치의학석사학위논문

# Secular trend in the growth changes of Korean adolescents in socioeconomic environment

## 한국의 시대적 사회경제환경에 따른 청소년기의 성장양상의 변화

2014년 2월

서울대학교 치의학대학원

치 의 학 과

김 상 기

# Secular trend in the growth changes of Korean adolescents in socioeconomic environment

## 한국의 시대적 사회경제환경에 따른 청소년기의 성장양상의 변화

지도 교수 이 신 재

이 논문을 치의학석사 학위논문으로 제출함
2013 년 10 월

서울대학교 치의학대학원
치 의 학 과
김 상 기

김상기의 치의학석사 학위논문을 인준함
2013 년 11 월

위 원 장 ________ 박 영 석 ________ (인)

부위원장 ________ 이 신 재 ________ (인)

위 원 ________ 양 일 형 ________ (인)

**ABSTRACT**

# Secular trend in the growth changes of Korean adolescents in socioeconomic environment

Sang-Ki Kim

School of Dentistry, Seoul National University

(Directed by Professor Shin-Jae Lee, DDS, MS, PhD, PhD)


*Background*: Height, weight and body mass index are used as indicators of socioeconomic status and overall welfare. The objectives of this study is (1) to investigate the trends of these growth indicators and relations within the socioeconomic environment and (2) to reveal the changes in growth parameters over time and over various socioeconomic factors.

*Subjects and methods*: The cross-sectional growth data was obtained from government student physical examinations from 1964 to 2011. Gross Domestic Product (GDP) per capita was chosen to represent the socioeconomic environment. The growth data was organized by birth year and growth parameters were obtained using Preece and Baines Model 1. Regression analysis with growth parameters on years and GDP per capita was performed.

*Results*: Height, weight and Body Mass Index (BMI) increased as time went on or when GDP per capita increased. Age at takeoff and PHV decreased. Velocity at takeoff, velocity at PHV, height at takeoff, and height at PHV all increased as either time passed or income increased. For females, velocity at PHV and height at takeoff had no statistically significant relation with GDP per capita.

*Conclusions*: Korean adolescents became taller, gained weight, and matured earlier and faster as time passed and income increased.

**Keywords:** Height, body mass index, takeoff, peak height velocity, Gross domestic product (GDP)

**Student Number :** 2010-22434

# CONTENTS

# List of Tables

# List of Figures

# I. Introduction

## 1.1. Background

Human growth, especially adult height is determined by biological inheritance and environmental factors. Known environmental factors are nutrition status, infectious disease, food contamination, pollution, income, and health care service. Therefore, height is an indicator of the socioeconomic status and overall welfare of both an individual and the population. Weight and body mass index (BMI) are also widely used to evaluate the relation between human growth and socioeconomic status (Cardoso & Caninas, 2010; Cha et al., 2005; Deaton, 2007; Moraes, 2013; Pak, 2004; Ulijaszek, 2006; Wolf & Colditz, 1996).

Korea has achieved remarkable economic development with rapid industrialization since the 1970s. Protein intake from animal sources and fat-derived energy intake increased during this period. The overall nutrition status improved. (Kim et al., 2000). The education level and social healthcare services also improved. As a result, Korean adolescents now get taller and bigger than in the past (Cha et al., 2005; Kim et al., 2002). Several publications reported the simple trends of height and weight in Korea, but most of them did not explain the correlation between human growth and socioeconomic factors.

To better understand the human growth pattern, an analytic approach identifying important growth points such as peak height velocity (PHV) is more meaningful. There have been many attempts to describe human growth by mathematical functions. Nonlinear growth functions fit the growth data well, and they can describe growth characteristics by means of growth parameters such as age at takeoff, velocity at takeoff, or PHV.

## 1.2 Objectives

The aims of our study are (1) to investigate the indicators of growth trends, such as height, weight, and BMI while determining the relations between the growth indicators and the socioeconomic environments; (2) to obtain the biological growth parameters derived from nonlinear growth curves and describe the trends and the relations between the growth parameters and the socioeconomic environments.

# II. Materials and methods

## 2.1 Growth indicators and socioeconomic indicators

**Height**

Height of an individual reflects skeleton size well and has a good association with bone and muscular mass. So it is an important indicator of general health and robustness. It is well known that the average height of a population reflects its general state of nutrition (Tanner, 1976), and the nutrition conditions are closely related with the socioeconomic status (Popkin & Lidman, 1972). Since human growth responds to environmental quality, positive trends in height have been attributed to improved social, political, nutritional, and health conditions within a society (Ulijaszek, 2006).

**Weight**

Weight is one of the typical measurements of the physique. A greater weight generally represents well-developed muscle, fat and skeleton. Therefore, weight can be used to evaluate the physical growth status and overall health status of adolescents. However, unlike height, weight does not always show positive correlation with socioeconomic status and the wealth of a society. Weight has it uses for growth evaluation, but it can be misleading because a human body is a combination of different tissues in varying proportions (Tanner, 1976). Moreover, overweight and obesity have become serious health problems in developed countries.

