Growth Reacceleration of School Children in the City of Sendai, Japan

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NAKATSUKA, H., SATOH, H. and IKEDA, M. *Growth Reacceleration of School Children in the City of Sendai, Japan.* Tohoku J. Exp. Med., 1998, **184** (4), 301–309 — Height and weight of 6th year-grade children in primary schools and the 3rd year-grade children in junior high schools have been recorded in Sendai in every October since pre-World War II days, and the secular trends of the annual gains in the measures were compared among the latest three decades of 1965–74, 1975–84 and 1985–94. Acceleration and then reduction in acceleration in growth were observed in the first and the second decade, respectively, and such were followed by reacceleration in the latest 10 year-period. The three-phased changes were most evident in height and weight of primary school children of both sexes, whereas less clear or unclear among children in junior high schools. ————— growth; height; reacceleration; school children; weight © 1998 Tohoku University Medical Press

It is widely accepted that the growth of children especially secular gain or loss in height and weight is a general marker of health of the people in the community (Buzina 1976; Irwig 1976; Monteiro and Torres 1992; Frongillo and Hanson 1995). Accordingly, we have been monitoring the secular changes in growth of the 6th year-grade (12 year-old) children in primary schools and 3rd year-grade (15 year-old) children in junior high schools in the city of Sendai since pre-World War II days till the present time (Kondo et al. 1978; Ikeda et al. 1983; Nakatsuka et al. 1988, 1990). When the gains in height or weight in a given year over the measures in the immediately preceding year (i.e., secular gains) were calculated, the general trends in secular gains in late 1970's to early 1980's were such that the gains although positive were gradually reduced year by year to

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suggest that the body size curve of adult Japanese as represented by the Sendai citizens would reach a plateau in nearest future (Ikeda et al. 1983; Nakatsuka et al. 1988). Rather contrary to such reduction in annual gains, however, a new trend of reincrease (or reacceleration) in body size gain has been observed in very recent years. This new observation is described in the present communication.

SUBJECTS AND METHODS

Study population

It is a well established tradition of the City of Sendai (Kondo et al. 1978) that the Education Commission of the city measures, in every October, the height and weight of all children at the 6th year-grade in primary schools (i.e., at 12.0 years of age on an average) and in the 3rd year-grade in junior high schools (15.0 years of age). Measurements were made with minimum underwear and without shoes (to the nearest 0.1 cm and 0.1 kg for height and weight, respectively). The measures in the latest decade (1985–1994) were kindly supplied by the Commission to the Department of Environmental Health Sciences, Tohoku University Graduate School of Medicine, under the conditions that due caution be taken not to invade the privacy of the children. The data were combined with the 1965–1984 values which were previously published (Kondo et al. 1978; Ikeda et al. 1983; Nakatsuka et al. 1988, 1990) for statistical evaluation.

The area of the city was expanded in 1988 by merging with surrounding towns. Accordingly, the measures of the children in the pre-merge area were selected for better comparison. In practice, the measures of about 4000 boys and roughly equal number of girls were available in each of the two year-grades (thus 15 000 to 16 000 children in total/year; Tables 1 and 2), which accounted for approximately 70% of the corresponding school children population in the whole city of Sendai.

Data on national school health statistics

The data were cited from annual publications from the Ministry of Education, Science, Sports and Culture of the Government of Japan (1966–1995).

Statistical analysis

Regression analysis was conducted to examine annual trends. Statistical significance of the difference in the slopes of calculated regression lines was examined after Ichihara (1990).

