ORIGINAL

Correlation of month and season of birth with height, weight and degree of obesity of rural Japanese children

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Abstract : Month and season of birth are thought to influence height, weight and degree of obesity in schoolchildren. A cross-sectional study was designed to measure the height and weight of all children aged 6-15 years attending primary and junior high schools in Tokushima Prefecture, Japan. Data were standardized (*z*-scores) and analysed separately by gender and age. The mean *z*-score for height and weight were the highest in subjects born during the months of spring and the lowest in those born during the months of winter ($p < 0.0001$), whereas the means were significantly higher in children born during the months of summer than in those born during the months of autumn ($p < 0.0001$). A gradually decreasing trend of height and weight was observed in children of both genders born between May and Mar (from spring to winter). There was no significant difference in degree of obesity among the four seasons of birth for boys and girls. The highest prevalence of obese boys have born during spring (among 6-year-old boys) and summer (among 7-year-old boys), whereas the highest prevalence of obese girls have born during spring (among 6-year-old girls) and winter (among 10-year-old girls). Our findings suggest that month and season of birth influence height and weight of schoolchildren in Tokushima but not their degree of obesity. J. Med. Invest. 54 : 133-139, February, 2007

Keywords **:** *month of birth, height, weight, degree of obesity, schoolchildren*

INTRODUCTION

Obesity in children is one of the most serious public health problems in Japan (1). The prevalence of obese children has been increasing remarkably each year (2), and a large proportion (54.7%) of obese Japanese children aged 6 -15 years develop adulthood overweight or obesity (3). Overweight and obesity are particularly serious in Tokushima Prefecture, a rural area located in Shikoku Island, where about 15% of boys and 14% of girls were obese (unpublished data, 2000). Among Tokushima children aged 6 -16 years, 1.85% were severely obese ; of these, 80.4% showed at least one of eight complications (hypercholesterolaemia, low serum high-density lipoprotein cholesterol, hypertriglyceridaemia, hyperuricaemia, hyperglycaemia, hyperinsulinaemia, liver dysfunction and hypertension) (4). To deal with these problems, a committee (Committee for Prevention Strategy against Lifestyle-related Disease) was set up by the Tokushima Prefecture Medical Association in 2000 to collect data on physical growth and obesity for better interventions. Since then, the physical growth of schoolchildren and obesity have been

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studied from several aspects, including geographical, environmental and lifestyle factors. One aspect that needs to be taken into account is the effect of month of birth on physical growth (height, weight) and degree of obesity in Tokushima schoolchildren.

The apparent influence of birth month on many human traits has been reported in several studies. Birth month affects human conceptions and births (5), sex ratio at birth (6), menarche (7), lifespan (8) and the probability of falling ill (9), such as the risks of breast cancer (10) and cerebrovascular diseases (11). Month of birth has also been shown to influence the later height and weight of both children and adults in various countries (12-15). However, these findings are inconsistent owing to small sample size, geographical and socioeconomic differences, and lack of analysis stratified by gender and age. It is necessary to conduct researches in different geographical locations, climates and cultures. Therefore, we performed a cross-sectional study in a large sample to investigate the effects of month and season of birth on height, weight and degree of obesity in Tokushima schoolchildren.

SUBJECTS AND METHODS

Subjects

This cross-sectional study, a part of the activities of the Committee for Prevention Strategy in Tokushima Prefecture, was carried out from Apr to Jun 2003 in all 269 primary schools and 94 junior high schools of Tokushima Prefecture, Japan. A total of 69,693 schoolchildren (35,884 boys and 33,809 girls) aged 6 -15 years were enrolled in this study.

Measurements

Data on region, school, grade, sex, birthday, height and weight were collected using the methods recommended by the Japanese government (16). School nurses (Yogo-teacher) took all the anthropometrical measurements. Height was measured to the nearest 0.1 cm, with the subject standing without shoes. Weight was measured to the nearest 0.1 kg with only underclothing. Because the standard body mass index (BMI) varies with the stage of growth, we adopted the degree of obesity as the criterion for being obese, which was calculated by the method described by Murata, *et al.* (17) and the Japan Society for the Study of Obesity (18) : degree of obesity (DOB) = (weight - standard weight)/standard weight $\times$ 100.

