

Relational Composition between Periodic Fluctuation and Seasonal Variation in Height Growth

Nozomi Tanaka

Toukai Gakuen University, Aichi, Japan

Katsunori Fujii

Aichi Institute of Technology, Aichi, Japan

ABSTRACT

The influence of seasonal variations in height growth has been frequently discussed previously. In recent years, however, Fujii [1] has hypothesized periodic fluctuations, accordingly the variation is not from the environmental factor of season; rather, height growth is achieved with periodic variations due to genetic factors. Based on this logic, wavelet interpolation was applied to observed data values measured three times a year in this study to investigate the periodic fluctuations in height and weight growth in elementary school children, and an attempt was made to verify the periodic fluctuations from the behavior of the derived velocity curve. The longitudinal time series information on subjects' height and weight were measured three times a year from the first to sixth grades. The data used in the analysis were for 17 boys and 11 girls. The results showed that the height growth pattern is essentially achieved with periodic fluctuations, and that there are seasonal stimulating phenomena within that periodicity. If this growth mechanism also applies to body weight, growth in body weight would occur together with increases in height, but with additional seasonal stimulating effects weight would be affected not only by genetic factors as height is, but also by seasonal environmental factors.

Keywords: Periodic Fluctuation, Seasonal Variation, Dissimilarity, Local peak velocity (LPV)

INTRODUCTION

In research regarding height growth, seasonal variations in height growth cannot be observed with once yearly measurements. At minimum, cross-sectional time series information at short intervals is essential to investigate periodic fluctuations such as seasonal variation in the process of transitioning from childhood to puberty, which are also affected by individual differences in physical growth, yet there have been no attempts at such analysis to date.

Togo and Togo [2-3] and Togo [4] conducted monthly measurements of height and weight in five children over a long period. In one boy monthly measurements were made from age 4 to 29 years, and a time series analysis was conducted. A report by Kobayashi [5], in which that time series analysis is applied to kindergarten children, presents findings of seasonal variation during that time. In classic study's findings on seasonal variations include those of Shima [6], Ozaki [7], Fukuda and Ishikawa [8], Saito [9], and Nakamura [10]. There are also findings [2-3]

on the maximum values seen from April to August, when seasonal variations in height growth. Other studies have found no distinct seasonal variations [8-10]. In recent years, Togo [3], Kamioka [11], Oyama [12], Yoshioka [13], and Suzuki [14] investigated seasonal variations in height growth, but no clear conclusions have been reached for seasonal variation in height growth, since there are problems in the hypothesis of periodic fluctuation with genetically programmed growth.

In fact, however, the essential meaning of seasonal variations in height growth has not been clarified. According to Marshall [15], a certain species of animal (weasel) shows mating behavior based on the time period of light in the eyes, and animals that are completely blind do not exhibit that behavior. Taking those findings as a hint, a comparison was done of height growth in blind children, children with low vision, and healthy children by month of age, and a relationship with season was reportedly seen only in the healthy children. Tanaka et al. [16] reported affirmatively on the relationship with daylight hours shown by Marshall [15], but there are no reports that can immediately affirm that seasonal variations are due to hours of daylight. In any event, even if seasonal variations are considered to be periodic fluctuations, clarification of the patterns in height growth rhythm are promising for elucidation of the relationship between those periodic fluctuations and hormones, as well as the genetic contribution. Fujii et al. [1] applied wavelet interpolation to cross-sectional growth in height for month of age over one year in older children, and investigated the seasonal variation and periodic fluctuation. It was found that height growth over one year is not linear; rather there are months of much growth and months of almost no growth. This phenomenon has traditionally been understood as seasonal variation, but one wonders if height growth is really affected by season as an environmental factor. Fujii et al. [1] advocated periodic fluctuation in that study. In other words, the variation is not from the environmental factor of season; rather, height growth is achieved with periodic variations due to genetic factors.

Based on this logic, wavelet interpolation was applied to observed data values measured three times a year in this study to investigate the periodic fluctuations in height and weight growth in elementary school children, and an attempt was made to verify the periodic fluctuations from the behavior of the derived velocity curve.

