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Proposal for Physical Maturation Level Derived from WHO Standard Height Data

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1. Abstract

Disclosure of standard physical growth values by the WHO has been very important. With this data, physical growth in individual countries becomes easier to assess with the status of global physical growth published as standard physical growth. However, while cross-sectional assessment is possible if standard physical growth distance values are known, longitudinal assessment determined from the velocity curve with differentiation of growth distance values is not. This is because no method that can describe these velocity curves has been established. In this study, we successfully described growth velocity curves by applying the wavelet interpolation model to standard growth values for height from the WHO. Then, using the described standard growth velocity curves, the age at maximum peak velocity of height was specified. The age at maximum peak velocity of height is taken to be a biological parameter that indicates the level of physical maturation. That is, by specifying biological parameters, the level of physical maturation can be indexed as a global standard value. Hence, the possibility that the level of physical maturation of youth in each country in the world can be assessed is established. Moreover, it also becomes possible to infer the economic conditions in a given country by analogy from the age at the maximum peak velocity of height.

2. Introduction

To understand the healthy growth of children, it is necessary to evaluate the degree to which the growth status of the individual deviates from standard growth, or whether it is located in the standard range. Therefore, construction of standard growth values is essential. For standard physical growth values in childhood and adolescence in particular, the values published by the World Health Organization (WHO) and Centers for Disease Control and Prevention (CDC) are well known, but individual countries have also made standard growth values that are unique to those countries [1]. In Japan, early childhood growth records have been published every decade since 1960, and with application of the percentile method the third to 97th percentile preparing evaluation charts of standard values from the early childhood growth records of the WHO or Japan, smoothing methods with least squares approximation polynomials are used in many cases. For example, Kato [2] made a standardized curve by applying the smoothing method of Tango [3] to percentile values and mean values, but there has been little discussion on methods of preparing standardized curves. While such efforts are considered essential actions, one may question whether a detailed verification of data implemented on a national scale has really been achieved. In other words, assessments of physical growth are important, but more important is analysis of physical growth patterns in early childhood. Specifically, a method to construct percentile curves has been a problem. Nor has there been any discussion on whether the smoothing method of Tango [3] is the best for growth patterns in early childhood.

In any event, growth velocity curves cannot be described even if least squares approximation polynomials or a spline smoothing method is discussed to construct an evaluation chart from standard physical values for children and adolescents from the WHO or Japan's school health statistical survey reports. That is because the adolescent growth spurt in physical growth cannot be precisely detected. Particularly, while the standard physical growth values published by the WHO are very important findings, there is some question as to whether those standard values are effectively used. While assessments of individual countries are possible as global standard values, a more important assessment may be the economic level of that country seen from physical growth. However, the economic level cannot be simply inferred by analogy from the standard values for height and weight. As indicated by Tanner [4, 5], Malina and Bouchard [6], and Cole [7], the peak phenomenon that appears in the adolescent growth spurt period is viewed as an important biological parameter. Behind this it becomes apparent that the pubertal peak is meaningful as the level of physical maturity. Growth researchers have pursued this pubertal peak for many years. The pubertal peak is an indicator of not only physical growth, but can also be a parameter of the economic development of a nation [8].

When a nation's infrastructure is developed with economic growth, the food situation has of course also become stable. Hence, in recent years global nutritional support has been put into place, particularly in the years since World War II, and it is common knowledge that physiques are becoming larger. The scientific background for this is taken to be the phenomenon in which the consumption of protein induces activation of IGF-1. However, this phenomenon has not been fully elucidated; only the phenomenon of a younger peak age in puberty has been verified as a clear fact [9]. Therefore, if the pubertal peak in WHO growth data were to be elucidated, standards for understanding the status of economic development from the physical maturation rate in countries around the world could probably be proposed.

In this study, we described the distance curve for growth in height by applying the wavelet interpolation model to standard values from the WHO, and further attempted to identify the maximum peak velocity, or the pubertal peak, by describing the velocity curve with differentiation of those distance curves. By standardizing the identified pubertal peaks, we tried to understand the physical maturation level and state of economic development of different countries.

