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Establishment of a measurement system for similarity and dissimilarity of twins

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Abstract

Using previous twins study methods, it is thought that assessments of a given level may certainly be derived by analysis of similarity. However, there is the drawback that analysis cannot be done without a large population of twin pairs. In this study, author attempted the combined use of WIM and cross correlation function as a method that can evaluate similarity even in small populations of twin pairs. An evaluation chart was constructed for similarity from cross correlation function statistics with random pairs in the height growth of general boys, and from that chart a cross correlation function, r of 0.9 or higher, became a standard indicating high similarity. When cross correlation functions for height growth in monozygotic and dizygotic twins are applied to this evaluation chart, the correlation in monozygotic twins is high and that in dizygotic twins is somewhat high. Higher similarity is thus seen in monozygotic twins.

Keywords: Twins, Similarity, Measurement system, Growth velocity curve, Wavelet interpolation method (WIM).

Introduction

In research on twins, the degree of genetic involvement is often investigated when comparing the similarities in monozygotic and dizygotic twins. While hereditary influences differ by trait, the hereditary influence on physique is thought to be stronger than that on physical strength and motor ability, and in physique the inheritance of height is considered to be stronger than that of weight. According to Fujii et al. [1], there is little difference in height at birth between monozygotic and dizygotic twins, with a correlation coefficient of about 0.7, but as they age the correlation coefficient increases in the case of monozygotic twins and decreases in dizygotic twins. Thus, similarity in height increases with age in monozygotic twins but gradually decreases with dizygotic twins. This is thought to show the high hereditary similarity in height of monozygotic twins. These trends are generally the same even in weight, although the similarity in weight is less than that in height. This means that weight is more strongly affected by environmental and nutritional factors than height. Fischbein [2] showed correlations between twins in peak height velocity (PHV) age, PHV, peak weight velocity (PWV) age, and PWV, and stated that the correlation in PHV age between monozygotic twins was high in both boys and girls, while that between dizygotic twins was low. Tanner [3] proposed that PHV age in particular was meaningful as in indicator of maturity, and thought that there is a strong hereditary influence on height maturity. However, hereditary influences cannot be explained by correlation coefficients alone.

Ooki [4], applied a covariance structure analysis with the use of longitudinal growth data on twins to investigate hereditary factors in height growth in childhood, and attempted to analyze how the involvement of hereditary and environmental factors trended with age. However, even using longitudinal data on twins, data on many pairs is needed. Hence, it would be useful to be able to determine similarity from data on a small number of twins, if even just single pairs of monozygotic and dizygotic twins could be measured.

Fujii et al. [1], attempted using the wavelet interpolation method (WIM) to clearly ascertain similarity in monozygotic and dizygotic twins, and compared the growth velocity curves for height. They found in a comprehensive view of the growth curves that very close similarity was seen between the two graphs, and showed that there was good similarity appearance of the maximum peak velocity (MPV) and mid-growth spurt [5]. Therefore, monozygotic twins were similar through the height growth process, and this was interpreted as suggesting a clear hereditary influence. However, even though it was possible to derive velocity curves with WIM and make comparisons between twins, this does not mean that comparisons could be done objectively. That is, no method has been established to verify similarities between growth and velocity curves. To establish a verification method for similarity, growth and velocity curves must be quantified in order to measure similarity. Correlations between quantified curves can then be analyzed. A cross correlation function that analyzes the differences between two curves by folding one of them can be proposed as such a statistical technique. However, to apply a cross correlation function, one must be able to make a function for the minimum growth curve. That would require an approximation of the growth curve using the wavelet interpolation method (WIM) proposed by Fujii [6]. Application of a cross correlation function to a curve quantified by WIM would then be possible.

Even if a method to measure similarity were established, however, evaluation criteria for similarity have not been constructed. Hence, if one takes physical elements and then makes judgments from Scammon's [7], growth curve and attempts to evaluate similarity from height growth pattern, which follows the general type, it is first necessary to determine how much of a cross correlation function there is in the height growth patterns of unrelated pairs. That is, criteria for similarity between the same physical elements need to be ascertained. In this study, we first randomly extracted longitudinal height growth data and applied a cross correlation function to growth velocity curves for those unrelated pairs. We then built a mean evaluation chart from cross correlation function statistics and investigated the validity of the criteria for similarity by judging the similarity of twins from the evaluation chart.