A child was classified as obese if his or her DOB was $\geq$20%. According to the Japanese calendar, the four seasons are spring (Apr to Jun), summer (Jul to Sep), autumn (Oct to Dec) and winter (Jan to Mar).

Statistical analysis

To nullify the effect of child's age being taken as a confounding factor, height and weight were standardized (z-scores) with respect to the Tokushima School Health Statistics reference. Data were then analysed separately by gender and age. Since the z-score for height was normally distributed, multiple group comparisons were made by one-way ANOVA and group differences were assessed using Tamhane's T2 post hoc test. Because the z-score of weight and DOB was not normally distributed after transformation, we performed the Kruskal-Wallis test and Dunn's procedure to investigate the relationship of month and season of birth to z-score of weight and DOB. $p < 0.05$ was considered statistically significant. We also used the χ^2-test to evaluate the relationship between month, season of birth and obesity. The adjusted residual was then calculated, and values of adjusted residual $\geq$+2 or $\leq$-2 were regarded as statistically significant (19). All statistical procedures were performed using SPSS version 11.0 (SPSS, Inc., Chicago, IL).

RESULTS

Trend in anthropometrical measurements according to month and season of birth

Data on height, weight and DOB of the schoolchildren by gender according to the month of birth are presented in Table 1. As shown in Fig. 1a,b, average z-scores of height and weight increased from Apr, reached a peak for births in May and then gradually decreased in children born between May and Mar. This tendency was repeated annually, with a peak in May or Jun during eight consecutive years (1989-1996), when we analysed data by year of birth (data not shown). Further comparative analyses showed statistically significant differences in height and weight z-scores among months of birth ($p <$ 0.0001). The average z-scores of height and weight were the highest for the months of spring (May and Jun) and the lowest for the months of winter (Jan, Feb and Mar) compared with other seasons ($p <$ 0.0001). These values were significantly higher in the months of summer (Jul and Aug) than those during autumn (Nov and Dec) ($p < 0.0001$).

The above analyses led to the hypothesis that season of birth affects growth in height and weight among children. In view of this, we next evaluated the relationship of season of birth with height and weight (Fig. 2a, b). The average z-scores of height and weight in both genders were the highest during spring and the lowest during winter compared with others, whereas values during summer were significantly higher than those during autumn.

Table 1. Mean of height, weight and degree of obesity by sex among months of birth in schoolchildren

Month of birth	Boys				Girls			
	N	Height (cm)	Weight (kg)	DOB	N	Height (cm)	Weight (kg)	DOB
Apr	2970	143.2	39.7	5.60	2873	141.1	38.0	4.12
May	3036	143.9	40.1	5.47	2934	141.1	38.3	5.14
Jun	3108	143.0	39.4	5.06	2719	140.4	37.4	4.16
Jul	3205	142.3	39.0	5.60	3077	140.2	37.3	4.29
Aug	3209	142.0	38.9	5.83	2923	140.3	37.5	4.35
Sep	3035	141.6	38.4	5.11	2936	139.2	36.6	4.09
Oct	2942	140.7	37.7	5.02	2826	139.9	37.2	4.38
Nov	2867	140.5	37.8	5.80	2707	138.6	36.2	3.84
Dec	3009	139.8	37.6	6.27	2834	138.5	36.3	4.49
Jan	2969	138.7	36.4	5.57	2860	137.9	35.9	4.25
Feb	2746	138.7	36.5	5.87	2437	136.9	35.1	4.00
Mar	2788	138.4	36.4	5.86	2683	136.9	35.0	3.93
Total	35884	141.1	38.2	5.58	33809	139.3	36.8	4.26