**Body mass index (BMI)**

Body mass index is defined as an individual's body mass divided by the square of their height. It shows the amount of body fat and represents the degree of obesity (Keys et al., 1972). BMI can be calculated as below:

$$\text{BMI} = \frac{body\,mass\ [kg]}{(height\ [cm])^2} = [\frac{kg}{cm^2}]$$

Obesity criteria of Korean adults follow that of WHO Asia-Pacific region criteria and Korean society for the study of obesity. BMI under 18.5 is low weight, between 18.5 and 22.9 is normal, over 23 is overweight, 25~30 is first stage obesity (light obesity), 30~35 is second stage obesity (moderate obesity), and over 35 is severe obesity

## 2.2 Sampling of research subject

Due to national policy requirements, for many years, educational institutions in Korea have collected serial growth data on growing children and adolescents as a part of routine student physical examinations (Korean Ministry of Education, 2009). The heights and weights of first grade elementary school students (six years of age) to third grade high school students (17 years of age) were recorded in centimeter and kilogram units for each from 1964 to 2011 and published in the Statistical Yearbook of Education (Korean Ministry of Education, 1991~2011). Each data set had 3000 to 9000 samples per year with some variation.

Height and weight data contains measurements at different ages. For example, a set of data that was measured in 2000 contains the heights and weights of six-year-old elementary school students who were born in 1993 as well as those of 17-year-old high school students who were born in 1982. To better analyze the changes in biometrics of students at various ages and differing growth stages, the original data which was originally collected by measurement year was modified and re-grouped by birth year, like a birth cohort. E.g. data from first grade elementary school students in 2000, data from second grade elementary school students in 2001, and data from third grade high school students in 2011 were integrated as one group since they all were born in 1993. These two different sets of data will be called "data by measurement year" and "data by birth year".

Socioeconomic indexes provided by the World Bank were between 1961 and 2010 (World Bank, 2012). GDP per capita, infant mortality, life expectancy, ratio of medical expenditure, and illiteracy are commonly accepted as the prominent socioeconomic indicators related to human growth. Among those indicators, GDP per capita (Gross Domestic Product per capita, constant 2000 US Dollar) was chosen to be the indicator since it is most widely used.

## 2.3 Data analysis

**Relationship between growth indicator and GDP per capita**

In economic literature, it is generally assumed that height responds proportionally rather than in absolute changes in income (Gortmaker, 1979). Consequently, the semilogarithmic model of income and height were widely used (Deaton, 2007; Murasko, 2013; Steckel, 1983; Steckel, 1991). We have formulated a regression model in semi-logarithms to compare and analyze the relationship between height, weight, and BMI of Koreans with GDP per capita. For convenience, third year high school students at 17 years of age were categorized as adults.

## 2.4 Fitting growth model and calculation of the growth parameters

**Data examination and organization**

The physical examination data consists of the average height and weight of each grade. However there was no exact age of each grade in the examination data, we assumed and calculated the age by using monthly birthrate statistics from 2000 to 2010. This resulted in additional 0.72 years added to each grades associated age of entry; i.e. first grade elementary school students were called the six-year-old group, but the average age used for growth model fitting was actually 6.72 years.

**Growth model fitting**

Preece and Baines proposed a family of mathematical functions to fit longitudinal growth. Among them, Preece and Baines model 1 (PB 1) was especially accurate and robust, and had a reasonable number of parameters and a simple functional form.

The equation of PB1 is,

$$h = h_1 - \frac{2\,(h_1 - h_\theta)}{\exp[s_0(t-\theta)] - \exp[s_1(t-\theta)]}$$

where $s_0$ and $s_1$ are rate constants, $\theta$ is a time constant and $h_\theta$ is height at $t=\theta$ (Preece & Baines, 1978).

Fitting the longitudinal growth data into the growth curves were executed by nonlinear regression analysis using the Levenberg-Marquardt fitting algorithm (Marquardt, 1963), and five parameters of PB1 model were calculated. Applying the obtained PB1 parameters, the growth curve of height was determined. Growth velocity function was derived by differentiation of the growth curve. Finally, growth parameters (age, height, and velocity) were obtained both at takeoff (TO) (which is the minimum value of the growth velocity curve) and at peak height velocity (PHV) (which is the point of local maximum value of the growth velocity curve). The R programming language (R core team, Viennna, Austria, 2013) was used to perform the mathematical processes. Nonlinear regression analysis was performed using the minpack.lm package and differentiation and calculation of the growth function were performed using the mosaic package.

**Analysis of the growth parameters**

Six growth parameters of height were obtained using the PB1 growth model from the data by measurement year, and by birth year respectively. Growth parameters by birth year were plotted and investigated by a linear regression model. Growth parameters by measurement year were only plotted and used as reference. The trends of growth parameters obtained from the height by birth year and the relation between growth parameters and GDP per capita were also discussed.

# III. Results

## 3.1 Relations between adult height, weight, BMI and GDP per capita

Height, weight, BMI of adult males and females tend to increase as time goes (Figure 1). From 1964 to 2010, while GDP per capita had increased by 12.3 fold, male height had increased by 10.1 cm, female height by 4.9 cm, male weight by 13.6 kg, and female weight by 4.3 kg. It showed a greater increase in males than females both in height and weight. After 2000, the data from the last ten years showed a slowdown in the increase. Male BMI had changed from 20.4 to 22.6, while 2.2 increased from the normal range to overweight. On the other hand, female BMI had an increasing tendency, but the amount of the increase was small, just 0.4, from 21.1 to 21.5 during the last 50 years. A large variation in female BMI was noticeable.