Methods

Subjects and Materials

Longitudinal height growth data from age six (first year of elementary school) to 17 (last year of high school) were obtained for 14 pairs of Japanese monozygotic twins and two pairs of dizygotic twins born between 1994 and 1998. To construct evaluation criteria for similarity, longitudinal growth data were established by level of maturity to make a random pair correspondence in height growth data for general 68 boys born in the same years. The longitudinal growth data for height in suitable pairs were established between groups classified by level of maturity.

Analysis

Wavelet interpolation method

The Wavelet Interpolation Method (WIM) is a method to examine growth distance values at adolescent peak and menarchal age. A growth curve is produced by data-data interpolation with a wavelet function and by deriving the growth velocity curve obtained by differentiating the described distance curve to approximately describe the true growth curve from given growth data. The effectiveness of the WIM lies in its extremely high approximation accuracy in sensitively reading local events. Details on theoretical background and the basis for this effectiveness are omitted here as they have already been set forth in prior studies by Fujii [8-10].

Cross correlation function

A cross correlation function is used to show the similarity between two waveforms, and the cross correlation function may be evaluated by convolving one function as shown below. In addition, the degree of time lag can be examined when there are similar regions [11,12]. In this study, a cross correlation function was assumed from the velocity curve values found from differentiation using the WIM for growth distance values of change of BMI, muscle muss and fat percentage with age. If the calculated values for the two velocity curves are given as *x'(t)* and *y'(t)*, then the median value-subtracted transformation *x(t)* and *y(t)*, is given as *x(t)=x'(t)-μ* and *y(t)=y'(t)-μ*. Using the transformations *x(t)* and *y(t)*, the cross covariance is defined as follows, with τ as the time lag assigned to the other data-set and n as the sample size.

$$C_{xy}(\tau) = \overline{x(t)y(t+\tau)} = \lim_{T\to\infty}\frac{1}{T}\int_{-T/2}^{T/2} x(t)y(t+\tau)\,dt$$

The cross correlation is the cross covariance Cxy(τ) normalized by the standard deviation of the values for the two velocity curves x'(t) and y'(t), and is given as follows:

$$R_{xy}(\tau) = \frac{C_{xy}(\tau)}{C_x(0)C_y(0)N-j} = \frac{\overline{x(t)y(t+\tau)}}{\sqrt{\overline{x^2}}\sqrt{\overline{y^2}}}$$

Analysis was conducted using the cross correlation function Rxy (τ) calculated as outlined above.

Results

Application of Cross Correlation Function to Monozygotic and Dizygotic Twins

Wavelet interpolation is applied to the height growth of one pair of monozygotic twins in Figure 1. In both graphs, a visual overview of the velocity curve for height growth reveals that, visually, there is a high level of similarity in the monozygotic twins. Then, applying a cross correlation function to the height growth of monozygotic and dizygotic twins described by WIM, the change in the cross correlation function derived by folding the growth distance and velocity values on one side is shown in Figure 2 and 3. Looking at the changes in the correlation coefficients shown in the two graphs, a high degree of similarity is clearly seen in the monozygotic twins, with r=0.9 in the monozygotic twins and r=0.7 in the dizygotic twins. For height, which has a high level of heritability, this objectively verifies that there is a high degree of similarity in monozygotic twins, as would be expected. However, since this was a comparison of only single pairs of monozygotic and dizygotic twins, similarity could be determined by comparing the correlation coefficients between the two pairs. An attempt to determine similarity in many pairs of twins, however, would require criteria for evaluating similarity. We therefore randomly extracted longitudinal height data in general boys and made suitable pairs. A cross correlation function was applied to those pairs and criteria for evaluating similarity were constructed.

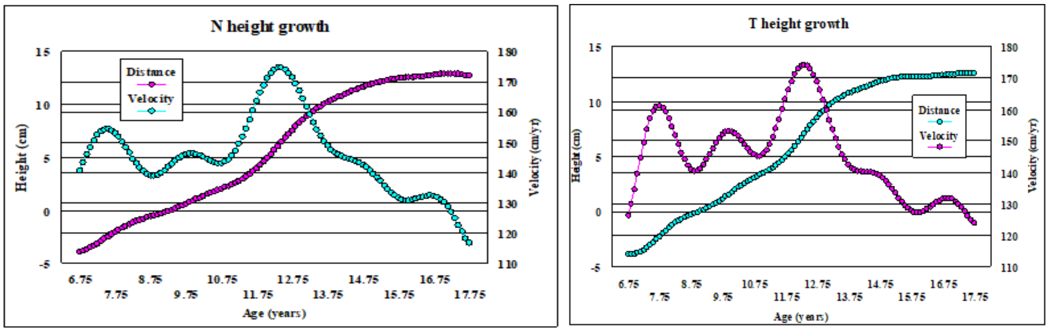

Figure 1: Height growth of monozygotic twins.