METHODS

Subjects

The subjects were students at an elementary school in Shizuoka City, born between April 2002 and March 2003. Longitudinal growth data on height was obtained from grades 1 to 6. Height was measured three times a year. This study used the longitudinal time series information on height and weight measured three times a year from the first to sixth grades. The data used in the analysis were for 17 boys and 11 girls.

Analytical Techniques

To approximate the true growth curve from the supplied growth data with the wavelet interpolation method (WIM), the data are interpolated from the wavelet function of the data and a growth distance curve is drawn. This distance curve is differentiated to arrive at the growth velocity curve, and the growth distance value of the age at menarche and the puberty peak is examined. The WIM can sensitively read local phenomena, and has an extremely high

level of approximation accuracy. The theoretical background and grounds for its efficacy have been described in previous reports ([Fujii and Yamamoto [17]; Fujii and Matsuura [18-19]]). In the present paper we shall describe the method of analyzing data using the WIM.

In this study was applied to height values from 6 to 11 years of age in the Japanese elementary school boys and girls for WIM. First, WIM was applied to the age distance value of height for each individual. Then, the age distance curves for height in both groups were differentiated, and the age at LPV of height (age at local peak velocity in school age) from the velocity curve was specified through this process. Please note that the derived velocity value from the differentiation of the current function here is expressed as the annual growth rate in centimeters per year.

Analytical Procedures

- 1) Wavelet interpolation was applied to the growth distance values in longitudinal time series data for height from April of first grade to April of sixth grade in 17 elementary school boys and 11 elementary school girls. In this case it is necessary to construct an age axis with one year divided into three equal parts, taking April of first grade as 6.0 years old and then August as 6.33 years old and December as 6.66 years old, April of second grade as 7.0 years old, and April of sixth grade as 11.0 years old. In other words, to obtain correspondence month of age, age was set to be approximately 6.0 years old around April, approximately 6.33 years old around August, and approximately 6.66 years old around December.
- 2) Growth distance values and velocity curves were drawn with computer simulation. It should be noted that in this case velocity is cm/year and kg/year (growth in height and weight in one year).
- 3) The peak states in the drawn velocity curves were investigated.
- 4) The correspondence between the velocity peak and the age axis (month of age) was determined and the relationship between the periodic fluctuations and seasonal variation was investigated.

Local Peak Velocity (LPV)

LPV is the name given to local velocity peaks with respect to MPV. Fujii[20] detected the appearance of 2–3 peaks during growth spurts in a process in which mid-growth spurts were verified with application of wavelet interpolation to height growth. However, the essential meaning of this method is that it reveals sudden increases and static phenomena in growth and development by showing locally detected maximum velocity values. Based on the characteristics and theoretical grounds of the wavelet interpolation method, the size of the LPV is a projection of sudden increases and slowdowns in growth. It is very useful in elucidating growth phenomena.

RESULTS

Pattern of Height LPV Appearance and the Pattern Appearance Rate

With regard to the appearance of LPV in height, it was shown that there are cases in which LPV appears in 3 places, 4 places, and 5 places in the limited span of elementary school. As shown in Figures 1 and 2, in boys LPV appeared in 3 places in 1 boy (5.9%), 4 places in 7 boys (41.2%), and 5 places in 9 boys (52.9%). In girls, it appeared in 3 places in 1 girl (9.1%), 4 places in 4

girls (36.4%), and 5 places in 6 girls (54.6%). Judging from these appearance rates, it seems that LPV appears in 4 or 5 places in nearly all boys and girls both. In elementary school this kind of periodic pattern is formed in which this LPV appears in 4 to 5 places.

