Short Communication

Retrospective individual tracking of body mass index in obese and thin adolescents back to childhood

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The objective of this study is to track body mass index (BMI) in obese or thin adolescents from adolescence to childhood on an individual basis. This was performed at a single school with a 12-year combination education system in an urban city in Japan. A total of 617 students in the 3rd grade of senior high school (17 years old) during 2005-2009 were enrolled. Based on the Japanese BMI reference in childhood adjusted for age and gender, obesity and thinness were defined as ≥90th percentile and ≤5th percentile, respectively. Sixty-three (10.2%) and 84 (13.6%) students were found to be obese and thin, respectively. Complete annual tracking of BMI back to the 1st grade of elementary school (6 years old) (1994-1998) was possible in 47 obese (74.6%) and 67 thin students (80.0%). The most common ages when obesity was first detected were 6-8 years for males, and 12-14 years for females, and the most common ages when thinness was first detected were 12-14 years for males, and 15-17 years for females. Once obesity or thinness started, these conditions remained until 17 years old in most students. Obese students whose obesity started earlier tended to have higher BMIs at 17 years old in both genders. This will be the first tracking study of BMI in obese and thin adolescents on an individual basis. A longitudinal study of BMI during childhood is useful for establishing intervention programs to prevent obesity or thinness in adolescence.

Key Words: body mass index, adolescence, thinness, obesity, tracking

INTRODUCTION

Childhood obesity and thinness are major public health concerns in both developed and developing countries.[1,2] Each condition has many adverse effects on both present quality of life and later health in adulthood. These include lifestyle-related disorders,[1,3,4] psychological problems and adverse pregnancy outcomes.[5,6] Furthermore, adolescent obesity was reported to cause increased mortality in middle age form a variety of diseases.[7] Therefore, grasping the exact prevalence of obesity or thinness in childhood is potentially important to reduce future risks of undesirable outcomes.

There are abundant reports on the epidemiology of obesity in children and adolescents. The prevalence of obesity differs depending upon the definition of obesity, the study population, and the year of data collection.[8-10] Several repeated cross-sectional studies indicate an increasing trend of obesity in both developed and developing countries,[8-10] although the prevalence has already started to abate in some developed countries.[1] Researchers in developed countries have paid less attention to thinness in childhood than to obesity. Recently, Cole *et al.* have published body mass index (BMI) cut-offs to define thinness in children and adolescents based on the data from 6 different countries, and their data presented the possibility for global use.[11] By using this cut-off, the authors of several reports from developed countries estimated the recent prevalence of thinness in schoolchildren as approximately 7-10%.[12-14]

Longitudinal studies are advantageous compared to cross-sectional studies for gaining a better understanding of the patterns of obesity or thinness development over time. Numerous studies focused on the transition of obesity from childhood to adulthood, and revealed a close relationship between childhood and adulthood obesity.[15,16] However, tracking studies of obesity/overweight during childhood to adolescence are limited,[17-19] and those for thinness are quite scanty. Therefore, we performed an individual retrospective tracking of BMI from adolescence to childhood in both obese and thin adolescents.

MATERIALS AND METHODS

Samples

Nara is an urban city in Japan with a population of approximately 370,000 and 150,000 households. The mean annual income of each household was almost identical to the average of household income in Japan (2006, census). Nara Women's University has an elementary, junior and senior high school attached to the university for the pur

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pose of 12 years' combined education. In April of every year, students receive a health examination that includes the measurement of body height and weight. Data are recorded on students' health charts and kept for at least 5 years. Measurement is done by trained specialists using the same equipment. A total of 617 children in the 3rd grade of senior high school (17 years old) during 2005-2009 participated in the present study. BMI was calculated as weight (kg) divided by height (m) squared. BMIs equal to or more than the 90th percentile, and equal to or less than the 5th percentile were classified as indicating obesity and thinness, respectively, based on the Japanese reference chart of BMI adjusted for age and gender (Shobi Insatsu, Tokyo, Japan).[20]

Tracking of BMI

We retrospectively tracked the height and weight of students who were diagnosed as either obese or thin from the present back to the 1st grade of elementary school (6 years old) (1994-1998). For the tracking study, students with incomplete data or those with physician-diagnosed type II diabetes mellitus or renal diseases were excluded. BMIs were calculated, and plotted on a reference chart curve. Parents provided consent for the anonymous use of these data for further health study when their children entered the school. This study was approved by the ethical committee for epidemiological study at Nara Women's University.