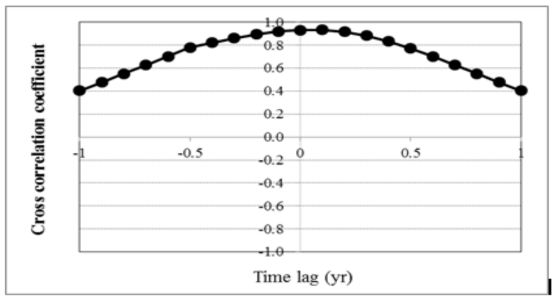

Figure 2: Cross-correlation coefficiens between monozygotic twins.

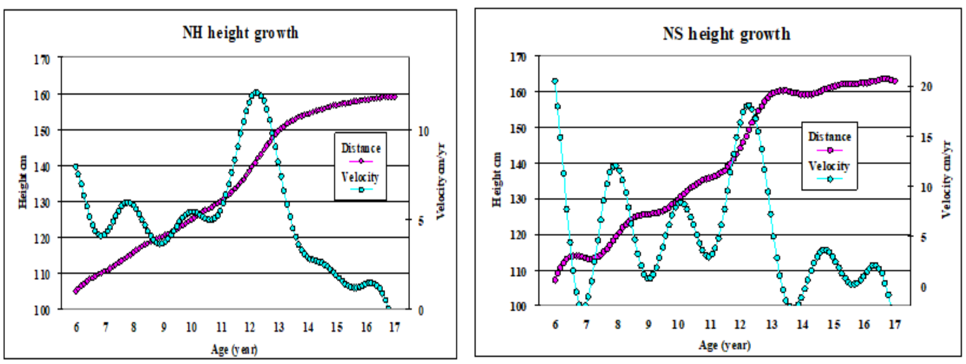

Figure 3: Height growth of dizygotic twins.

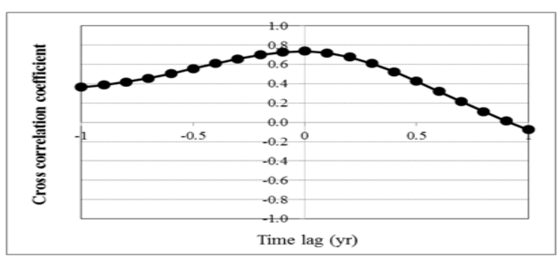

Figure 4: Cross-correlation coefficiens between dizygotic twins.

Construction of Evaluation Criteria for Similarity in Monozygotic and Dizygotic Twins

Suitable pairs were made from among groups with the same level of maturity in the randomly extracted longitudinal height growth data for general boys. The cross correlation function was applied to the growth data for those pairs, and the derived correlation coefficient statistics are shown in Table 1. Table 2 is a chart that constructs evaluation criteria for similarity from these correlation coefficient statistics. According to this chart, the cross correlation function in unrelated pairs of boys has a mean r of about 0.6 (r=0.59, SD=0.22) for height. For evaluations of similarity, a high similarity is not obtained unless r is ≥9. However, by deriving this evaluation chart first, it was possible to evaluate similarity in twins.

Evaluation of similarity in monozygotic and dizygotic twins: Table 3 shows the cross correlation functions for 11 pairs of monozygotic twins and three pairs of dizygotic twins. The dizygotic twins had little relationship and individual cross correlation functions are shown, but basically it is understood that the similarity of monozygotic twins is high. Because the number of dizygotic twins was small they must be handled individually, but when the mean cross correlation function of monozygotic twins is calculated, r was found to equal 0.915 (SD=0.067) and the similarity of monozygotic twins can be evaluated as high even when judging from the evaluation chart.

Table1: Statistics of cross-correlation coefficient applied to random pair of general height growth.

