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Pattern Analysis Based on Standardization Model in Human Growth －Proposal for Fujimmon's & Scammon's Comparative Growth Curve－

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Abstract **-** The Fujimmon growth curves have been proposed as standardization of a new growth system built on Scammon's growth curves. Analysis of the changes in human body proportions with this may be considered significant. Therefore, the theory proposed by Scammon was first examined in order to investigate a standardization of the human growth system, construct a new growth curve model as a standard growth pattern for humans, and test the changes in proportions based on those growth patterns. As the results, that the velocity curves in general type visceral growth and genital type testicular growth can be shown to be very similar is something that seems to have been demonstrated for the first time by Fujii (2015). This proposal for the Fujimmon growth curves as a standardization of the human growth system may make it possible to verify the changes in human proportions formed from three patterns, a neural type, lymphoid type, and general type, from the relative changes in the growth of the head, which is representative of the neural type, and the growth in height, which is representative of the general type.

Keywords**:** Pattern analysis, Fujimmon growth curve, Scammon growth curve, Standardization, Wavelet interpolation

1. Introduction

In Animals as Social Beings, Portmann [1] said that, physiologically, humans are born prematurely as they are completely helpless at the time of birth. It takes about 20 years for a human to become an adult, the longest of all the primates. From a human evolutionary point of view, there must be some meaning in being in this "helpless" state at birth. The author[2] has previously shown that even large four-legged animals reach an adult weight in about two years, and their weight growth curve differs from the growth curve of humans. In terms of the growth curves of Scammon [3], they show a "neural type" of growth curve; that is, they do not have puberty. Simians show a slight pubertal peak in their body weight growth, although it is not as long as in humans. Among mammals, four-legged animals grow uniformly, with no difference in growth pattern depending on the body area. This means that there is no change in their body proportions. For example, there are no major differences in the body proportion of a four-legged animal at birth and when they are adults. Humans, on the other hand, have very different proportions (change in head and body height ratio) at birth and as adults. Adult humans have a body height to head ratio of 7–8, whereas in newborn babies this ratio is about 4. In the womb there is even a period when it is 3. These changes in the height to head ratio with growth may be unique to humans.

Why are proportion changes seen in humans? A key to this may be in the phenomenon of puberty. In humans, head size approaches that of adults in the first half of growth, as it does in four-legged animals, while the body size continues growing after that. This causes a change in the relative proportions of the body. There is thought to be a deep causal association between this and upright walking on two legs in humans as a result of evolution. For humans, growth of the brain has an important role, and a time such as puberty is needed to protect the brain and facilitate active growth. One may speculate that this period is necessary for development of the brain, and it may be why changes in human body proportion have become a fixture of growth today.

Scammon's [3] growth curves have been convenient to use in demonstrating changes in human body proportion. Takaishi [4] explained that these changes are easy to understand by grasping the relative growth of things that follow the general growth pattern, such as body height and weight, and those that follow the neural growth pattern shown in the growth of the head. Behind this explanation is a history of conveniently demonstrating changes in body proportion with the use of Scammon's growth curves. However, even if human growth phenomena can be explained conveniently in this way, this approach will probably not lead to universal findings.

In discussing growth phenomena to date, Scammon's growth curves are often occupy a central position in the arguments given. However, Scammon's growth curves were proposed more than 85 years ago, and the theory was constructed in an age when computers did not exist. Today, when so much more is understood scientifically, it is natural that we should to try and verify the validity of a theory proposed more than 85 years ago. No report has yet clearly validated this theory. Given the above, in this study the theory proposed by Scammon was first re-examined to investigate the standardization of the human growth system, and a new growth curve model was constructed for the standard human growth pattern. That growth model pattern is proposed as the Fuijimmon growth curve. The two growth curves are compared on the same scale for easy understanding of the differences in the model patterns.

2. Methods

Data sets

As data showing the four attributes classified from the growth curves of Scammon, the data used were cross-sectional growth data from age 1 year to 20 years for brain weight (as the neural type), thymus gland and tonsils (as the neural type), testicles (as the genital type), and liver and heart (as the general type) shown by Takaishi et al.[5].

Analytical method

1. 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 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 approximate 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 [6][7][8][9].