As the GDP per capita changed, the height, weight, and BMI of both males and females have increased. The rate of increase of males was faster than that of females (Figure 2). The height and weight of boys were always larger than those of girls. The BMI of girls was larger than that of boys before early 1990. However, after then, as GDP per capita became larger than log 8.5, approximately 5000 USD, the BMI of boys grew larger than that of girls.

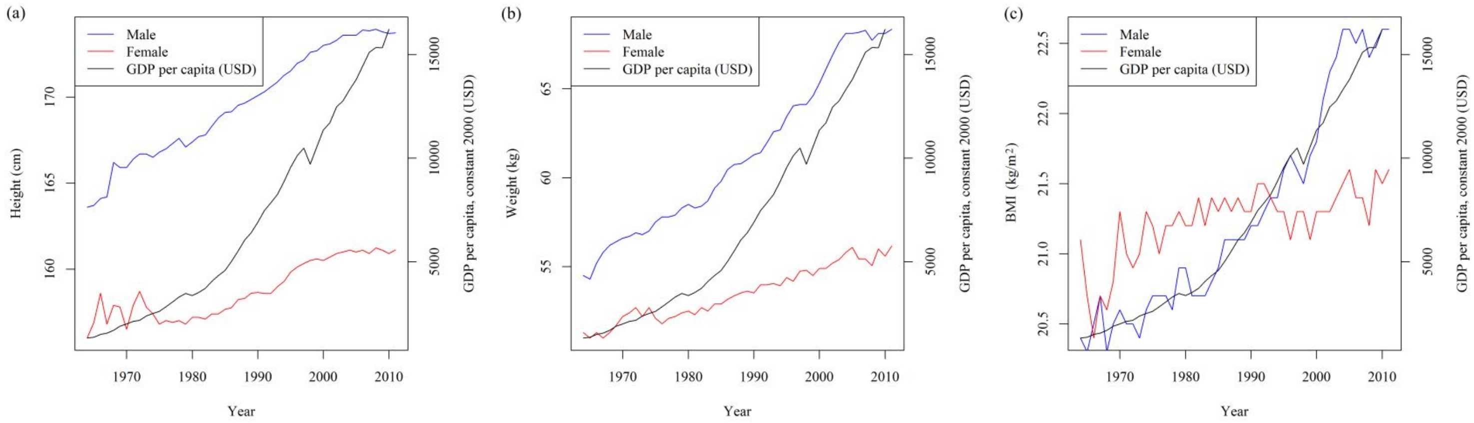


**Figure 1**. Trends in adult height, weight, BMI, and GDP per capita. (a) Height; (b) weight; (c) BMIy

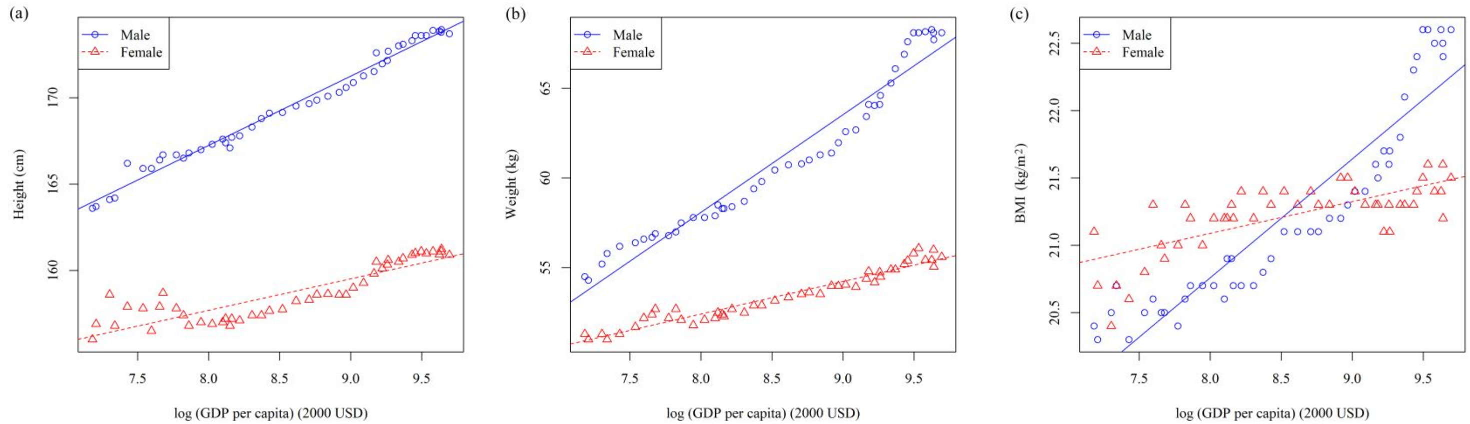


**Figure 2**. The relations between adult height, weight, BMI, and the log of GDP per capita. (a) Height; (b) weight; (c) BMI