3. Methods

3.1. Data

The height growth data for boys and girls from 1900 to 2019, taken from school health statistical surveys, is used for Japan. In South Korea, the height growth data for boys and girls from 1960 to 2019 used by Mori et al.[10] were used. Standard values for height growth of boys and girls from materials published by the WHO [11] were also used.

3.2. Analysis Method

3.2.1. Wavelet interpolation method: The wavelet interpolation method (WIM) is a method in which data points are interpolated with a wavelet function to approximately describe a growth curve from given growth data. Growth distance value curves are then drawn, these drawn growth distance value curves are differentiated, and growth velocity value curves are derived. Growth distance values at times such as the pubertal peak or the age at menarche can then be investigated. The effectiveness of the wavelet interpolation method is shown in the sensitive reading of local events and a very high approximation accuracy. Details on the theoretical background and evidence for its validity are omitted here as they have been described in previous reports by Fujii [12, 13, 14]. Then, age at maximum peak velocity (MPV) is identified from the velocity curve derived from differentiation of the growth distance values of height and weight. This age at MPV is the age at maximum peak velocity during puberty (peak age of puberty) and has meaning as a biological parameter. Biological parameters are described in detail by Fujii [15].

3.2.2. Age at maximum peak velocity (MPV; maximum growth velocity during puberty) of height: The age at MPV of height is the age at maximum peak velocity during puberty identified by the wavelet interpolation method. In fact, the growth mechanism of earlier physical maturation occurs in association with increased adult height. In the past, Tanner [4, 5] explained the phenomenon of increased height associated with secular trends in height from the phenomenon of younger age at maximum peak velocity (MPV). That is, the MPV age, which is an indicator of the pubertal growth phenomenon, is positioned as the level of physical maturity of humans and a recognized biological parameter. This MPV age is always shown to be earlier together with increases in adult height over time. A mechanism for increased height over time is, superficially, caused by abundant nutritional intake, especially protein intake. That increase mechanism occurs mainly in early childhood, and beyond early childhood there is no difference in the amount of increase over time [16]. Thus, since height growth is affected by early childhood growth mechanisms, increases in adult height depend greatly on physical growth in early childhood. That increase in early childhood then leads to earlier growth; that is, to the occurrence of the growth mechanism of earlier maturity.

4. Results

4.1. Physical Maturation Rate Derived from Growth Curves with WHO Data

Figure 1 is a graph of the wavelet interpolation model applied to height growth data for boys published by the WHO [11], and Figure 2 is a graph of height growth data for girls. The yellow circles are the raw height growth data of the WHO, and the red squares show the growth distance curve described with wavelets. The differential curve of that distance curve is the velocity curve of the blue squares. Growth from 115.95 cm at age six to 176.14 cm at age 18 is graphed, and it is seen that all follow the raw data. The WHO constructed a percentile curve based on this raw data, from which it is possible to evaluate the height growth from early childhood to adolescence for the entire world. However, the WHO does not derive the age at the pubertal peak (MPV age). Naturally, if height growth is to be evaluated, it is meaningless without deriving the MPV age for height and understanding the level of physical maturity. That is, it is important to discuss this as a set with evaluations of height. The MPV age for height obtained as a result of applying the wavelet interpolation model to the raw height growth data of the WHO was 13.1 years old, the growth distance value at that time was 157.08 cm, and the velocity was 7.27 cm/yr.

What can be understood from the graph in Figure 1 is that the age of 13.1 years old is the standard for mean physical maturation worldwide, from which level of maturation can be evaluated. The time when the average becomes 157 cm is the time when height increases the most, and 7.27 cm serves as a rough standard for that increase. Mean adult height has then become 176 cm, and if the SD is 7.45 it is possible to evaluate height in each country of the world. For example, if adult height in Japanese is 171 cm and adult height in South Koreans is 173.5 cm, Japanese are judged to be somewhat short and South Koreans are judged to be in the lower part of the standard range. If the MPV age for height is tall, there tends to be late maturation and if it is short there tends to be early maturation. This finding was derived by Tanner [4], and confirmed by Fujii [15].

