to be valid for epidemiological study of childhood asthma, dyspnea in obese children might be interpreted as a symptom of asthma.¹³ Further limitation is that a cross-sectional study cannot address mechanistic questions. Prospective studies that account for variables in the social and physical environment are needed to clarify the pathophysiology linking obesity and asthma.

In conclusion, we have shown that there is a clear association between obesity and current asthma in Japanese school-aged children. Asthma and obesity are multifactorial diseases, and the affecting factors seem independent of each other. Further understanding of the mechanisms that could explain the relationship between both disorders may lead to new preventive strategies.

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