## 3.2 Fitting growth model and calculation of growth parameters

Heights by measurement year and by birth year were fitted into the PB1 growth model. The height in 1968 by measurement year was not able to fit the PB1 growth model. All other growth data was fitted and the six growth parameters: age at takeoff, velocity at takeoff, height at takeoff, age at PHV, velocity at PHV, height at PHV were obtained for boys and girls

Figure 3 shows the growth parameters by measurement year and by birth year for males and females. The early ages of the plots by birth year were not congruent with the overall changing tendency. Therefore, as is common in statistical fitting, some data was initially excluded to establish a proper linear relation. For example, the first three measurements between in 1957 and in 1959 were excluded from the data of age at takeoff and PHV for males. The results of the linear regression are shown at Table 1. The last two columns of Table 1, 1963 and 1993, represent the calculated growth parameters from the linear model.

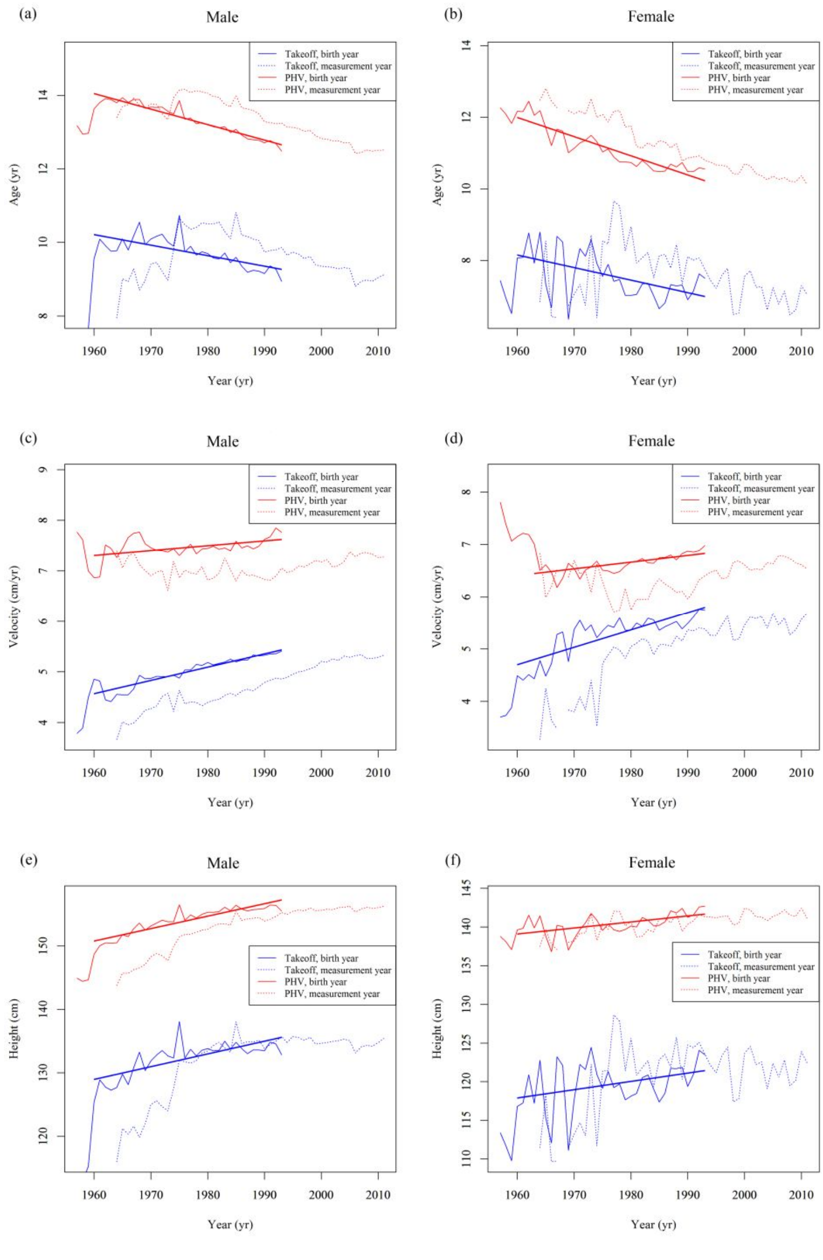


**Figure 3.** Changes in growth parameters on years. (a) Age at takeoff and PHV for males; (b) age at takeoff and PHV for females; (c) growth velocity at takeoff and PHV for males; (d) growth velocity at takeoff and PHV for females; (e) height at takeoff and PHV for males; (f) height at takeoff and PHV for females

