

Characteristics on the Physical Growth of Children and Youth in Modern Korea*

Myung Kim* · Hye kyeong Kim**

*Department of Health Education, Ewha Womans University

**Korea Association of Health Promotion, Health Promotion Research Institute

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I. Introduction

Youth(adolescence) is the period of transition from childhood to adulthood(Kim et al., 2002, Leifer and Hartston, 2004). During this time, there are traumatic physical changes that occur in the development of brain, stature, motor skills and hormone production which result in sexual maturation(Beunen et al., 1988). Especially, physical growth of youth should be a great concern to all because it could be the statement of his or her general condition for

health. Tanner proposed that children and adolescents be measured often and accurately to identify individual's and groups of individuals within a community who require special care and to identify illness that influence growth. Measurement of growth could be used as an index of the general health and what the key solutions are, and nutrition of population or subpopulation of adolescents(Rogol et al., 2000). Furthermore, the various measures of physical growth are valid indicators of future outcomes of functional significance, such as

* The research on which this paper is based was supported by Ewha Womans University Research Grant in 2005.

Corresponding Author: Myung Kim

11-1 Daehyun-dong Seodaemoon-gu Seoul, Korea (120-750)
Department of Health Education, Ewha Womans University
Tel: +82-2-3277-2582, E-mail: mykim@ewha.ac.kr

school achievement or employment(WHO, 1999).

The characteristics on physical growth of youth changes over time. Current general understandings about physical growth of youth must be different from those commonly recognized 10 years ago. Our previous study(Kim et al., 2002) analysed the secular trend in Korean adolescents' physical growth from 1964 to 1999. Results indicated that the measures of adolescents' physical growth including stature, weight, chest girth, and sitting height were shown to be gradually increased between 1964 and 1999. Annual changing trends are influenced by various socioeconomic conditions, habits of meal, practice of exercises, overall lifestyle and so on. Annual changing trends may suggest what problems adolescents are facing on their physical growth and what the key solutions are.

In this study, we investigated the difference in growth distance of Korean youth between 1999 and 2005, and significant differences were found at nearly all ages of 6 through 16. This could be the only one of evidences concerning the era differences in physical growth of youth. In this sense, we tried to formulate the most recent traits of physical growth of youth, and to identify the need of youth for health promotion planning in modern Korea.

II. Methods

1. Study Participants and Data Collection

Study participants were 171 boys and 400 girls in two senior high schools in Seoul, Korea. They were all third graders.

Data collection was conducted in May, 2005. The individual students were asked for the growth records on stature, body weight, sitting height and chest girth from 6 years old through 16, with health records. If the health records were not kept in themselves, they were asked to visit the elementary school or junior high school to take the health records. Through this process, students' longitudinal data on physical growth from 6 through 16 years old were collected(the retrospective way though). For some data sets with missing data, interpolation was attempted. Several data sets in which some funny data or datum were included were also found. The funny data were also checked and revised by using the interpolation methods, if possible and necessary. Furthermore, their life styles were also surveyed as the back ground data supporting their physical growth, but they were not discussed in this paper.

2. Data Interpolation

For interpolation, two kinds of techniques were used; the divided difference method

and cubic spline method. For the case in which two successive data existed at both neighbours of lacked datum, cubic spline method was applied, and for the case in which only one datum was found at either side of neighbour of lacked datum, the divided difference method was applied.

For other cases in which interpolation was not applicable, data sets were excluded from the analysis. After these checking procedures were applied to all data sets, sample size of 571 was obtained.

3. Data Analysis

Data on stature and body weight were analysed for this study. Mean and standard deviation were calculated for stature, body weight, peak age and peak velocity of stature and body weight. Significance tests on some measures were performed by t-test and ANOVA.