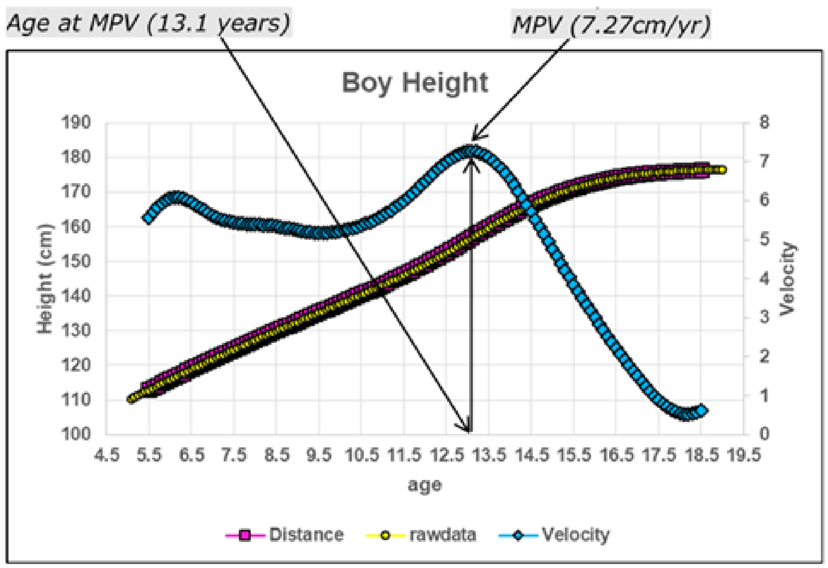

Figure 1: Male height growth data described by wavelet interpolation model. Based on WHO values.

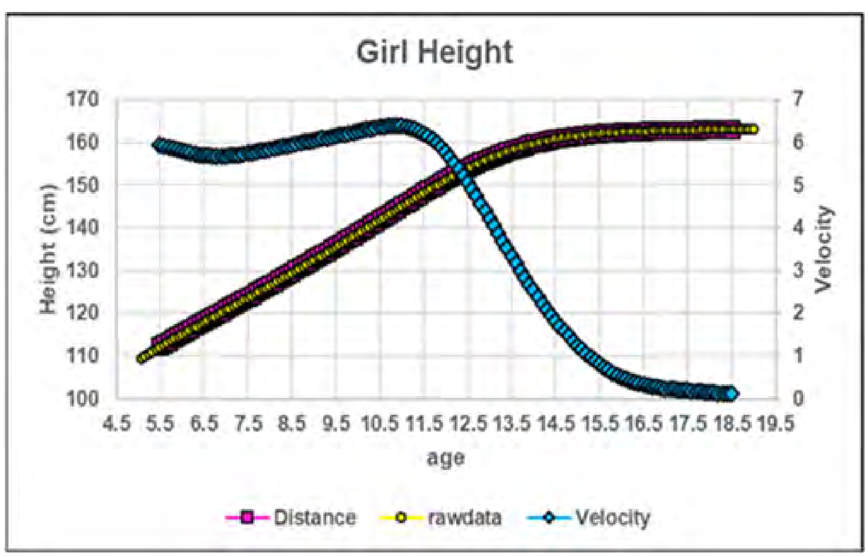

Figure 2: Female height growth data described by wavelet interpolation model, based on WHO values (Age at MPV 10.8 years, MPV: 6.40cm/yr).