**Table 1**. The result of the linear regression of growth parameters *by birth year* on years. Last two columns, 1963 and 1993 represent the calculated growth parameters from the linear model

| | | Intercept | Estimate | *p*-value | 1963 | 1993 |
|---|---|---|---|---|---|---|
| Male | Age at takeoff | 66.23 | -0.0286 | 0.000‡ | 10.12 | 9.27 |
| | Age at PHV | 96.62 | -0.0421 | 0.000‡ | 13.92 | 12.66 |
| | Velocity at takeoff | -46.75 | 0.0262 | 0.000‡ | 4.65 | 5.43 |
| | Velocity at PHV | -11.26 | 0.0095 | 0.005† | 7.34 | 7.62 |
| | Height at takeoff | -265.46 | 0.2012 | 0.000‡ | 129.56 | 135.59 |
| | Height at PHV | -233.74 | 0.1962 | 0.000‡ | 151.40 | 157.29 |
| Female | Age at takeoff | 76.80 | -0.0350 | 0.000‡ | 8.06 | 7.00 |
| | Age at PHV | 116.82 | -0.0535 | 0.000‡ | 11.83 | 10.23 |
| | Velocity at takeoff | -60.51 | 0.0333 | 0.000‡ | 4.80 | 5.80 |
| | Velocity at PHV | -18.70 | 0.0128 | 0.000‡ | 6.45 | 6.83 |
| | Height at takeoff | -91.84 | 0.1070 | 0.043* | 118.20 | 121.41 |
| | Height at PHV | -13.62 | 0.0779 | 0.000‡ | 139.33 | 141.67 |

* $p < 0.05$; † $p < 0.01$; ‡ $p < 0.001$.

Age at takeoff and PHV for both males and females had statistically significant decreasing tendencies (Figure 3a and 3b, Table 1). Age at PHV decreased more rapidly than age at takeoff. Age at takeoff for females was earlier than for males, by 2.06 in 1963 and by 2.27 in 1993. Age at PHV for females was earlier than for males, by 2.09 for females in 1963 and by 2.43 in 1993. Males and females matured earlier and the difference between the genders for age at takeoff and PHV became larger as time went on. Velocity at takeoff and PHV for both males and females had statistically significant increasing tendencies (Figure 3c and 3d, Table 1). Velocity at PHV was faster than velocity at takeoff for both males and females; but the increment of velocity at PHV during the period was smaller than that of velocity at takeoff. Velocity at PHV of males was faster than that of females, but velocity at takeoff for females was faster than for males. Height at takeoff and PHV for both males and females had statistically significant increasing tendencies (Figure 3e and 3f, Table 1). The increment height of males during the period was larger than that of females. Height at takeoff and PHV for females had a large variation. Large variations of growth parameters were common for females.

Then the relations between the growth parameters by birth year and GDP per capita were investigated (Figure 4, Table 2). As GDP per capita increased, age at takeoff and PHV for both males and females decreased. The amount of change of age at PHV was larger than that of age at takeoff. Velocity at takeoff and PHV for males increased as GDP per capita increased. Velocity at takeoff for females increased as GDP per capita increased, but velocity at PHV for females did not have a statistically significant relationship with GDP per capita. Height at takeoff and PHV for males were proportional to GDP per capita. In contrast, height at takeoff for females had no statistically significant relationship with GDP per capita.

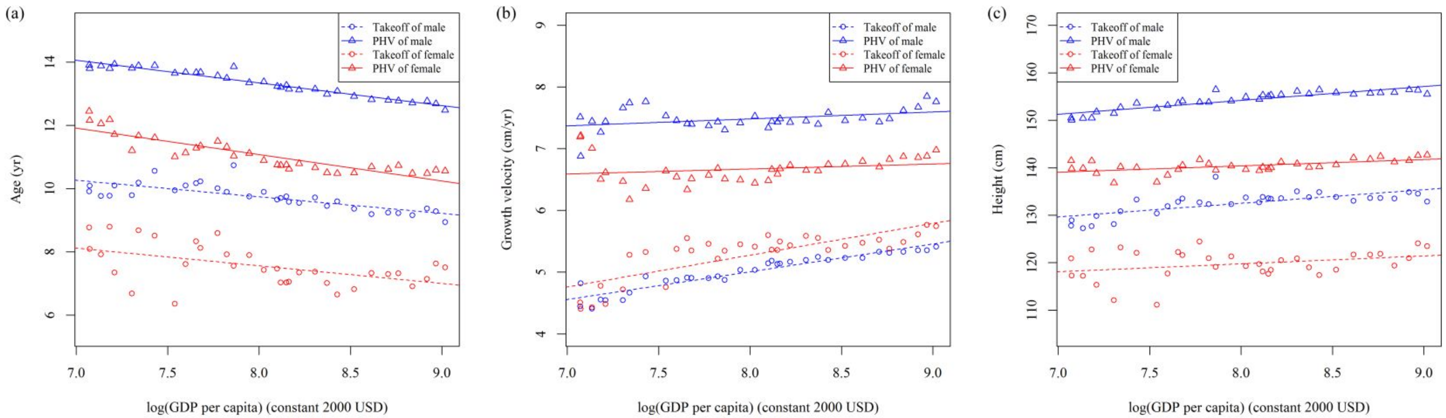


**Figure 4**. The relations between growth parameters by birth year and the log of GDP per capita. (a) Age at takeoff and PHV; (b) velocity at takeoff and PHV; (c) height at takeoff and PHV