III. Results

1. General traits of physical growth:

Stature and body weight

1) Stature

The general growth curves of stature were shown in Fig. 1. These curves were

determined through connecting the means of stature by age and gender. The growth differences between boys and girls were tested and the results were shown in Table 1. The significant gender differences were found at all ages except 9 and 12 years old. Before 9 years old, boys were significantly taller in stature than girls, but girls were significantly taller than boys at age of 10 and 11, and after 13 years old, the boys were significantly taller than girls again. This has been widely and commonly recognized in many studies. That is, the girls became taller in stature than boys during the specific time of adolescence, although only a few years. Furthermore, this understanding has been recognized widely in many studies of physical growth, so this can be recognized as one of general rules of physical growth.

However, Fig. 2 shows the growth distance curves of peak age 11 for boys and girls. They did not show any traits understood in over-all mean growth distance curves. At all ages, boys were taller in stature than girls. Therefore, it could be recognized that such a common understanding as mentioned above was induced only from over-all mean growth curves.

Table 1. Gender difference in growth distance at each age

Unit: Mean±SD

Variable	Stature (cm)			Body weight (kg)		
	Age	Boy (n=171)	Girl (n=400)	p	Boy (n=171)	Girl (n=400)
6	119.7 ± 4.63	118.6 ± 4.81	>	22.6 ± 3.64	21.8 ± 3.46	>
7	125.6 ± 4.95	124.4 ± 5.06	>>	26.2 ± 4.57	24.8 ± 4.16	>>
8	131.3 ± 5.27	130.3 ± 5.57	>	29.5 ± 5.68	28.1 ± 5.11	>>
9	136.5 ± 5.56	136.1 ± 6.02	ns	33.5 ± 6.73	31.9 ± 6.54	>>
10	141.8 ± 5.88	143.0 ± 6.68	<	37.5 ± 7.95	36.4 ± 7.65	ns
11	147.9 ± 6.83	149.7 ± 6.72	<<	42.4 ± 9.10	41.6 ± 8.22	ns
12	156.0 ± 8.24	155.0 ± 5.95	ns	49.0 ± 10.24	46.5 ± 8.44	>>
13	162.9 ± 7.57	158.1 ± 5.21	>>	54.4 ± 10.89	50.5 ± 8.38	>>
14	168.0 ± 6.48	159.8 ± 5.02	>>	60.3 ± 11.68	53.1 ± 8.56	>>
15	171.3 ± 5.75	160.7 ± 5.02	>>	64.7 ± 12.31	54.7 ± 8.67	>>
16	172.4 ± 5.58	161.3 ± 5.03	>>	67.3 ± 12.90	56.0 ± 8.85	>>

Note: >and >> means that boys are significantly larger at p<0.05 or p<0.01, and < and << means that girls are significantly larger at p<0.05 or p<0.01, and ns means that no significant differences were found between boys and girls.