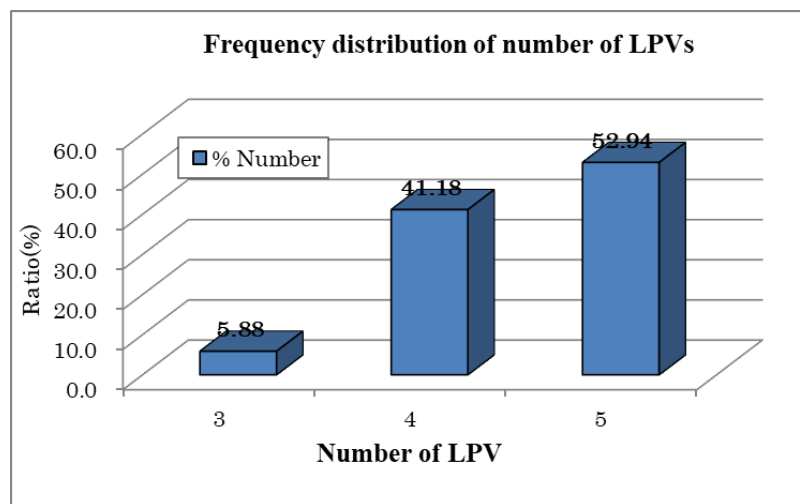


Figure 1: Height frequency distribution of % number in appearance patterns of LPV in boys

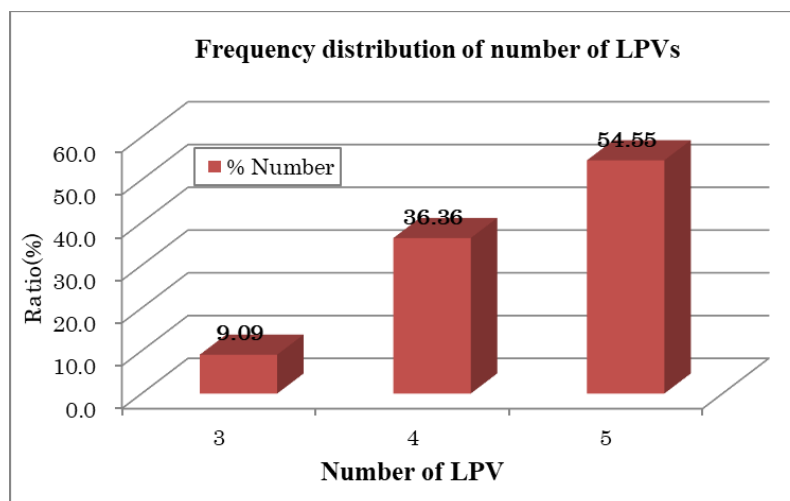


Figure 2: Height frequency distribution of % number in appearance patterns of LPV in girls

Relationship between Appearance Pattern of LPV in Height and Seasonal Month

To investigate the month in which LPV of height appears, the statistics for LPV age in the cases of LPV in 4 or 5 places was calculated. It was found that in boys with LPV in 4 places, the first LPV was around mid-May in 7-year-old children, the second around mid-June in 8-year-olds, the third around late June in 9-year-olds, and the fourth around late June in 10-year-olds. With LPV in 5 places, the first was around late November in 6-year-olds, the second around late August in 7-year-olds, the third around early July in 8-year-olds, the fourth around early July in 9-year-olds, and the fifth about mid-June in 10-year-olds. In girls with LPV in 4 places, the first was around early July in 7-year-olds, the second around mid-June in 8-year-olds, the third around mid-June in 9-year-olds, and the fourth around early August in 10-year-olds. With 5 places, the first appearance was detected around late November in 8-year-olds, the second was

around early August in 7-year-olds, the third around mid-June in 8-year-olds, the fourth around mid-July in 9-year-olds, and the fifth around early December in 10-year-olds. From this it is seen that LPV appears periodically from early summer through summer in both boys and girls when it appears in 4 places. When it appears in 5 places, it appears once in the winter in boys and twice in the winter in girls, and then appears 4 times periodically from early summer through summer in boys, and 3 times periodically from early summer through summer in girls. In patterns with the appearance of LPV in 4 or 5 places in boys and girls, nearly all LPV appearance points agree and no sex difference is seen when looking at the sex differences in the same appearance patterns. In both boys and girls, periodicity was seen from early summer through summer (Figures 3 and 4).