Statistical analysis

Difference in the prevalence of obesity or thinness according to gender was examined by chi-square test. Difference in BMI at 17 years old among 4 age groups, classified by the age of when obesity or thinness was first detected, was examined by one-way ANOVA. *P* values less than 0.05 were considered significant.

RESULTS

Prevalence of obesity or thinness in the total study population

Among a total of 617 students, 63 (10.2%) and 84 (13.6%) were found to be obese and thin, respectively (Table 1). The prevalence of obesity tended to be higher in males (37; 12.2%) than in females (26; 8.3%), but the difference was not statistically significant (p=0.11). The prevalence of thinness was quite similar among males (40: 13.2%) and females (44: 14.1%) (p=0.74).

Tracking of BMI in obese students

Complete annual tracking of BMI back to the 1st grade of elementary school was possible in 47 out of 63 obese students (74.6%). We could not track some of the students due to either a change of school or absence from school on the day of the health examination. Ages when obesity was first detected are summarized and classified into 4 age groups as indicated in Table 1. They are most common in the first half of elementary school (6-8 years old) and junior high school (12-14 years old) for males and females, respectively. Thirty-eight students (80.9%) were found to remain obese, once their BMI exceeded the 90th percentile of the reference for each age. The changes of mean BMI in each age group of obese students are summarized in Figure 1. Students with obesity starting at a younger age tended to have higher BMI at 17 years, but the trend was significant only in females (p values; 0.34 for males, 0.048 for females).

Tracking of BMI in thin students

In thin students, the BMIs of 67 (80.0%) students were able to be perfectly tracked. Ages when thinness was first detected are most common in junior high school (12-14 years old) and senior high school (15-17 years old) for males and females, respectively (Table 1). Sixty-one students (91.0%) were found to remain thin, once their BMI became below the 5th percentile for each age. The changes of mean BMI in each age group of thin students were summarized in Figure 2. In contrast to obese students, BMI among 4 age groups classified by the age when thinness was first observed did not show any significant difference in both genders (p values; 0.44 for males, 0.063 for females).

Table 1. Tracking status of BMI in obese or thin students

	Male	Female	Total
Total students	304	313	617
Obese students†	37 (12.2)ǂ*	26 (8.3)*	63 (10.2)
Tracking possible obese students	29 (78.4)	18 (69.2)	47 (74.6)
Age when obesity first detected (years)			
6-8	13 [11]§	5 [4]	18 [15]
9-11	5 [4]	3 [3]	8 [7]
12-14	5 [4]	7 [4]	12 [8]
15-17	6 [6]	3 [2]	9 [8]
Thin students†	40 (13.2)**	44 (14.1)**	84 (13.6)
Tracking possible thin students	33 (82.5)	34 (77.3)	67 (80.0)
Age when thinness first detected (years)			
6-8	6 [4]§	7 [6]	13 [10]
9-11	3 [3]	9 [7]	12 [10]
12-14	16 [16]	4 [4]	20 [20]
15-17	8 [7]	14 [14]	22 [21]

† Obesity or thinness was defined at 17 years of age.

ǂ Numbers in parentheses indicate percentages.

§ Numbers in brackets indicate the number of students who remained obese or thin after their first detection.

* p=0.11, ** p=0.74 (Chi-square test)