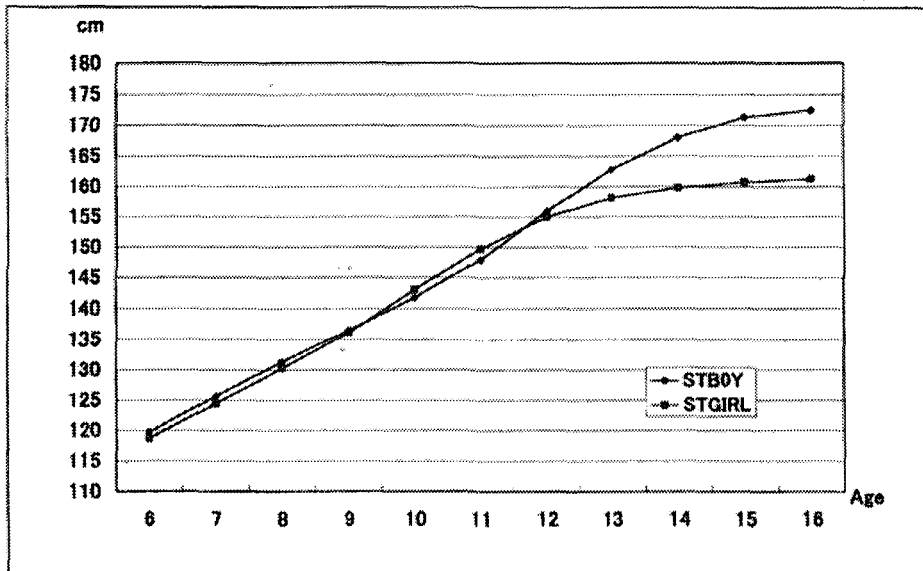


Fig 1. Gender differences in stature growth

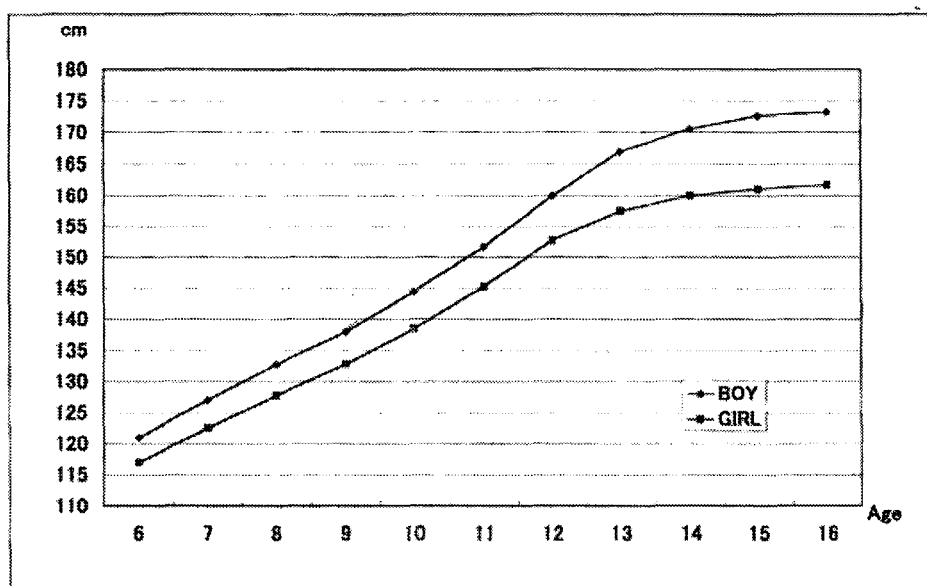


Fig 2. Gender differences in stature growth of same peak age at 11

2) Body Weight

The body weight of boys seemed to be heavier than girls at all ages. Table 1 shows significant differences at nearly all age except 10 and 11 years old, at which the boys' means were larger than girls', but the differences were not significant. In stature, the differences found at these ages showed that girls were taller than boys, but this was not the case in body weight.

2. General traits of growth velocity

1) Stature

Fig. 3 shows the boys' general trend of

growth velocity and growth distance in stature from 6 through 15 years of ages. The growth velocity was estimated by annual increments. The maximum of increments showed the so-called peak velocity, so the peak age of boys is 11 years old and the one of girls 9 years old, so it was inferred that the peak velocity of stature tended to appear 2 years later in boys than in girls, and the boys' velocity seemed to be a little smaller than the one of girls; 8.09cm in boys and 8.67cm in girls, but any significant difference was not found between them.