DOB : degree of obesity

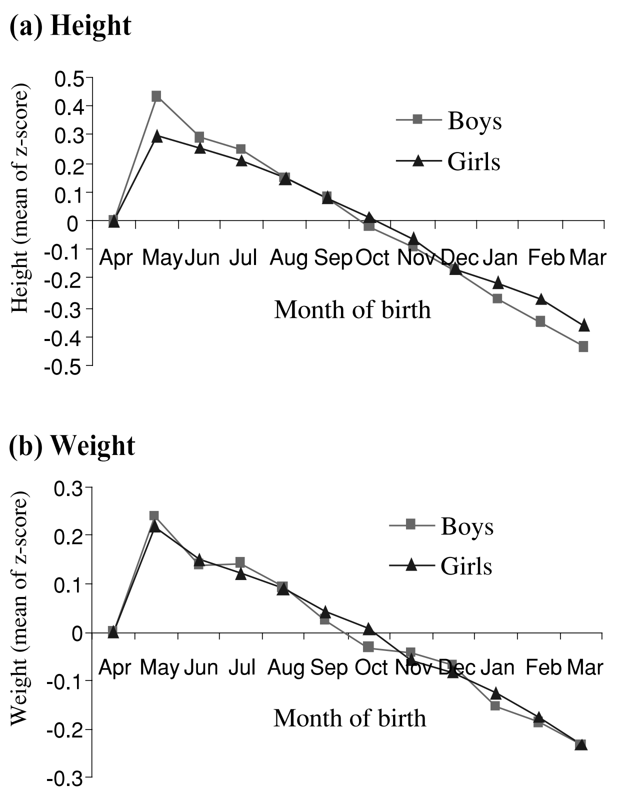

Fig. 1. Average z-score of height and weight by sex according to month of birth in schoolchildren aged 6 -15 years.

Relationship of obesity with month and season of birth

The fluctuation of DOB with the month of birth is shown in Fig. 3. The DOB reached a peak for boys born in Dec and for girls born in May. However,

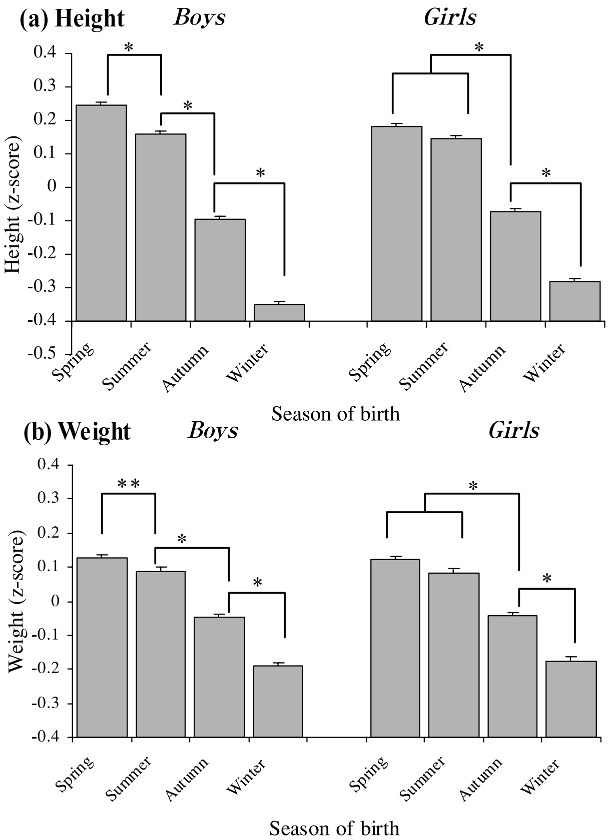

Fig. 2. (a) Pair-wise comparison of z-score of height by ANOVA test, * $p < 0.0001$. (b) Pair-wise comparison of z-score of weight by Dunn procedure, * $p < 0.0001$. ** $p < 0.05$. Data are presented as mean ± SE.