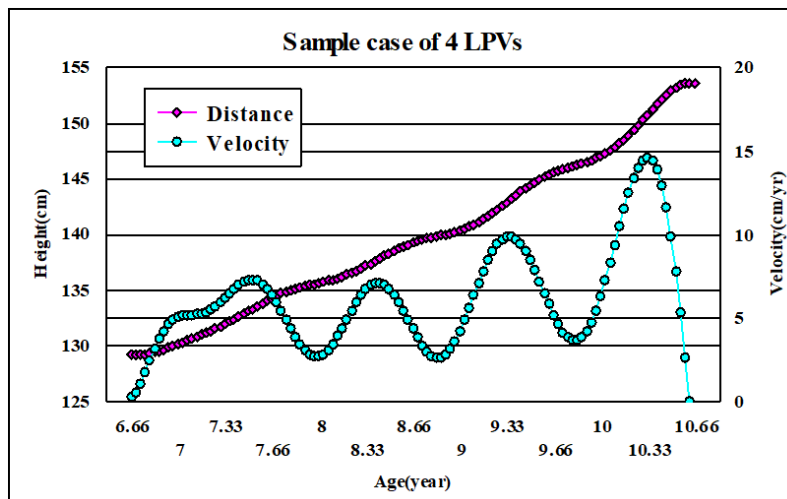


Figure 3: A sample pattern of growth of the case which the LPV appear in four places during elementary school

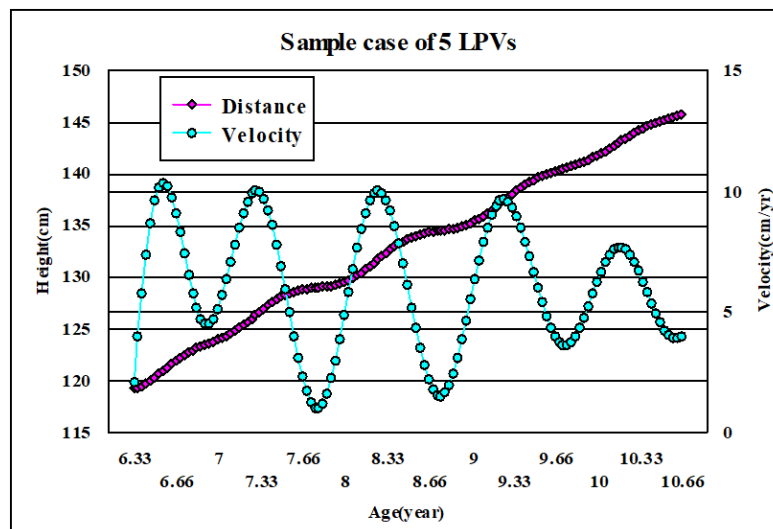


Figure 4: A sample pattern of growth of the case which the LPV appear in five places during elementary school

Relationship Between LPV Appearance Pattern Periodic Variations and Seasonal Variations

To In both boys and girls, the LPV appearance pattern in elementary school shows LPV in 4 or 5 places in nearly all cases. The peak age for LPV closely agrees with those respective patterns. As shown in Table 1-1, 1-2 the standard deviation against the mean is very small, ensuring the degree of coincidence. These peak time points often appear from early summer through summer, and may seem to be seasonal variations but are in fact showing periodic fluctuations. Thus, it may be that periodically fluctuating energy is displayed from early summer through summer, a season when there are many hours of daylight. Such phenomena have traditionally been viewed as seasonal variations, but the results of analysis with the application of wavelet interpolation showed periodic fluctuations. If one considers the hereditary strength of height growth in particular, hereditary periodic variation would seem to be more valid than seasonal variation as an environmental factor.