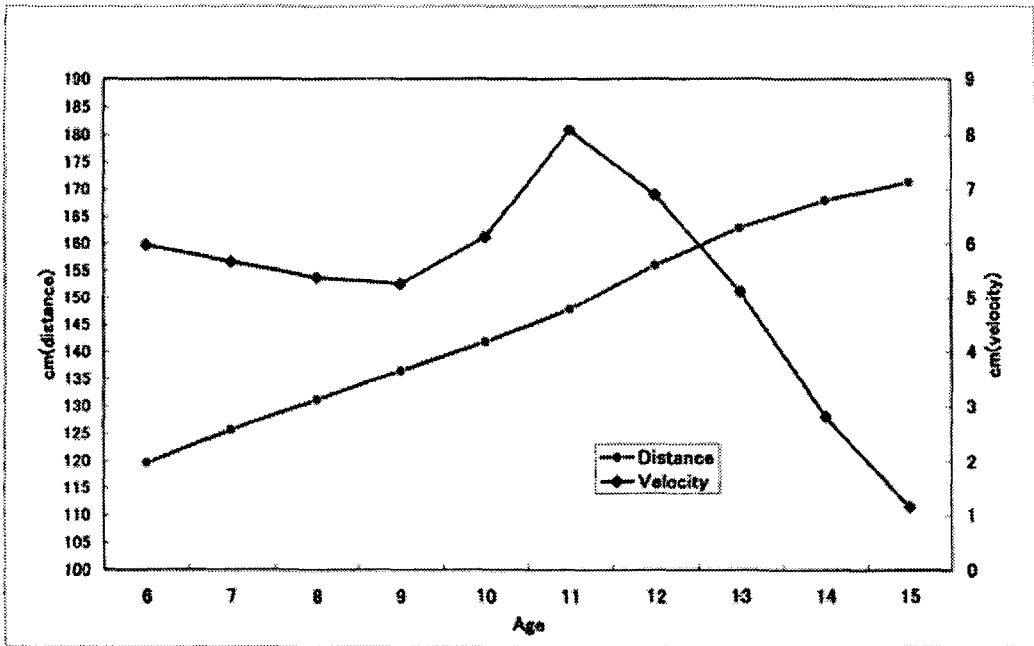


Fig 3. Boys' growth distance and velocity in stature

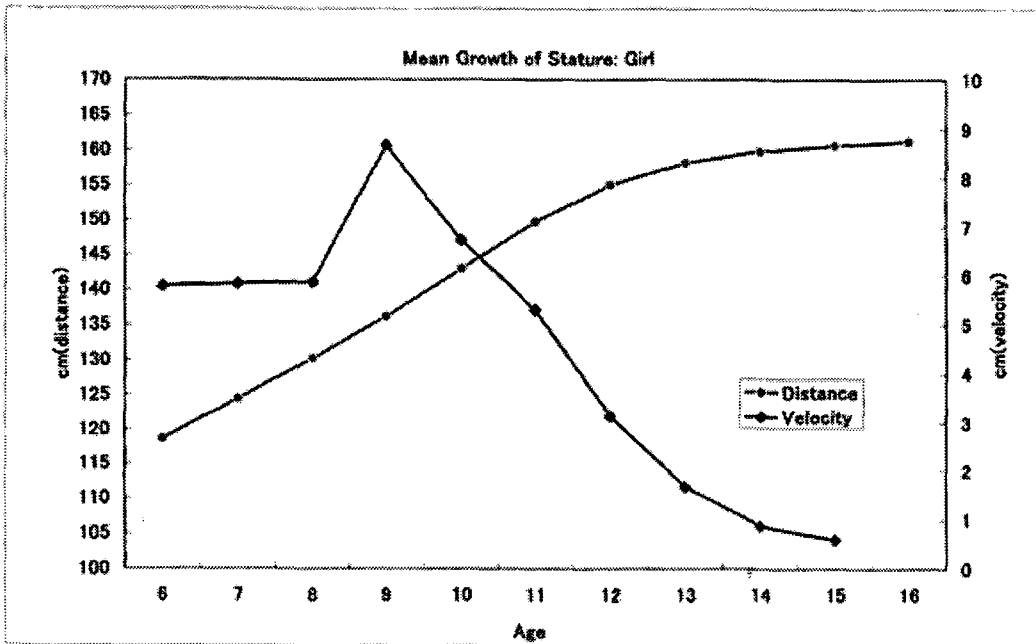


Fig 4. Girls' growth distance and velocity in stature

2) Body weight

The peak velocity appeared at 11 years old for boy and 10 years old for girls. Thus it could be inferred that the peak age was one year later in boys than in girls. But the peak velocity was significantly larger in boys than girls.

3) Comparison of stature with body weight on peak age and peak velocity

Table 2 shows the means of peak age and peak velocity in stature and body weight by gender. In peak age, any significant difference between stature and body weight was not found for boys, but the peak age of stature was significantly nearly one year younger than that of body weight for girls. The differences in peak age of stature and body weight between boys and girls were significant, so it could be inferred that the peak velocity would appear significantly

later in boys than in girls for both stature and body weight.