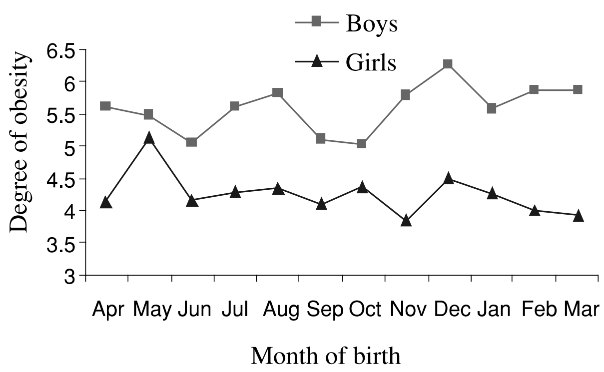

Fig. 3. Average degree of obesity by sex according to month of birth

we did not find any significant differences in DOB among months and seasons (data not shown).

We next used the χ^2 test to investigate the relationships of month and season of birth with obesity. For both sexes, there were no statistically significant differences in the prevalence of obesity among months and seasons of birth when all age groups were analysed together (data not shown). Separate analyses for each stratum of age revealed that the highest prevalence of obese boys have born during spring (among 6-year-old boys) and summer (among 7-year-old boys), whereas the highest prevalence of obese girls have born during spring (among 6-year-old girls) and winter (among 10-year-old girls) (Table 2).

Table 2. Comparison of obesity prevalence among season of birth by age

Age	Season of birth	Boys		Girls	
		Obese	Non-obese	Obese	Non-obese
6	Spring	94(11.5%) **	722(88.5%)	75(10.2%) **	663(89.8%)
	Summer	93(9.8%)	855(90.2%)	77(8.0%)	885(92.0%)
	Autumn	61(6.5%) *	880(93.5%)	70(7.8%)	826(92.2%)
	Winter	66(7.7%)	796(92.3%)	51(5.8%) *	829(94.2%)
7	Spring	108(11.2%)	856(88.8%)	112(11.9%)	828(88.1%)
	Summer	134(13.0%) **	900(87.0%)	109(11.6%	833(88.4%)
	Autumn	74(8.2%) *	827(81.8%)	76(9.1%)	756(90.9%)
	Winter	91(9.9%)	825(80.1%)	84(9.7%)	780(90.3%)
8	Spring	140(15.0%)	795(85.0%)	120(13.3%)	780(86.7%)
	Summer	152(15.1%)	858(84.9%)	124(12.6%)	861(87.4%)
	Autumn	140(14.2%)	846(85.8%)	116(12.8%)	791(87.2%)
	Winter	124(13.2%)	816(86.8%)	101(11.7%)	763(88.3%)
9	Spring	184(18.3%)	822(81.7%)	127(13.6%)	809(86.4%)
	Summer	173(17.8%)	800(82.2%)	145(15.3%)	803(84.7%)
	Autumn	153(16.5%)	773(83.4%)	114(13.7%)	719(86.3%)
	Winter	152(16.4%)	775(83.6%)	112(13.0%)	751(87%)
10	Spring	190(19.0%)	810(81.0%)	144(15.6%)	778(84.4%)
	Summer	204(18.8%)	880(81.2%)	121(12.3%) *	860(87.7%)
	Autumn	163(17.5%)	768(82.5%)	122(13.7%)	768(86.3%)
	Winter	180(18.6%)	788(81.4%)	142(16.6%) **	715(83.4%)
11	Spring	175(17.2%)	840(82.8%)	133(14.2%)	804(85.8%)
	Summer	185(16.8%)	914(83.2%)	143(14.9%)	819(85.1%)
	Autumn	205(20.6%)	792(79.4%)	161(15.5%)	881(84.5%)
	Winter	179(20.1%)	713(79.9%)	141(16.2%)	732(83.8%)
12	Spring	171(17.6%)	800(82.4%)	150(15.6%)	811(84.4%)
	Summer	173(17.0%) *	846(83.0%)	169(16.0%)	886(84.0%)
	Autumn	210(20.7%)	804(79.3%)	151(15.8%)	802(85.1%)
	Winter	203(21.2%)	753(78.8%)	131(15.4%)	720(84.6%)
13	Spring	187(17.7%)	872(82.3%)	155(15.6%)	842(84.4%)
	Summer	196(18.0%)	896(82.0%)	160(16.1%)	835(83.9%)
	Autumn	180(17.7%)	836(82.3%)	152(15.8%)	808(84.2%)
	Winter	187(17.8%)	862(82.2%)	119(12.3%)	846(87.7%)
14	Spring	180(15.7%)	970(84.3%)	151(14.8%)	872(85.2%)
	Summer	197(16.5%)	994(83.5%)	166(15.0%)	940(85.0%)
	Autumn	177(16.0%)	929(84.0%)	140(13.3%)	914(86.7%)
	Winter	165(16.6%)	828(83.4%)	143(14.9%)	820(85.1%)
15	Spring	30(15.2%)	167(84.8%)	15(8.7%)	157(91.3%)
	Total	5676(15.8%)	30208(84.2%)	4522(13.4%)	29287(86.6%)