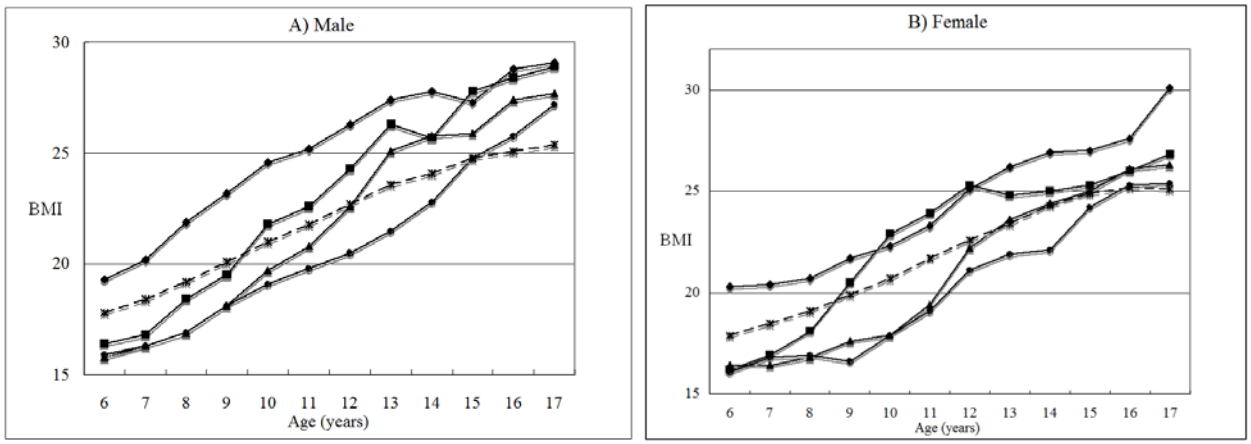

Figure 1. Tracking of BMI in obese students. Tracking possible students were divided into 4 groups based on age when obesity was first detected. Then, the mean values of BMI in students of each group at the indicated follow-up age were calculated. A) Male, B) Female; (♦) 6~8 years group, (■) 9~11 years group, (▲) 12~14 years group, and (●) 15~17 years group. The dotted line shows the 90th percentile line of BMI in healthy Japanese students among 6 and 17 years old.

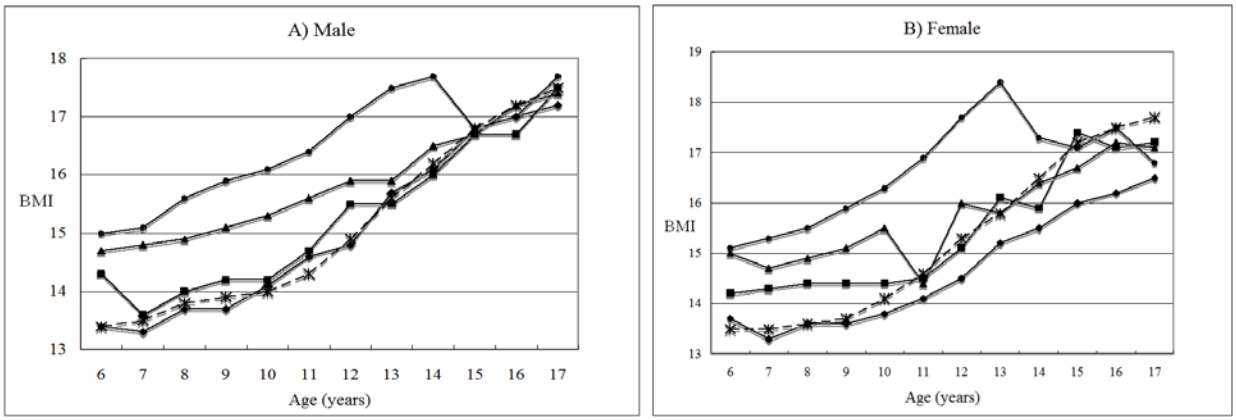

Figure 2. Tracking of BMI in thin students. Tracking possible students were divided into 4 groups based on age when thinness was first detected. Then, the mean values of BMI in students of each group at the indicated follow-up age were calculated. A) Male, B) Female; (♦) 6~8 years group, (■) 9~11 years group, (▲) 12~14 years group, and (●) 15~17 years group. The dotted line shows the 5th percentile line of BMI in healthy Japanese students among 6 and 17 years old.

DISCUSSION

There is ample consensus about the appropriateness of using BMI cut-offs to determine the prevalence of obesity or thinness in children and adolescents.[21] However, since BMI changes substantially during childhood, establishment of standard BMI values considering age and gender is potentially important. The International Obesity Taskforce (IOTF) released BMI cut-offs for overweight/ obesity[22] and thinness.[11] The IOTF references are available and appropriate for international use, because they are simple, and are based on a large amounts of data from six countries. However, the IOTF references have the drawback that they do not represent non-Western populations.[23] Therefore, in the present study we adopted the gender-specific Japanese BMI percentile curve based on the 2000 national growth survey.[20] In adults, BMI cut-offs of 25, 30, and 18.5 are used to define overweight, obesity, and thinness, respectively. In several references other than the IOTF references, the 85th, 95th, and 5th percentiles are used as the cut-offs for overweight, obesity, and thinness, respectively.[24,25] In the present study, we used the cut-off values of the 90th percentile for obesity, and the 5th percentile for thinness. According to the Japanese BMI reference in children, the 90th percentiles correspond to 25.4 for males and 25.1 for females, and the 95th percentiles correspond to 27.7 for males and 27.2 for females. Therefore, considering the definition of obesity as BMI >25.0 in Japanese adults (concept of overweight is not used in Japan), we thought that the 90th percentile is more suitable for the cut-off value for obesity.