Table 3 shows the frequency distribution of peak ages in stature and body weight for boys and girls. Between the ages of 10 and 13, about 90% of boys arrived at the peak age of stature growth. On the other hand, nearly 95% of girls arrived at the peak age of stature growth between 6 and 12 years old. In body weight growth, nearly 87% of boys arrived at the peak age between 10 and 14 years old, and more than 94% of girls did so during the ages of 6 through 12. Thus, it could be inferred that boys' peak ages of stature and body weight distributed more narrowly than those of girls. In general, the peak ages of body weight distributed a little more widely than those of stature for both boys and girls.

Table 2. Significance test of mean differences on stature and body weight

Variable	Stature		Body weight		t-test 1)
	n	Mean ± SD	n	Mean ± SD	
Mean Peak Age					
Boy	162	11.64 ± 1.01	158	11.78 ± 1.38	t=1.056
Girl	397	9.42 ± 1.39	397	10.23 ± 1.51	t=7.834 **
t-test 2)	t=18.301 **		t=11.120 **		
Mean Peak Velocity					
Boy	162	10.15 ± 2.12	158	9.39 ± 2.51	
Girl	397	8.56 ± 1.29	397	8.56 ± 1.29	
t-test 2)	t=10.810 **		t=9.607 **		

Note: 1) t-test 1) means the comparison between stature and body weight, and t-test 2) means the comparison between boys and girls.
 2) ** shows that significant difference was found at p<0.01.

Table 3. Frequency of peak age on stature and body weight

Unit: no. of person

Peak Age	Boy				Girl			
	Stature		Body Weight		Stature		Body Weight	
	n	%	n	%	n	%	n	%
6					17	4.3	15	1.3
7					22	5.5	11	2.7
8	4	2.3	6	3.5	46	11.5	41	10.3
9	5	2.9	9	5.3	110	27.5	59	14.8
10	16	9.4	18	10.5	111	27.8	96	24.0
11	67	39.2	46	26.9	75	18.8	94	23.5
12	47	27.5	29	17.0	10	4.0	75	18.8
13	24	14.0	38	22.2	3	0.8	14	3.5
14	8	4.7	18	10.5	0	0	3	0.8
15	0	0	7	4.1				
Total	171	100.0	171	100.0	400	100.0	400	100.0

4) The growth velocity by peak age on stature and body weight

General trend curves of growth velocity were shown and discussed at the previous section. And it was also discussed that the trend of growth velocity determined by peak age was different from the general trend determined by over-all means at each age.

Table 4 shows the means and standard deviations of peak velocity by peak age on stature and body weight. Significant differences were found in mean peak velocity between different peak ages in stature and body weight for both genders. For boys' stature, the peak velocity tended to

decrease with increase of peak age. There were significant differences among different peak age groups on stature and body weight for both genders. Therefore, it could be inferred that peak velocity might tend to increase with increase of peak age up to 9 years old, but thereafter, it might tend to decrease.

In body weight, as shown in stature, significant differences were found in growth velocity among different peak age groups. For boys, it could be inferred that peak velocity might tend to increase with increase of peak age, with an exception of peak age 12. In girls, significant differences were

found among different peak age groups, just as in boys. Therefore, it could be inferred that the peak velocity tended to decrease after 8 years old, and any significant

difference was not found in peak velocity between 6 and 7 years old(although the sample sizes of these peak age groups were so small).