Data are presented as number (% within month).

* Adjusted residual ≤-2 ; ** Adjusted residual ≥+2.

DISCUSSION

In the present study, we found that the height and weight of schoolchildren were influenced by variation in month and season of birth, with a tendency to increase from Apr, reach a peak in May or Jun and then gradually decrease until Mar (from spring to winter) ; this trend was pronounced during eight consecutive years of repeated observation.

The influences of month and season of birth on growth in height and weight have been well documented (12-15). In agreement with our findings, Weber, *et al.* (12) indicated that in Australia (southern hemisphere), males born between Feb to Jul were taller than those born in the remaining months, and Kihlbom, *et al.* (13) reported that in Sweden (northern hemisphere) males born between Mar and May were significantly taller than those born in Nov or Dec. Because the effect seems to be similar in both the hemispheres, some common factor across the world was suggested. However, the studies of Shephard, *et al.* (14) and Koscinski, *et al.* (15), both in the northern hemisphere, revealed contradicting findings that children born between Jul and Mar and those between Oct and Mar were significantly taller and heavier, respectively, than those born in the remaining months. Consequently, the above-mentioned literature do not support the hypothesis that global factors, including the total amount of energy reaching the earth and hemisphere-related climatic conditions, act through the UV-dependent production of vitamin D, enzymes or hormones influencing growth of body size. These inconsistent results may surface from differences in geographical location, season, climate, month of anthropometric measurement, genetic, environmental and socioeconomic factors.

In addition, high birth weight and early exposure to cold conditions have been reported to be associated with obesity during adulthood because of the increase in the number of adipose tissues during cold conditions (20). In view of this, the highest prevalence of obese 6-year-old children born during spring and obese 10-year-old girls born during winter can be explained partly by the temperature rhythm in Tokushima Prefecture (Fig. 4). However, early exposure to cold condition alone cannot account for the greater prevalence of obese 7-year-old boys born during summer, but rather the interaction between high birth weight and early exposure to cold or other factors. Unfortunately, such interaction cannot be used to explain our findings because of the lack of birth weight data in Tokushima schoolchildren. Since no significant difference in DOB among the four seasons was found in both boys and girls, we infer that there is no influence of season of birth on DOB.

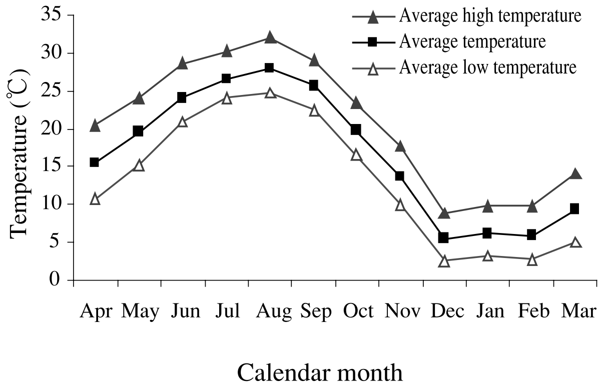

Fig. 4. Temperature rhythm in Tokushima Prefecture. Data from the annual report of Tokushima meteorological observatory, 2005.

Until date, there have been no definitive explanations of why body height and weight depend on the month of birth. Nevertheless, there are several possible explanations of the observed dependence of height, weight and DOB on month and season of birth.