2. 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 (Matsuura et al ; 2006, Yamada et al ; 2006). In this study, a cross correlation function was assumed from the velocity curve values found from differentiation using the WIM for twins' physiques, internal organ types classified in the Scammon growth curve and growth distance values for athletic ability. 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.

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

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:

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

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

3. Result

1. Re-verification regarding Scammon's growth curve

Scammon determined growth types by classifying human growth systems into four basic patterns. As shown in Fig. 1, they are the general type, neural type, lymphoid type, and genital type.

As can be seen in Fig. 1, Scammon's graph of growth consists of estimated growth curves drawn freehand, with which it would have been difficult to standardize the growth system. Fujii [10] confirmed that the human growth phenomenon is formed of four major standard growth types as advocated by Scammon, but did not elucidate the evidence that established these four standard growth patterns. Therefore, it is first necessary to investigate whether these four growth curve patterns describe independent curve patterns. An attempt was made to investigate this by applying cross-correlation functions for similarities and differences between the growth curves.

Figure 2 shows the growth in testicular weight described by wavelet interpolation, and Fig. 3 shows the growth in brain weight. Figure 4 shows the results with the application of a cross-correlation function to analyse the similarities and differences between these growth velocity curves. The results showed an inverse correlation with $r = -0.446$. The differences in the growth in brain weight, which is the neural type, and the testicles, which is the genital type, were obvious. Since it may be that the differences between patterns vary in degree in this way, the respective levels of difference between other physical attributes with this method were derived from cross-correlation functions. The results showed a level of $r = 0.743$ between brain weight (neural type) and the thymus (lymphoid type), and an inverse correlation of $r = -0.639$ between brain weight and the liver (general type). Next, the results showed a value of $r = -0.70$ between the thymus and testicles, $r = -0.860$ between the thymus and liver, and a fairly high correlation of $r = 0.94$ between the testicles and liver. Thus, the cross-correlation functions clearly differed between the four patterns and pattern discrimination was shown to be possible. Surprisingly, however, they also indicated the possibility of similarity between brain weight and the thymus and the possibility of very high similarity between the testicles and liver. Therefore, as a result of applying cross correlation functions, 3 standardized type patterns could be distinguished as standardized patterns of growth systems: the neural type, lymphoid type, and general type. The genital type classified by Scammon is then classified in the general type. Thus, new growth system standard type is formed by the classification of a morphology/organ type pattern and a genital type growth pattern within the general type.

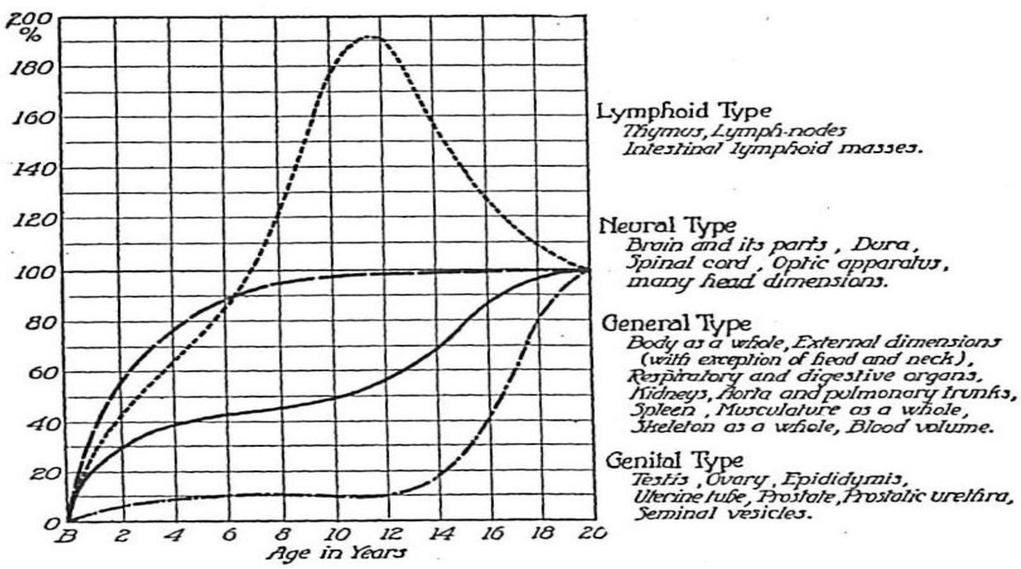

Fig.1: Four growth patterns in human growth described by Scammon's idea.