Table 4. Mean peak velocity by peak age on stature and body weight

Peak Age	Boy		Girl	
	n	Mean ± SD	n	Mean ± SD
Stature				
6	*		17	8.37 ± 2.18
7	*		22	8.63 ± 1.75
8	*		46	8.69 ± 1.33
9	*		110	8.78 ± 1.12
10	16	10.24 ± 1.49	111	8.70 ± 1.14
11	67	10.91 ± 2.37	75	8.18 ± 1.12
12	47	9.87 ± 1.96	16	7.60 ± 1.20
13	24	9.15 ± 1.33	*	
14	8	8.60 ± 0.59		
Total	162	10.15 ± 2.12		
	F=8.25, p<0.01		F=6.91, p<0.01	
Body Weight				
6	*		5	7.48 ± 2.16
7	*		11	7.39 ± 1.67
8	*		41	8.31 ± 2.31
9	9	8.78 ± 1.77	59	7.68 ± 1.53
10	18	8.81 ± 2.05	96	7.63 ± 1.90
11	46	9.67 ± 1.80	94	7.35 ± 1.60
12	29	8.18 ± 2.02	75	7.32 ± 1.80
13	38	9.96 ± 2.78	14	6.49 ± 1.53
14	18	10.29 ± 3.59		
Total	158	9.39 ± 2.51		
	F=3.03, p<0.05		F=6.21, p<0.01	

Note: 1) * means sample size is 0 or less than 10, so any statistics are not shown.

2) Only statistics shown in table were used to determine grand mean and SD in the table.

3. Types of age trend of growth velocity

1) The number of local maxima appeared in growth velocity curve

Growth velocity gives more information on growth trait than growth distance. More studies have been focused on the peak velocity, but several local maxima were found generally in growth velocity curves. The peak velocity is defined as a maximum in several local maxima in growth velocity curve. The number of local maxima is also hypothesized to specify the changing trend of growth velocity. For example, one of local maxima existed before peak age may be defined as growth velocity at mid-growth spurt, and another local maximum appeared after peak age may be defined as the growth velocity at after-growth spurt. Actually, other kinds of local maxima may be found in the individual growth velocity curves. Thus, how growth can be characterized from the number of local maxima existed in growth velocity curve will be discussed in this section.

Table 5 shows the frequency of local maxima appeared in the changing trend of growth velocity. In 97% of boys and 99% of girls, one to three local maxima were found in the stature's growth velocity curves, and in 98% of boys and 95% of girls, one to three local maxima were found in the body weight's growth velocity curves. Then, if local maximum appears, the local minima is also

found in many cases. The table 5 also shows the frequency of local minima. The age of local minima appearance may be the set-up age of growth spurt; for example, local minimum just before peak age stands for the set-up age of adolescent growth spurt and its velocity, and local minimum just before mid-growth spurt peak age and the one just before after-growth spurt peak age are the set-up age of these growth spurt. Furthermore, as shown in Table 5, the case of more local maxima and minima also were found. This type can be also classified into three types in which the youngest age of local maximum is the peak age, the second age is the peak age, and the third age is the peak age at after-growth spurt. Among these local maxima, two local minima may exist. As mentioned before, the ages of these local minima suggest the start of growth spurt followed by. For boys and girls, a local maximum appears at 7 years of age in all types of three local maxima.

Although only maximum in several maxima of growth velocity curves has been widely discussed in many studies, but actually several local maxima appear in growth velocity curves. In other words, the growth process of individual may be characterized not only by peak velocity represented as maximum in several local maxima of growth velocities, but also by other maxima represented by the growth process.

Table 5. Frequency of local maximum and minimum in growth velocity curve

F	Stature				Body Weight			
	Local Max		Local Min		Local Max		Local Min	
Boy	n	%	n	%	n	%	n	%
0	0	0	2	1.2	0	0	1	0.6
1	25	14.6	50	29.2	15	8.8	23	13.5
2	82	48.0	83	48.5	72	42.1	85	50.0
3	58	33.9	35	20.5	75	43.9	51	29.8
4	6	3.5	1	.6	9	5.3	11	6.4
Total	171		171		171		171	
F	Local Max		Local Min		Local Max		Local Min	
Girl	n	%	n	%	n	%	n	%
0	0		17	4.3	2	.5	14	3.5
1	98	24.5	119	29.8	63	15.8	74	18.5
2	203	50.8	197	49.3	173	43.3	172	43.0
3	96	24.0	64	16.0	133	33.3	125	31.3
4	3	.8	3	.8	29	7.3	15	3.8
Total	400		400		400		400	

Note: 1) F stands for Frequency of No. of Local Max. or Min. in the term over 6 and 16 years old.