First, we agree with the postulation of Weber, *et al.* (12) that the periodicity of height and weight may be due to influences extending from the time of late pregnancy to the first postnatal year, and infer a phylogenetic remnant in humans because seasonal photic input is known to regulate various body functions and growth in mammals. Human growth appears to be the fastest during the three months before birth and during infancy. Weight doubles and infants grow taller by about 10 cm during the first three months of birth (21), and body fat percentage increases rapidly from 12% at birth to 25% in about 6 months (22). Meanwhile, growth deficits that arise before the fourth year cannot be compensated fully even if good or excellent environmental conditions follow (23).

Second, the dependence of height, weight and obesity on nutritional factors and diseases has been known for a long time. In Japan, eating habits and the composition of food have been influenced by changes in climate and temperature over the four seasons (24). Of 30 nutritional components of the diet, most intakes (87%), including energy, proteins, lipids, vitamins and minerals (except for carbohydrate, phosphorus, vitamin D, oleic acid, alpha-linolenic acid and cholesterol) varied significantly with seasons. The average daily intake of these nutrients reduced in the order, autumn, winter, spring and summer (25, 26). In addition, there was significant seasonal variation in the amount of unabsorbed dietary carbohydrate from breakfast, which was the largest during winter and the smallest during autumn among young female Japanese subjects (27). On the other hand, children are more prone to infectious diseases in the cold season than in others and birth month affects the probability of falling ill (9-12). Thus, we infer that the effect of month of birth on height and weight may be due to seasonal variation in food intake, eating habits and early exposure to diseases.

Third, the socioeconomic status of the family may be important in determining height and weight. Kihlbom, *et al.* (13) and Koscinski, *et al.* (15) reported strong and significant effect of month of birth in a group of people with high socioeconomic status. Fathers in this group more often had their children during spring. We cannot draw any conclusion on such a relationship in this study owing to lack of socioeconomic data.

Finally, these growth characteristics (height, weight and obesity) are influenced by genetic factors as well as environmental and socioeconomic conditions. Studies on candidate-gene associations and genome-wide scans for human obesity have implicated many loci and genes on autosomal chromosomes in the development of human height and obesity (28, 29).

All the hypotheses discussed above need to be tested by prospective studies taking into account the effects and interactions among environmental and socioeconomic conditions, as well as genetic factors during the process of growth in children. Accordingly, in the context of a cross-sectional study conducted on a large sample with data standardization and separate analyses with regard to gender and age, our findings suggest that the month and season of birth influence height and weight but not the degree of obesity in Tokushima schoolchildren.

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REFERENCES

1. Matsushima Y, Yoshiike N, Kaneda F, Yoshida K, Takimoto H : Trends in childhood obesity in Japan over the last 25 years from the national nutrition survey. Obes Res 12 : 205-214, 2004
2. Kobayashi M, Kobayashi M : The relationship between obesity and seasonal variation in body weight among elementary school children in Tokyo. Econ Hum Biol 4 : 253-261, 2006
3. Togashi K, Masuda H, Rankinen T, Tanaka S, Bouchard C, Kamiya H : A 12-year follow-up study of treated obese children in Japan. Int J Obes 26 : 770-777, 2002
4. Sei M, Nakatsu T, Yuasa K, Tanaka H, Indriani, Munakata H, Nakahori Y : The prevalence of metabolic complications in children with severe obesity. Pediatrics International 49, 2007 (in printing)
5. Lam DA, Miron JA, Riley A : Modeling seasonality in fecundability, conceptions and births. Demography 31 : 321-346, 1994
6. Miura T, Nonaka K, Shimura M, Nakamura I : A study of the sex ratio of first-born according to the mother's month of birth. Arch Gynecol 233 : 263-266, 1983
7. Miura T, Nakamura I, Nonaka K, Shimura M : Correlation between month of menarche and month of birth. Arch Gynecol 240 : 195-200, 1987
8. Doblhammer G, Vaupel JW : Lifespan depends on month of birth. Proc Natl Acad Sci 98 : 2934-2939, 2001
9. Severson RK, Davis S : Breast cancer incidence and month of birth : evidence against an etiologic association. Eur J Cancer Clin Oncol 23 : 1067-1070, 1987
10. Hu YH, Kuroishi T, Matsushita Y, Nagata C, Shimizu H : Birth season and breast cancer risk in Japan. Breast Cancer Res Treat 39 : 315-319, 1996
11. Nonaka K, Imaizumi Y : Deaths from cerebrovascular diseases correlated to month of birth : elevated risk of death from subarachnoid hemorrhage among summer-born. Int J Biometeorol 44 : 182-185, 2000
12. Weber GW, Prossinger H, Seidler H : Height depends on month of birth. Nature 391 : 754-755, 1998
13. Kihlbom M, Johansson SE : Month of birth, socioeconomic background and development in Swedish men. J Biosoc Sci 36 : 561-571, 2004
14. Shephard RJ, Lavallee H, Jequier JC, LaBarre