4.2. Application of the Wavelet Interpolation Model to Physical Growth in Japanese and South Koreans

Figure 3 is a graph of male height growth of Japanese, and Figure 4 is a graph of male height growth of South Koreans. Both graphs were prepared with the wavelet interpolation model. Both graphs were made with birth cohort data, and the MPV age for height of Japanese was 12.4 years and that for South Koreans was 12.0 years. Thus, evaluation based on the MPV age of 13.1 years for height of the WHO leads to the finding that the physical maturation is a little earlier for both Japanese and South Koreans. This shows not that physical maturation is earlier in Mongoloids, but is a mechanism in which maturation is earlier in people with a short adult height and later in those with a tall adult height. As mentioned previously, Tanner [4] reported this finding, which was later confirmed by both Malina and Bouchard [6] and Fujii [15]. That is, it may be considered a growth mechanism in which, if the MPV age for height appears early, height growth also slows from that point and as a result adult height is shorter. If the MPV age is later, growth continues by that much and as a result adult height is taller. Therefore, it may be said that, unrelated to race, maturation is slower in Western countries with tall heights.

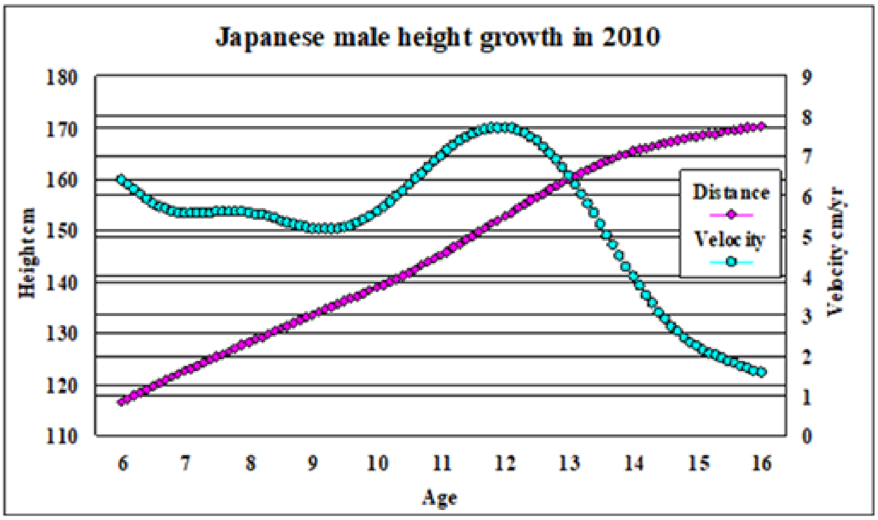

Figure 3: Japanese male height growth curve described by wavelet interpolation model.

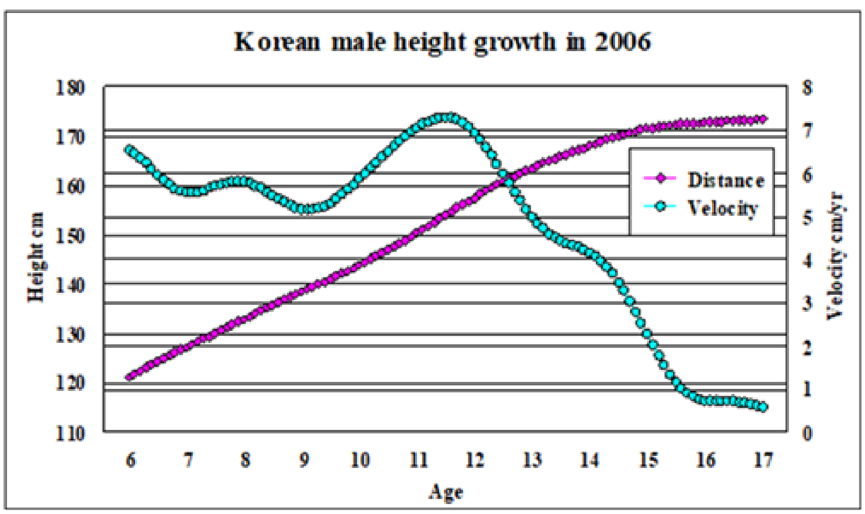

Figure 4: South Korean male height growth curve described by wavelet interpolation model.