RESULTS

The arithmetic mean height and weight for 6 year-grade primary school children in 1965 to 1994 are presented in Table 1, and the values for the 3rd year-grade junior high school children are shown in Table 2. In both tables, a code number (i.e., 1 to 30) was given to each year to facilitate reading. When the

TABLE 1. *Height and weight of school children in Sendai, 1965–1994: 6th year-grade children in primary schools*

Code	Boys				Girls		
	Year	Number	Height (cm)	Weight (kg)	Number	Height (cm)	Weight (kg)
1	1965	3680	144.0	36.0	3423	146.1	37.9
2	6	3586	144.4	36.4	3218	146.3	38.2
3	7	3604	144.6	36.8	3313	146.5	38.6
4	8	3665	144.9	36.9	3334	146.7	38.9
5	9	3477	145.2	37.3	3273	146.9	39.0
6	1970	3705	144.9	37.3	3631	147.3	39.4
7	1	3604	145.4	37.8	3255	147.2	39.4
8	2	3766	145.7	38.1	3525	147.7	39.9
9	3	3745	145.8	38.5	3631	148.0	40.0
10	4	3875	146.3	38.5	3700	147.9	39.8
11	5	4039	146.1	38.2	3767	147.8	39.5
12	6	4063	146.6	38.7	3885	148.1	39.9
13	7	4399	146.8	38.7	4130	148.5	40.0
14	8	4081	146.1	38.3	3850	148.1	39.6
15	9	4705	146.8	39.1	4483	148.6	39.3
16	1980	4819	146.8	39.1	4370	148.5	40.1
17	1	4708	146.7	38.9	4463	148.5	40.0
18	2	4902	146.9	39.1	4606	148.5	40.0
19	3	5056	147.0	39.2	4815	148.7	40.3
20	4	5282	146.9	39.1	4927	148.6	40.1
21	5	5355	147.0	39.5	5034	148.8	40.5
22	6	5243	147.3	40.0	4997	148.9	40.7
23	7	5028	147.7	40.3	4694	149.0	40.9
24	8	4915	148.1	40.7	4594	149.2	41.4
25	9	4673	148.1	40.9	4405	149.3	41.3
26	1990	4713	148.0	40.8	4271	149.5	41.4
27	1	4445	148.5	41.3	4177	149.5	41.8
28	2	4362	148.4	41.2	4026	149.5	41.8
29	3	4100	149.0	41.8	3936	149.7	42.3
30	4	4166	149.6	41.3	3884	149.8	41.6

Arithmetic means are shown.

increment in the measures (i.e., height and weight) was calculated as the difference of the value for the 10th year of a given decade from that for the first year (i.e., the gain in the decade), it was found that the gain in the decade may not be uniform among the three decades. For example, 6th year-grade boys became taller by 2.3 cm (as the difference of 146.3 cm [for 1974] from 144.0 cm [for 1965])

TABLE 2. *Hight and weight of school children in Sendai, 1965–1994: 3rd year-grade children in junior high schools*

Code	Boys				Girls		
	Year	Number	Height (cm)	Weight (kg)	Number	Height (cm)	Weight (kg)
1	1965	4488	162.9	51.5	3820	154.7	48.2
2	6	4115	163.3	52.3	3586	154.7	48.7
3	7	3440	163.6	52.9	2877	155.0	49.2
4	8	3743	163.8	53.2	3219	155.2	49.8
5	9	3625	164.4	53.5	3046	155.6	49.9
6	1970	3763	164.7	54.3	3162	155.5	50.0
7	1	3722	164.7	54.1	3231	155.6	50.1
8	2	3551	165.1	54.6	2974	156.0	50.4
9	3	3699	165.2	54.0	3274	156.1	49.8
10	4	3826	165.4	54.3	3198	156.0	49.6
11	5	3831	165.7	54.4	3376	156.1	49.8
12	6	3646	165.6	54.6	3350	156.2	50.0
13	7	3661	165.9	54.7	3351	156.3	49.6
14	8	3884	166.0	55.0	3436	156.4	49.4
15	9	4087	166.0	55.3	3803	156.3	49.8
16	1980	4207	166.2	55.6	3822	156.7	50.4
17	1	3840	166.1	55.3	3509	156.6	50.4
18	2	4574	166.3	55.9	4125	156.7	50.1
19	3	4759	166.2	56.2	4217	156.7	50.4
20	4	4570	166.3	56.1	4278	156.8	50.6
21	5	4744	166.5	56.4	4407	156.9	50.6
22	6	4873	166.7	56.8	4627	157.0	51.1
23	7	5113	166.7	56.8	4691	157.0	51.0
24	8	5089	166.7	57.2	4796	157.0	50.9
25	9	4931	166.7	57.3	4711	157.0	50.8
26	1990	4741	167.1	57.9	4418	157.1	51.1
27	1	4625	167.4	58.0	4233	157.2	51.3
28	2	4413	167.4	58.0	4071	157.2	51.4
29	3	4399	167.3	58.2	3940	157.3	51.5
30	4	4124	167.5	57.7	3888	157.2	51.1