Previous cross-sectional studies identified childhood (7-8 years old) and adolescence (12-14 years old) as two critical periods for the development of obesity.[26] In a tracking study of BMI from 6 years old to 20 years old, Magarey *et al.* suggested that a person's BMI at 6 years old is a good indicator of later BMI.[16] In a Finnish study using 138 children born in 1981-82, it was shown that BMI at 7 years old, but not at 6 months old, was significantly associated with BMI at 15 years old. Moreover, children in the highest tertile of BMI at 7 years old had a significantly higher risk of being in the highest tertile of BMI at 15 years old.[27] Similar results were presented from Iceland[18] and Japan.[19] In a Chinese study of 95 overweight children (6-13 years old) over a 2-year-period, Wang *et al.* found that urban boys rather than rural boys, and children with a diet of higher fat intake, and lower carbohydrate intake (% of energy) tended to remain overweight.[28]

The advantages of the present study design are as follows: (1) the data were obtained on annual basis, (2) there was a limited number of students who dropped out during the follow-up period, and (3) there were no ethical obstacles to using the health examination data for further research, because consent was obtained from the parents when their children entered the school. Consequently, this study indicates several important issues. First, both obesity and thinness were found to be stable, once students experienced these morbidities. Second, if obesity started at a younger age, participants tended to have higher BMI at 17 years of age. Finally, a substantial number of children were already obese during their early elementary school. These results altogether suggest the necessity of early intervention to prevent later undesirable health outcomes in obese and thin students.[1-7] In accordance with our observation, the earliest significant difference in BMI between adults with and without the metabolic syndrome occurred at age 8 in boys and age 13 in girls, suggesting that children at risk for the metabolic syndrome in adulthood should be identified as early as the first decade of life.[29]

There are several weaknesses in the present study. First, the number of subjects was limited, resulting in some restrictions in the statistical analysis. Second, since this was a retrospective study, a prospective longitudinal study should be done. Third, this study lacks the information on the subjects' diet or socio-economic status, which are factors known to affect the appearance of obesity and thinness in childhood.[30] Finally, an investigation of the relationship between obesity or thinness and health consequences such as the metabolic syndrome, lifestyle-related disorders, or ovarian dysfunctions is lacking. Further tracking beyond age of adolescence is also necessary to clarify the relationship. In spite of these weaknesses, our study will provide us with important information about the initiation and transition of obesity or thinness during childhood. Early detection and tracking of obesity or thinness in childhood are potentially important to establish the most appropriate period of intervention for these morbidities.

AUTHOR DISCLOSURES

There is no conflict of interest in this article. This study did not receive any funding.

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回溯追蹤肥胖及過瘦青少年身體質量指數至幼兒期

本篇研究目的為追溯肥胖或過瘦的青少年身體質量指數之變化，每位個體從青少年回顧至幼兒時期。樣本來自日本都市的一所 12 年級聯合學校，在 2005-2009 年間，共有 617 位高三學生(17 歲)納入研究。根據日本兒童之身體質量指數參考值，調整年齡及性別，並定義肥胖為≥90 個百分位，過瘦定義為≤5 個百分位。結果發現有 63 位(10.2%)學生為肥胖，84 位(13.6%)學生為過瘦。其中能追溯至小學一年級(6 歲) (1994-1998)的完整記錄，在肥胖的學生有 47 位(74.6%)，在過瘦的學生有 67 位(80%)。開始肥胖最常見的年齡層，男生為 6-8 歲，女生為 12-14 歲；過瘦最常開始發生的年齡層，男生為 12-14 歲，女生為 15-17 歲。一旦肥胖或過瘦情況發生後，體位通常會持續至 17 歲。當肥胖的發生年齡較早時，不論男女性 17 歲時的身體質量指數皆相對較高。本篇為追蹤肥胖及過瘦青少年個別身體質量指數的首次研究，而本研究方法能提供對於青少年體位問題，建立介入政策之參考依據。

關鍵字：身體質量指數、青少年、過瘦、肥胖、追蹤