2) n stands for the number of cases, and % stands for % of n to total number of cases: sample size.

2) The number of local maxima and minima in growth velocity curves

Table 6 shows mean and standard deviations of number of local maxima and minima in growth velocity curves from the age of 6 to 16 by peak age. In boys, the means of number of local maxima ranged from 1.96 to 2.38 for local maxima and 1.69 to 2.13 for local minima. ANOVA showed no significant differences in number of local maxima and minima among means in stature

and body weight. In girls, no significant differences were found in number of local minima only for body weight, but significant differences were found in both numbers for stature and number of local maxima for body weight.

IV. Discussion

The growth distance curves showing

general trend of over-all means at each age must be recognized as a representative growth curve which can give us general knowledge on growth. However, it was clarified that such a general representative curve lacks some information on those could be given from some more realistic curves, such as growth velocity curves by peak age.

Several local maxima exist usually in the changing process of growth velocity even from 6 to 16 years old, then this study proposed that the age showing each local maximum should be investigated just as peak age and velocity. The growth spurt before peak age was called as mid-growth spurt, and the one growth spurt appeared after peak age is called as after-growth spurt. These spurts can be represented by local maxima in growth velocity curve, so the investigation of local maxima may give some important information on individual growth. That local maxima may exist in many cases suggests that local minima also exist in many cases. Actually this study showed that local minima were found in 99% of boys and 96% of girls for stature growth velocity, and in 100% of boys and 97% of girls for body weight growth velocity. These local minima were also significant for the individual growth. In other words, one of minima might specify appearance of mid-growth spurt, and another minima might suggest appearance of after-growth spurt. Furthermore, other local

minima might also give some information that have not been discussed so far.

V. Conclusion

In order to investigate the traits of physical growth of youth in modern Korea, 571 adolescents' longitudinal data(6 through 16 years old) on stature and body weight were collected and analysed.

Major conclusions were as follows: First, the over-all mean growth curves of stature had a well-known trait; girls were taller than boys during the specific time of adolescence. This could be recognized as one of theorems widely approved. However, this phenomenon was not found in the growth process investigated by peak age. Furthermore, this was not found even in over-all mean growth process of body weight.

Second, peak age came later in boys than in girls in both stature and body weight. This meant that boys matured later in stature and body weight than girls. However, boys were larger in peak velocity than girls. This was consistent with common understanding.

Third, peak ages distributed more widely in girls than in boys both for stature and body weight. The peak velocity might tend to decrease as peak age increase in stature, but increase in body weight except peak age

12 in boys. In girls' stature, up to peak age 9, peak velocity tended to increase as peak age increased, but thereafter, it tended to decrease as peak age increased. In body weight, any specific trait was not found up to 7 and thereafter, it tended to decrease.

Forth, in growth velocity curves, several local maxima and minima tended to appear, and only maximum in several maxima has been investigated and discussed as peak age velocity widely. But other maxima and minima also had significant growth traits. Thus, it was attempted to classify the individuals' growth process by number of local maxima and minima. As a results, three types were found; one maximum, two maxima including two sub-types, and three maxima including three sub-types. In second type, there were two subtypes; the first sub-type in which the youngest age of maximum was peak age, and another was the age of after-growth spurt peak velocity. The youngest age of maximum was mid-growth spurt peak age and the older one was peak age. In the type of three maxima, there were three sub-types; 1) the youngest age was peak age and either one of others was after-spurt peak age, 2) the youngest was mid-growth spurt peak age. the second was peak age, and the third was after-growth spurt age, and 3) the oldest age of maxima was peak age and one of two ages before peak age was mid-growth peak age. In this

study, 6 different types were found in the changing trends of growth velocity. Therefore, even in such short growth process as from 6 through 16 years old, growth spurt tended to appear in several times but not in only one time; peak age.