**Table 2.** The result of the linear regression of growth parameters *by birth year* on the log of GDP per capita

| | | Intercept | Estimate | *p* value |
|---|---|---|---|---|
| Male | Age at takeoff | 13.93 | -0.524 | 0.000‡ |
| | Age at PHV | 19.10 | -0.719 | 0.000‡ |
| | Velocity at takeoff | 1.41 | 0.449 | 0.000‡ |
| | Velocity at PHV | 6.59 | 0.111 | 0.029* |
| | Height at takeoff | 109.49 | 2.875 | 0.000‡ |
| | Height at PHV | 130.77 | 2.929 | 0.000‡ |
| Female | Age at takeoff | 12.03 | -0.559 | 0.002† |
| | Age at PHV | 17.78 | -0.838 | 0.000‡ |
| | Velocity at takeoff | 1.15 | 0.516 | 0.000‡ |
| | Velocity at PHV | 6.01 | 0.082 | 0.228 |
| | Height at takeoff | 106.48 | 1.660 | 0.064 |
| | Height at PHV | 129.87 | 1.317 | 0.000‡ |

* $p < 0.05$; † $p < 0.01$; ‡ $p < 0.001$.

# IV. Discussion

From the mid-1960s to the mid-1970s, variations of female height and weight were larger than the overall increasing tendency (Figure 1). It is supposed that the sample may be biased at that period. Currently, almost all boys and girls enter high school. The high school entrance rate in Korea in 2011 was 99.6 % (Korean Educational Development Institute, 2012). However, in the 1960s, the entrance rate to a high school was low. In 1965, the nationwide entrance rate to middle school was 56.6 % (62.8 % for boys and 48.4% for girls). There was a significant regional difference in the entrance rate. For comparison, the entrance rate in Seoul, the capital city of Korea, was 82.9% (87.1% for boys and 78.2% for girls) at that time. Because of Japanese colonialism and the Korean War, Korea was a very poor and backward country at that time. The idea of predominance of men over women was prevalent, so there was a little concern for a girl's education. It was likely difficult for most girls to attend a higher school in such a poor environment, and those who entered a higher school had a higher socioeconomic status, were well-nourished and taller than the average girl. For this reason, we dropped out the outliers of that period to describe the growth trend more exactly when the regression analysis was performed.

Trends towards increasing adult height have been reported in many parts of the world. Studies of the United States, England, Germany, Spain, Netherlands, Italy, Brazil, Nepal and Vietnam, and many other countries show an increase in adult height during the 20$^{th}$ century (Cardoso & Caninas, 2010; Cavelaars et al., 2000; Floud, 1998; Heineck, 2006; Jacobs & Tassenaar, 2004; Joshi et al., 2005;

María-Dolores & Martínez-Carrión, 2011; Peracchi, 2008; Steckel, 2009; Strauss & Thomas, 1998). Some publications about Koreans also report this increasing tendency (Kim et al., 2002; Pak, 2004). In this study, we discovered increasing tendencies of weight and BMI as well as height for both males and females (Figure 1). It was noticeable that the increments for males were larger than those for females for all three indices; height, weight and BMI. In particular BMI of male outstripped that of female. Height, weight, BMI and the log of GDP per capita have similar patterns with the trends of growth indicators (Figure 2). As GDP per capita increase, height, weight and BMI also statistically significantly increase for both males and females. The increments of height, weight, and BMI for males were larger than those of females too. This accorded with previous reports that the height difference according to the socioeconomic status was less for females (Peck & Vågerö, 1987). The sexual differences of the muscular and bone mass, and the cultural reasons that girls are more sensitive to body weight gaining than boys are suspected to be causes of this sexual dimorphism (Park et al., 2008; Nho, 2012).

Although the linear regression results for height of both males and females had a statistically significant positive estimate, i.e. an increasing tendency, the height of males and females seem to reach a plateau the mid-2000s. Human growth is determined by both biological inheritance and environmental factors. As the environmental factors, such as nutrition status and health care service improve, human growth will reach the biological, or genetic, limit.  Consequently, the plateau delineated is likely the genetic growth potential of the Korean population. This is not a unique phenomenon in Korean. The stagnation of height in Norwegian draftees over the past two decades is reported and it is supposed that the end of increasing trend of height is near (Júlíusson et al., 2013). But, of course, this is in need of more thorough research to confirm such a hypothesis

Every growth parameter for males and females had statistically significant relations with years (Table 1). Females matured earlier than males. Age at takeoff and age at PHV for females were ahead of males by two years during the study period. In general, age at PHV was two years younger in females for several countries; American (Abbassi, 1998; Berkey et al., 1993), Taipei (Lee et al., 2004), Japan (Ali et al., 2000), and China (Mao et al., 2011). But age at takeoff itself and the difference between sexes were quite variable. Age at takeoff for females ranges from seven to eleven years. In most studies, the growth data begin from six to seven years-old, the entrance age for primary school and the initial age is close to age at takeoff, especially for females. So the lack of growth data younger than age at takeoff may cause the inaccurate calculation and high variabilty of age at takeoff. This can explain why age at takeoff of females have larger variablity than that of males.