Arithmetic means are shown.

in the first decade in Table 1, but gained less (i.e., 0.8 cm) in the second decade, and grew better with a gain of 2.6 cm in the third decade. Similarly, girls became heavier by 1.9 kg in the first decade, less so (0.6 kg) in the second decade, and substantially more (1.1 kg) in the third decade.

A similar calculation with the height of 3rd year-grade junior high school

Fig. 1. Height of 6 year-grade primary school children in Sendai, in 1965 to 1994. Open and solid circles are for boys and girls, respectively. The broken lines are calculated regression lines for the decade.

Fig. 2. Weight of 6 year-grade primary school children in Sendai, in 1965 to 1994. Notes are as under Fig. 1.

boys showed that the gain in the first decade was largest (i.e., 2.5 cm) followed by that in the third decade (1.0 cm), and the gain in the second decade was smallest (0.6 cm). The changes in height of girls and weight of boys and girls showed however a steady reduction in gains throughout the three decades.

For better visual understanding of the changes, the data in Table 1 was graphically presented in Fig. 1 (height) and Fig. 2 (weight). The figures suggest that there has been a reacceleration in growth in 1985-1994 after reduction in acceleration in the preceding decade, and that such changes appeared to be more evident in the body weight of the boys and girls (Fig. 2) rather than in height

(Fig. 1).

The changes were even better understood when regression lines were calculated for each of the three decades. Namely, the regression lines for each of the three decades were calculated for height and weight of boys and girls both in primary schools and junior high schools in Sendai. The slopes of the lines were then compared in Table 3 for quantitative evaluation of the possible changes in the annual gains (i.e., acceleration or its reduction). It should be added that all correlation coefficients of the regression lines were statistically significant ($p < 0.05$), the smallest coefficient value being 0.616.

The comparison of the slopes showed that the combination of large acceleration (in the first decade) followed by its reduction (in the second decade) and then

TABLE 3. *Annual gain in height and weight of children during three different decades, in the City of Sendai and In Japan as a whole*

School grade		Height				Weight			
Decade studied		Boys		Girls		Boys		Girls	
Area studied		A	r	A	r	A	r	A	r
6th year-grade in primary schools									
1965-74	Sendai	0.228 ^a	0.976	0.219 ^{ab}	0.985	0.287 ^a	0.992	0.234 ^a	0.973
	Japan	0.352 ^d	0.997	0.392 ^{de}	0.988	0.325 ^d	0.994	0.349 ^d	0.995
1975-84	Sendai	0.072 ^{ab}	0.666	0.077 ^a	0.778	0.092 ^{ab}	0.775	0.065 ^a	0.616
	Japan	0.122 ^d	0.938	0.113 ^d	0.890	0.134 ^d	0.942	0.112 ^d	0.886
1985-94	Sendai	0.243 ^b	0.958	0.108 ^b	0.985	0.212 ^b	0.929	0.164 ^a	0.899
	Japan	0.172 ^d	0.967	0.130 ^e	0.986	0.205 ^d	0.971	0.188 ^d	0.990
3rd year-grade in junior high schools									
1965-74	Sendai	0.277 ^c	0.984	0.162 ^c	0.964	0.292 ^c	0.899	0.167 ^c	0.742
	Japan	0.401 ^{fg}	0.997	0.252 ^f	0.981	0.390 ^{fg}	0.983	0.272 ^{fg}	0.975
1975-84	Sendai	0.076 ^c	0.908	0.079 ^c	0.944	0.204	0.975	0.093 ^c	0.729
	Japan	0.162 ^f	0.932	0.141 ^f	0.969	0.205 ^f	0.969	0.101 ^f	0.899
1985-94	Sendai	0.116 ^c	0.945	0.039 ^c	0.915	0.186 ^c	0.904	0.066 ^c	0.724
	Japan	0.167 ^g	0.986	0.044 ^f	0.917	0.203 ^f	0.986	0.083 ^g	0.905

Measurement was made in October of each year (thus, at the mean ages of 12.0 and 15.0 years) in Sendai, and it was in spring (at 11.5 and 14.5 years of age) in Japan as a whole. Sendai means the area of the City of Sendai as defined in the Materials and Methods section, and Japan means the whole country.