The cases showing more than two times of growth spurt in stature growth were 85% in boys and 76% in girls and, those of growth spurt in body weight were 91% in boys and 90% in girls. Thus, the cases showing only one of growth spurt were considerably smaller. This suggested that not only peak age and peak velocity must be investigated for study of growth but also other local maxima must be investigated.

Finally, the number of local maxima averages 2 to 2.48, but boys tended to be a little bigger in it than girls in both stature and body weight. In other words, growth spurt tended to appear more often in boys than in girls. Any significant differences were not found in the frequency of growth spurt between different peak age groups in both stature and body weight, but not the case in girls.

References

- Barton WH, Hunt EE. Somatotype and adolescence in boys: longitudinal study. *Human Biology* 1962;34:254-270.
- Beunen GP et al. Adolescent growth and motor performance. IL: Human Kinetics, 1989. pp.1-62.
- Borms J, Hauspie R, Sand A, Susanne C, Hebbelinck M. Human growth and development. Plenum, New York, 1984.
- Kim HK, Lim HJ. Secular trends in Korean adolescents' physical fitness from 1964 to 1999. 2002 Busan Asian Games Sport Science Congress 1894-1900, 2002.
- Kim HK, Park JE, Park HJ, Ahn HY, Kim M. Secular trends in Korean adolescents' physical growth from 1964 to 1999. *Growth and Development* 2002;10(1):11-24.
- Kimurea K. Studies on growth and development in Japan. *Yearbook of Physical Anthropology* 1984;27:179-213.
- Leifer G, Hartston DP. Growth and development across the lifespan. Saunders, Missouri, U.S.A., 2004.
- Lindgren G. Growth of schoolchildren with early, average, and late ages of peak height velocity. *Annals of Human Biology* 1978;5:252-267.
- Lowrey N. Growth and development of children(6th ed.). Yearbook Medical, Chicago, U.S.A., 1973.
- Malina RM, Bouchard C. Growth, maturation, and physical activity. Human Kinetics Books, Illinois, U.S.A., 1991.
- Matsuura Y. Development of physical fitness. Asakura, Tokyo, Japan, 1982.
- Matsuura Y. Statistical growth and development. Humaido, Tokyo, Japan, 2002.
- Matsuura Y. Introduction of physical growth and development. Humaido, Japan, 2005.
- Rogol AD, Clark PA, Roemmich JN. Growth and pubertal development in children and adolescents: Effect of diet and physical activity. *American Journal of Clinical Nutrition* 2000;72(suppl):521-528.
- Tanner JM. Growth at adolescence, 2nd ed. Blackwell Scientific Publications, London, 1962.
- Tanner JM, Whitehouse RH, Marubini E, Resele L. The adolescent growth spurt of boys and girls of the Harpenden Growth Study, *Annals of Human Biology* 1976;3:109-126.
- WHO. A critical link: Intervention for physical growth and psychological development, 1999.

ABSTRACT

This study was performed to formulate the most recent traits of physical growth of youth, and to identify the need of youth for health promotion planning in modern Korea. Study participants were 171 boys and 400 girls in two senior high schools in Seoul, Korea. Health records were collected from the individual students in May 2005. Longitudinal data on stature and body weight from 6 to 16 years old were analysed. Significance tests on some measures were performed by t-test and ANOVA.

Major conclusions were as follows:

1. Girls were taller than boys during the specific time of adolescence. However, this phenomenon was not found in the growth process investigated by peak age and in over-all mean growth process of body weight.
2. Peak age came later in boys than in girls in both stature and body weight. This meant that boys matured later in stature and body weight than girls. However, boys were larger in peak velocity than girls.
3. Peak ages distributed more widely in girls than in boys both for stature and body weight.
4. Even in such short growth process from 6 through 16 years old, growth spurt tended to appear in several times.
5. Growth spurt tended to appear more often in boys than in girls.

Key Words: Youth, Physical Growth, Stature, Body Weight, Growth Distance, Growth Velocity, Peak Age