As time went on and GDP per capita increased, age at takeoff and age at PHV for males and females became younger. Males and females matured earlier and the difference between the genders for age at takeoff and age at PHV became larger. The trend toward earlier puberty is common. However, the feature of age at takeoff is not consistent in researches. For Japanese, sex difference of age at takeoff was decreased and become almost insignificant (Ali et al., 2001). Velocity at takeoff and velocity at PHV increased as time passed and GDP per capita increased. It is noteworthy that increment of velocity at takeoff was larger than that of velocity at PHV for both males and females. This tendency was also observed for Japanese (Ali et al., 2000). It seems that the human being is more affected by the environmental factors when he or she is younger.

Since the log of GDP per capita is proportional to time, the trend of growth parameters on the GDP per capita have a similar pattern. Velocity at takeoff and height at takeoff for females demonstrated an increasing tendency but were not statistically significant. It was assumed that the large variation at the lower income section and the biased sampling of females as mentioned above were the causes for the lack of significance.

The trend of growth parameters on years and GDP per capita was significant. However, time is not a cause of the trend. In case of Japan, the secular trend of growth parameter was discontinued during World War II (Ali et al., 2000). The trend of an Italian male height showed an obvious proportional relation between height and GDP per capita, not height and time (Peracchi, 2008). From 1730 to 1830, height and GDP per capita declined together. After 1850, both height and GDP per capita had increased. So, it is more meaningful to study the effect of socioeconomic factors on the growth.

# V. Conclusion

There were increases in height, weight, and BMI for both males and females as time passed. Height, weight, and BMI were also proportional to the log of GDP per capita. The amounts of increase were larger in males than those of females. Age at takeoff and PHV decreased. Velocity at takeoff, velocity at PHV, height at takeoff, and height at PHV all increased for both males and females as time went on. Age at takeoff and age at PHV decreased for males and females as GDP per capita increased. Except for velocity at PHV and height at takeoff for females, the other growth parameters increased as income increased. In summary, people became taller and gained weight. They also got mature earlier and faster as time passed and income increased.

# REFERENCES


Abbassi V. 1998. Growth and normal puberty. Pediatrics 102:507-511.

Ali MA, Lestrel PE, Ohtsuki F. 2000. Secular trends for takeoff and maximum adolescent growth for eight decades of Japanese cohort data. Am J Hum Biol 12:702-712.

Ali MDA, Lestrel PE, Ohtsuki F. 2001. Adolescent growth events in eight decades of Japanese cohort data: sex differences. Am J Hum Biol 13:390-397.

Berkey CS, Dockery DW, Wang X, Wypij D, Ferris B. 1993. Longitudinal height velocity standards for US adolescents. Statist Med 12:403-414.

Cardoso HFV, Caninas M. 2010. Secular trends in social class differences of height, weight and BMI of boys from two schools in Lisbon, Portugal (1910–2000). Econ Hum Biol 8:111-120.

Cavelaars AE, Kunst AE, Geurts JJ, Crialesi R, Grotvedt L, Helmert U, Lahelma E, Lundberg O, Mielck A, Rasmussen NK and others. 2000. Persistent variations in average height between countries and between socio-economic groups: an overview of 10 European countries. Ann Hum Biol 27:407-421.

Cha JH, Lee DJ, Park JH. 2005. Secular trends in the growth curve of body mass index on female childhood. Korean Journal of Growth and Development 13:75-82.

Deaton A. 2007. Height, health, and development. Proc Natl Acad Sci U S A 104:13232-13237.

Floud R. 1998. Height, weight, and body mass of the British population since 1820. NBER Work Pap Ser No. 108.

Gortmaker SL. 1979. Poverty and infant mortality in the United States. Am Sociol Rev 44:280-297.

Heineck G. 2006. Height and weight in Germany, evidence from the German socioeconomic panel, 2002. Econ Hum Biol 4:359-382.

Jacobs J, Tassenaar V. 2004. Height, income, and nutrition in the Netherlands: the second half of the 19th century. Econ Hum Biol 2:181-195.

Joshi N, Rikimaru T, Pandey S. 2005. Effects of economic status and education level on the height and weight of community adolescents in Nepal. J Nutr Sci 51:231-238.

Júlíusson PB, Roelants M, Nordal E, Furevik L, Eide GE, Moster D, Hauspie R, Bjerknes R. 2013. Growth references for 0-19 year-old Norwegian children for length/height, weight, body mass index and head circumference. Ann Hum Biol 40:220-227.

Keys A, Fidanza F, Karvonen MJ, Kimura N, Taylor HL. 1972. Indices of relative weight and obesity. J Chronic Dis 25:329-343.

Kim HK, Park JE, Park HJ, Ahn HY, Kim M. 2002. Secular trend in Korean adolescents physical growth from 1964 to 1999. Korean Journal of Growth and Development 10:11-24.

Kim SW, Moon SJ, Popkin BM. 2000. The nutrition transition in South Korea. Am J Clin Nutr 71:44-53.

Korean Educational Development Institute. 2012. Educational statistics service. Available online at: http://cesi.kedi.re.kr/ (assessed September 13, 2012).

Korean Ministry of Education. 1991~2011. Statistical yearbook of education. Available online at: http://cesi.kedi.re.kr/ (assessed September 7, 2012).