Table 1-1: Appearance pattern of LPV and appearance rate of the pattern (male)

Number of LPV	The first LPV age	The second LPV age	The third LPV age	The fourth LPV age	The fifth LPV age
3 (1)	6.66	8.13	9.26		
4 (7)	7.12(SD=0.29)	8.23(SD=0.10)	9.25(SD=0.05)	10.22(SD=0.10)	
5 (9)	6.69(SD=0.14)	7.41(SD=0.13)	8.26(SD=0.07)	9.27(SD=0.05)	10.21(SD=0.14)

Table 1-2: Appearance pattern of LPV and appearance rate of the pattern (female)

Number of LPV	The first LPV age	The second LPV age	The third LPV age	The fourth LPV age	The fifth LPV age
3 (1)	8.13	9.40	10.23		
4 (4)	7.25(SD=0.15)	8.21(SD=0.07)	9.29(SD=0.08)	10.35(SD=0.23)	
5 (6)	6.66(SD=0.12)	7.36(SD=0.10)	8.21(SD=0.07)	9.30(SD=0.10)	10.68(SD=1.25)

DISCUSSION

Application of wavelet interpolation to height growth at measurement intervals of three times a year in elementary school is an approach used in this study for the first time. However, the time axis of age has a slightly extended projection and an attempt was made to investigate it on the same dimension as an age axis by smoothing of the one-third year time axes. Therefore, the phenomenon of sudden increases in velocity in this age axis differs from the pubertal peak (maximum peak velocity; MPV), and the implication is thought to be that, as with the mid-growth spurt local peak velocity (LPV) proposed by Fujii (2002), hormone released prior to puberty contribute to the continuous changes. That is, the velocity peak shows increased energy to increase height, for which a hormonal contribution is naturally suggested. It is conjectured that this may express a fluctuating periodicity in the growth coded in genes. This is the growth fractal phenomenon that Fujii and Yamamoto [17] and Fujii and Matsuura [19] explained in the proposed theory for the wavelet interpolation method, and is significant in leading to chaos phenomena.

In this study the patterns of LPV appearance in height in elementary school were investigated, and patterns were seen with local peaks in 3, 4, and 5 places. Of them, the patterns with 4 or 5 local peaks accounted for more than 90%. This shows that a periodic LPV pattern is shown in

nearly all boys and girls, and is thought to be evidence suggesting periodic fluctuations in growth. Looking only at height growth, when a pattern with 4 or 5 local peaks in LPV age is derived, a local peak appears from about June to August in most boys and girls. This finding is thought to suggest that much of the growth in height during a year occurs from early summer through summer. Marshall [15] hypothesized a relationship with daylight hours and Tanaka et al. [16] presented findings that supported such a relationship. Park and Kobayashi (1997) also showed a relationship with daytime hours. These findings are understood as seasonal fluctuations, and if the environmental factor of daylight hours acts on growth in height, the variation may well be understood as a seasonal fluctuation. However, Ooki[21], Ooki and Asaka[22] pointed out the strong hereditary nature of height growth in monozygotic twins from a study of twins, and if height growth is controlled by genetic factors the influence of environment should be very small. Therefore, from the fact that the appearance of LPV is seen in similar time periods it may be more reasonable to consider the growth to be due to a periodic fluctuation as a growth mechanism, rather than from a relationship with the season.

Judging from the LPV appearance pattern, it is conjectured that seasonal elements have a facilitatory action in the growth pattern due to periodic fluctuations. This kind of seasonal facilitatory action may have previously been seen as seasonal variations. It may be that the height growth pattern is essentially achieved by periodic fluctuations, with a seasonal acceleration phenomenon acting in this periodicity.

CONCLUSION

In this study, based on the hypothesis that height growth basically does not fluctuate from the environmental factor of season but is achieved by periodic fluctuations due to genetic factors to investigate the periodic fluctuations in height growth in elementary school. For that purpose, we applied wavelet interpolation to height measurements taken three times a year to verify the periodic fluctuations from movements in the derived velocity curves. The results showed that the height growth pattern is essentially achieved with periodic fluctuations, and that there are seasonal stimulating phenomena within that periodicity.

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