A is the slope of the regression line, $Y = AX + B$, where X is the year of the measurement as coded in Tables 1 and 2, and Y is either the height (in cm) or the weight (in kg). Thus, A means the gain (in height [in cm] or in weight [in kg]) per year. r is the correlation coefficient of the regression line; all r's are statistically significant ($p < 0.05$).

Values in the same (vertical) column and with the same superscript (i.e., a, b, c, d, e, f, g) are significantly ($p < 0.05$) different from each other.

small reacceleration (in the third decade) was most evident among primary school children (in both height and weight of boys and girls), whereas the gain turned out continuously smaller throughout the three decades for junior high school children especially among girls, although the changes in height gain (if not weight gain) among boys were more or less similar to that of the boys in primary schools.

In order to investigate if changes had been taking place nation-widely, the same analysis was conducted taking advantage of the data published in national school health statistics (Ministry of Education, Science, Sports and Culture 1966–1995). Interestingly enough, the national data exactly reproduced the findings in Sendai, as shown in Table 3.

DISCUSSION

It was previously made clear that the children of a given year were always taller and heavier than their counterparts of the preceding year, and that the increment was once as large as 0.5 cm and 0.4 kg per year (Kondo et al. 1978). Such acceleration in growth was then followed by gradual reduction in acceleration in the years around 1980 (Ikeda et al. 1983) to the extent that no additional gain in body size was foreseen in the nearest future (Nakatsuka et al. 1988). Children in the peripheral part of the city were once shorter and lighter than the children in the city center (Kondo et al. 1978), but such difference has also ceased to exist in recent years (Nakatsuka et al. 1990). Contrary to the estimation, the continuation of the monitoring disclosed reacceleration in growth (Figs. 1 and 2). The reacceleration was observed not only in Sendai but in a whole country of Japan, although the reacceleration was evident only among primary school children and not among junior high school children (Table 3). In connection with the observed reacceleration in body-size growth of boys and girls, it would be interesting to know possible acceleration in maturation. No related information (e.g., earlier onset of menarche among girls in Sendai) was available, unfortunately.

Attempts were once made to establish International Anthropometric Standards for adolescent populations, and evaluation studies (e.g., Kow et al. 1991; Ulijaszek 1994) followed to examine if the standards are globally acceptable. It is known that the genetic background and the environmental factors are two basic determinants of the growth of the children and that many environmental factors operate finally through nutrition and diseases (Steckel 1983), and that catch-up in growth may take place in children once the growth-suppressing factor(s) be removed (Roche 1981; Waterlow 1996). Succeeding studies mostly in developing countries identified that infections and poor nutritional conditions are among the most strongly affecting conditions (e.g., Adair and Guilkey 1997; Balam and Gurri 1994).

The life conditions of the children in the present study are however quite contrary to such situations, and essentially similar to what Hallberg et al. (1993)

called an "affluent society". In a policy document on education (Ministry of Education, Science, Sports and Culture 1996), for example, several pages were spent on psycho-social issues such as school absenteeism and scape-goating in class room, but only a few lines were used for nutrition (nutrition being in association with the roles of school canteen service in nutrition education) and essentially none for infectious diseases, implying that undernutrition and infections are in fact no longer matters of concern. Such is essentially the case also in a review document on the education (including school health) in Sendai (Education Board 1996).

Searches are yet to be done to identify the conditions which have suppressed the growth of the 6 year-grade primary school children in the years around 1980. It is equally important to examine possible long-term medico-biological significance of growth reacceleration in recent years, as it might be the case that the promotion of child growth is not always beneficial (Barker et al. 1990).

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