Korean Ministry of Education. 2009. School health inspection rule. Available online at: http://glaw.scourt.go.kr/ (assessed September 7, 2012).

Lee TS, Chao T, Tang RB, Hsieh CC, Chen SJ, Ho LT. 2004. A longitudinal study of growth patterns in school children in Taipei area I: growth curve and height velocity curve. J Chin Med Assoc 67:67-72.

Mao SH, Li HB, Jiang J, X. S, Cheng JCY, Qiu Y. 2011. An updated analysis of pubertal linear growth characteristics and age at menarche in ethnic Chinese. Am J Hum Biol 23:132-137.

María-Dolores R, Martínez-Carrión JM. 2011. The relationship between height and economic development in Spain, 1850–1958. Econ Hum Biol 9:30-44.

Marquardt D. 1963. An algorithm for least-squares estimation of nonlinear parameters. SIAM J Appl Math 11:431-441.

Moraes AC, Falcao MC. 2013. Lifestyle factors and socioeconomic variables associated with abdominal obesity in Brazilian adolescents. Ann Hum Biol 40:1-8.

Murasko JE. 2013. Associations between household income, height, and BMI in contemporary US schoolchildren. Econ Hum Biol 11:185-196.

Nho HS. 2012. An approach to validity of index evaluation based on change of BMI with age. Korean Journal of Growth and Development 20:1-7.

Pak S. 2004. The biological standard of living in the two Koreas. Econ Hum Biol 2:511-521.

Park SY, Lee JI, Lee SJ, Kim HK, An HS. 2008. Effects of home environmental characteristics on current growth status and adult stature estimates of sixth-graders. Korean Journal of Growth and Development 16:239-247.

Peck A, Vågerö DH. 1987. Adult body height and childhood socioeconomic group in the Swedish population. J Epidemiol Community Health 41:333-337.

Peracchi F. 2008. Height and economic development in Italy, 1730-1980. Am Econ Rev 98:475-481.

Popkin B, Lidman R. 1972. Economics as an aid to nutritional change. Am J Clin Nutr 25:331-344.

Preece MA, Baines MJ. 1978. A new family of mathematical models describing the human growth curve. Ann Hum Biol 5:1-24.

Steckel RH. 1983. Height and per capita income. NBER Work Pap Ser No. 880.

Steckel RH. 1991. Stature and living standards in the United States. NBER Work Pap Ser No. 24.

Steckel RH. 2009. Heights and human welfare: recent developments and new directions. Explor Econ Hist 46:1-23.

Strauss J, Thomas D. 1998. Health, nutrition, and economic development. J Econ Lit 36:766-817.

Tanner JM. 1976. Growth as a monitor of nutritional status. Proc Nutr Soc 35:315-322.

Ulijaszek SJ. 2006. The international growth standard for children and adolescents project: environmental influences on preadolescent and adolescent growth in weight and height. Food Nutr Bull 27:279-294.

Wolf AM, Colditz GA. 1996. Social and economic effects of body weight in the United States. Am J Clin Nutr 63:466S-469S.

World Bank. 2012. World development indicators. Available online at: http://data.worldbank.org/coun-try/korea-republic (assessed November 22, 2012)

-국문 초록-

# 한국의 시대적 사회경제환경에 따른 청소년기의 성장양상의 변화

김 상 기

서울대학교 치의학대학원 치의학과

(지도 교수: 이 신 재)

**연구 배경:** 성장지표(신장, 체중, 체질량지수)는 사회경제적 상태와 복지 수준을 가늠해주는 척도로 널리 활용되고 있다. 본 연구의 목적은 (1) 성장 지표들의 시간에 따른 변화 및 사회경제적 환경 변화와의 관계를 살펴보고, (2) 성장 양상의 시간 경과 및 여러 사회경제적인 요소들에 따른 변화를 확인하고자 한다.

**연구 대상 및 방법:** 성장 자료는 1964년부터 2011년까지의 교육통계 연보에 수록된 횡단적 자료를 사용하였고 사회경제적 지표로는 1인당 국내총생산을 선택하였다. 성장자료들을 출생연도를 기준으로 재정렬한 후 Preece and Baines Model 1에 적합시켜 성장변수들을 구하였다. 시대 및 1인당 GDP와 성장변수간의 관계에 대한 회귀분석을 수행하였다.

**결과:** 시간의 경과 및 소득 증가에 따라, 남녀의 신장, 체중, BMI는 증가하였다. 성장변수에 있어서 남녀 모두 age at takeoff, age at PHV는

감소하였으며 velocity at takeoff, velocity at PHV, height at takeoff, height at PHV는 증가하는 경향이 나타났는데, 이들 중 소득 증가에 따른 여성의 velocity at PHV, height at takeoff를 제외하고 모두 통계적으로 유의미한 경향을 보였다.

**결론:** 시간의 경과와 소득 증가에 따라서 한국 청소년의 신장과 체중은 증가하였으며, 신체적 성숙 또한 앞당겨지고 빠르게 진행되고 있다.

**주요어**: 신장, 체질량 지수, takeoff, peak height velocity, 국민총생산

**학 번:** 2010-22434