R, Volle M, Rajic M : Season of birth and variations in stature, body mass, and performance. Hum Biol 51 : 299-316, 1979
15. Koscinski K, Krenz-Niedbala M, Kozlowska-Rajewicz A : Month-of-birth effect on height and weight in Polish rural children. Am J Hum Biol 16 : 31-42, 2004
16. Health examination manual of schoolchildren (in Japanese). Nippon Gakkou Hoken Kai, Tokyo, 1995, pp.14-15
17. Yamazaki K, Matsuoka H, Kawanobe S, Hujita Y, Murata M : Evaluation of standard body weight by sex, age, and height on the basis of 1990 school year data. The Journal of the Japan Pediatric Society 98 (in Japanese, abstract in English) : 96-102, 1994
18. Japan Society for the Study of Obesity : Manual for Obesity child (in Japanese). Ishiyaku Publishers, Tokyo, 2004, pp.2-5
19. Everitt BS : The analysis of contingency tables (in Japanese). Shinyosha, Tokyo, 1980, pp.40-50
20. Phillips DI, Young JB : Birth weight, climate at birth and the risk of obesity in adult life. Int J Obes 24 : 281-287, 2000
21. Kuroda Y : Textbook of child health and child disease (in Japanese). Nankodo, Tokyo, 2001, pp.5-6
22. Morikawa A, Uchiyama M : Standard Pediatrics (in Japanese). Igakusyoin, Tokyo, 2004, p.8
23. Mahlmann N, Petersen K : Influences of environmental conditions during infancy on final body stature. Pediat Res 11 : 695-700, 1977
24. Kasai K : Meteorological medicine (in Japanese). Kanehara Publishing, Tokyo, 1980, pp.66-82
25. Tokudome Y, Imaeda N, Nagaya T, Ikeda M, Fujiwara N, Sato J, Kuriki K, Kikuchi S, Maki S, Tokudome S : Daily, weekly, seasonal, within- and between-individual variation in nutrient intake according to four season consecutive 7 day weighed diet records in Japanese female dietitians. J Epidemiol 12 : 85-92, 2001
26. Sasaki S, Takahashi T, Iitoi Y, Iwase Y, Kobayashi M, Ishihara J, Akabane M, Tsugane S : Food and nutrient intakes assessed with dietary records for the validation study of a self-administered food frequency questionnaire in JPHC Study Cohort I. J Epidemiol 13 : 23-50, 2003
27. Tsumura Y, Hirota N, Tokura H, Rutkowska D, Sone Y : Seasonal variation in amount of unabsorbed dietary carbohydrate from the intestine after breakfast in Japanese subjects. Chronobiol Int 22 : 1107-1119, 2005.
28. Christopher GB, Andrew JW, Philippe F : The genetics of human obesity. Nature 6 : 221-234, 2005
29. Liu YZ, Xiao P, Guo YF, Xiong DH, Zhao LJ, Shen H, Liu YJ, Dvornyk V, Long JR, Deng HY, Li JL, Recker RR, Deng HW : Genetic linkage of human height is confirmed to 9q22 and Xq 24. Hum Genet 119 : 295-304, 2006