	Random Pair
	32Pair
mean	0.59
SD	0.22

Table 2: Criteria of evaluation chart derived from the statistics of cross-correlation coefficient.

Evaluation	
High	r>0.9
Somewhat High	0.9≧r>0.7
Normal	0.7≧r>0.5
Somewhat Low	0.5≧r>0.3
Low	0.3≧r

Table 3: Cross correlation coefficients and evaluation of similarity in identical and fraternal twins.

Pairs	**Correlation coefficient**	**Result of evaluation**
MM1	0.92	High
MM2	0.82	Somewhat High
MM3	0.87	Somewhat High
MM4	0.92	High
MM5	0.98	High
MM6	0.87	Somewhat High
MM7	0.98	High
MM8	0.92	High
MM9	0.93	High
MM10	0.94	High
MM11	0.89	Somewhat High
MD1	0.85	Somewhat High
MD2	0.82	Somewhat High
MD3	0.56	Normal
(MM: Monozygotic twin; MD: Dizygotic twins)		

Discussion

Essentially, cross correlation functions show the level of the interdependence between two time series waveforms, or whether they are similar. Thus, they are expressed as the phase shift time, Δt function of two waveforms. For cross correlation functions, the correlation coefficient between the two can be obtained by performing calculations as Δt is increased when there is time series waveform x(t) and y(t+Δt). Therefore, they are in the range + ≥ r ≥ −1, the same as the correlation coefficient. When they are 0 it means that there is interdependence between x(t) and y(t), or that no similarity is seen. In this study, WIM was applied to growth distance values for each physical attribute as x(t), and it should be noted that this first derivative was used.

Using the properties of this cross correlation function, the similarities in monozygotic and dizygotic twins were examined in this study. Among twins, monozygotic twins are obviously thought to have higher similarity [13-15], but given the large individual differences among people there is also a possibility of high similarity between dizygotic twins. While these findings are somewhat old, Hoshi [16] showed that while the growth process should be essentially the same in the case of monozygotic twins, differences in the growth process appear because measurement errors always occur. In addition to measurement errors, however, individual differences may also arise from environmental factors. Hence, after determining similarity from an analysis in which percentile deviations were applied, he stated that disparities due to individual differences are detected even in monozygotic twins. In fact, there is a history of wide use of percentile deviations as an indicator of similarity in twins [17]. Oki and Asaka [18], analyzed the changes in similarity in height and weight from birth to 11 years old by applying percentile deviation and intra class correlation coefficients. Using these methods, it is thought that assessments of a given level may certainly be derived by analysis of similarity. However, there is the drawback that analysis cannot be done without a large population of twin pairs.

In this study, we attempted the combined use of WIM and cross correlation function as a method that can evaluate similarity even in small populations of twin pairs. Specifically, this was a comparative verification of the similarities in monozygotic and dizygotic twins for growth in height, but criteria to evaluate the degree of similarity were not established. In other words, the criteria to determine whether the level of similarity is high or low with given cross correlation function levels are not understood. Growth curves were then described with WIM for randomly extracted, unrelated height pairs and cross correlation functions were applied to the velocity curves of those pairs. The method of evaluating mean values from statistics of the derived cross correlation functions was adopted, and a similarity evaluation chart was constructed. According to this chart, r was about 0.9 in all 13 pairs of monozygotic twins and the level of similarity was judged to be high. The number of dizygotic twin pairs was low, but r was around 0.7 and the similarity was in the somewhat high category. However, previous studies have already shown that similarity is high in monozygotic twins [18-21]. Objective determinations of similarity objectively based on cross correlation function as in this study, however, may be useful in future analyses of physical growth patterns.

Conclusion

Analysis of similarity in monozygotic and dizygotic twins in previous twin research required much data on twin pairs. In this study, similarity in monozygotic and dizygotic twins was verified by describing a growth curve by WIM and applying cross correlation functions. Criteria for evaluating similarity in twins were not established. A system was proposed to quantify similarity in twins, including that point. As a result, an evaluation chart was constructed for similarity from cross correlation function statistics with random pairs in the height growth of general boys, and from that chart a cross correlation function, r of 0.9 or higher, became a standard indicating high similarity. When cross correlation functions for height growth in monozygotic and dizygotic twins are applied to this evaluation chart, the correlation in monozygotic twins is high and that in dizygotic twins is somewhat high. Higher similarity is thus seen in monozygotic twins.

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