5. Discussion

After World War II, which encompassed the entire world, infrastructure development has continued in each country and great progress has been made in nutritional support for the human body. As a result, bodies have become larger and height in particular has shown a marked increasing trend. Stable consumption of food nutrition is widely known to increase height. In particular, there are many reports that consumption of much protein is a major factor in taller height. However, as mentioned in the previous section, height will not increase simply with consumption of much protein in a single generation. The phenomenon of DNA methylation, an epigenetic mechanism, comes into play and an increase in height occurs in the next generation.

Or, as the birth cohort shows, a composition exists in which adult height values become taller with mean cross-sectional growth data; that is, height increases in a single generation. In any case, the phenomenon of increasing height over time is likely a fact to which stable nutritional intake, above all a greater intake of protein, has contributed.

The results of applying the wavelet interpolation model to the WHO height growth data shown in this study showed that the age at the pubertal peak for height (MPV) was 13.1 years old. That is, the standard for the physical maturation rate that is considered to be a biological parameter is 13.1 years old. Then, if the age at MPV of height is determined to be 12.4 years old for Japanese and 12.0 years old for South Koreans, their maturation level can be judged to be early. Of course, that is something that can be determined if the age at the pubertal peak (MPV age) can be identified, but this remains an issue for the future.

Parenthetically, a composition has been reported in which the MPV age becomes earlier when adult height increases over time [17,18]. This could be considered a reverse relationship with the composition of earlier MPV age and shorter height. Unrelated to the secular trends in height, if one considers the mechanism for height in a certain era, tall or short height is determined by early or late MPV age. When the time series concept of secular trends is introduced with respect to the growth mechanism, it may be that a mechanism of a naturally selected mini-evolution acts and the MPV age becomes earlier with increased height over time. In any case, an essential growth mechanism is presented in which stature is short if the MPV age for height is early, and so one is tempted to think that the phenomenon of increasing global height today has stalled because of natural selection preventing the MPV age for height from becoming any earlier than at the present.

In the basic mechanism for height growth, the growth of the legs (femur) occurs earlier than that of height, and the growth of sitting height (spine) lags behind that of full body height. Naturally, body height is a combination of leg and sitting height. The order of the appearance of the MPV age is thus the legs are first, body height next, and sitting height last. Then there is a trend in which the MPV age is early if stature is short, and the MPV is late if stature is tall. In other words, when the MPV (pubertal peak) occurs the increase in height stops, and so the growth mechanism of delayed MPV increases height. With this growth mechanism, the phenomenon of increasing height from secular trends is taken to be that the height growth in early childhood determines the increase in adult height. Height increases in early childhood means growth is happening earlier, and together with increases in adult height the MPV age for height also becomes earlier. The possible involvement of epigenetics in growth increases in height in early childhood is conjectured.

Given that the age at MPV of height is an indicator of the level of physical maturation, the above discussion suggests that the phenomenon of increased adult height indicates earlier maturation and that this phenomenon can be a parameter of economic conditions. Thus, assessments of maturation globally can be discussed by identifying the pubertal peak from height growth data by the WHO. Moreover, the possibility also seems to have been shown that even the level of economic development can be understood. Then, by applying the wavelet interpolation model, it may be possible to discuss biological parameters globally from height growth data by the WHO.

6. Conclusion

The age at the pubertal peak for height (age at MPV of height) of the WHO derived in this study is a phenomenon that is controlled by human growth mechanisms. The phenomenon of increased adult height becomes one of earlier maturation, and it was suggested that this phenomenon can be a parameter of economic conditions. In humans, adult height increases with stable intake of protein and the age at the pubertal peak becomes earlier. That fact may be said to show the possibility that assessments of maturity globally can be discussed and moreover the level of economic development can be understood by identifying the pubertal peak from the height growth data of the WHO. That it becomes possible to discuss a biological parameter globally from height growth data by the WHO by applying the wavelet interpolation model may be considered a very useful finding.

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