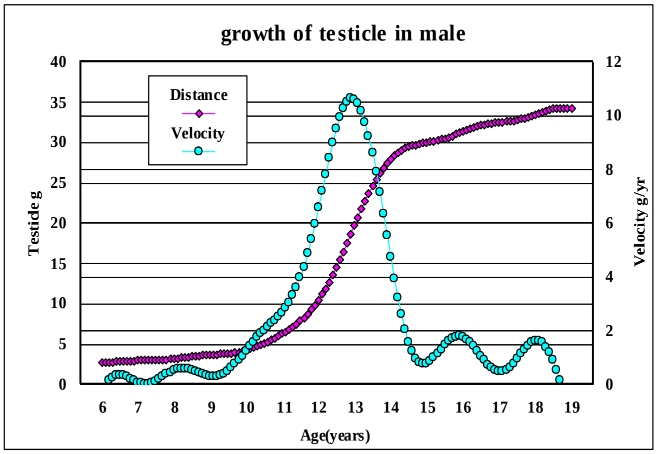

Fig. 2: Growth curve of testicle by wavelet model.

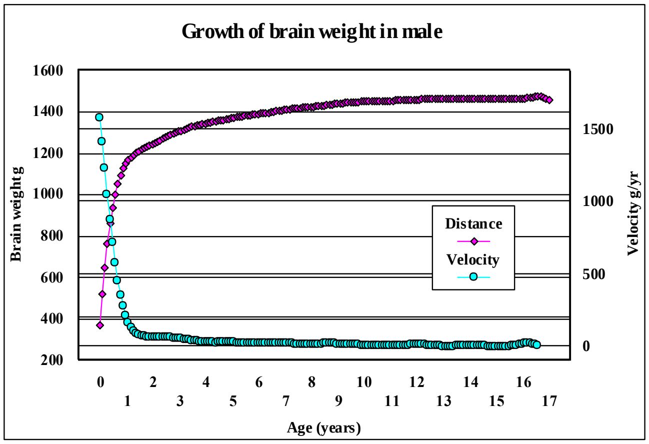

Fig. 3: Growth curve of brain weight by wavelet model.

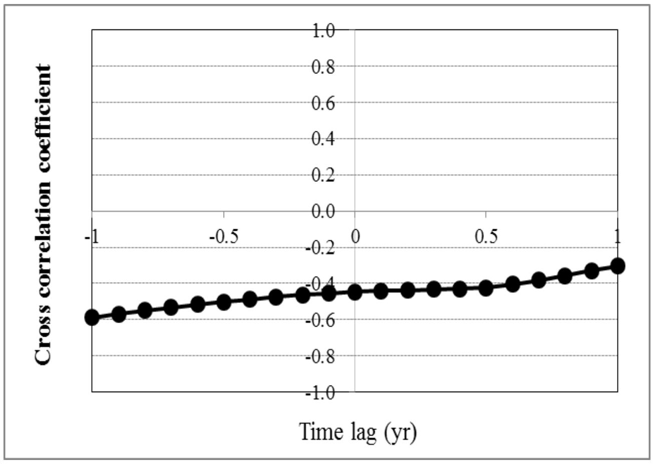

Fig. 4: Cross correlation between testicle and brain weight.

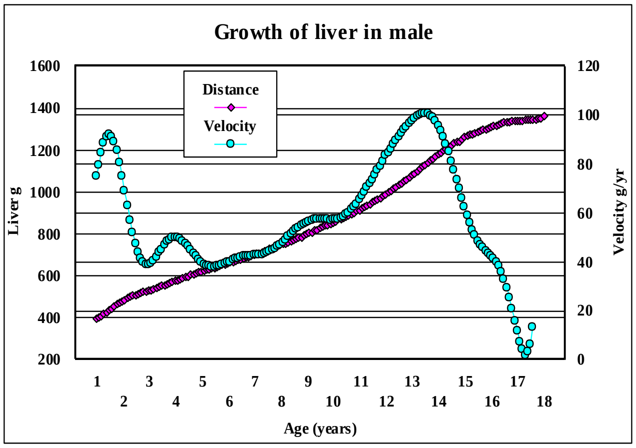

Fig. 5: Growth curve of liver by wavelet model.

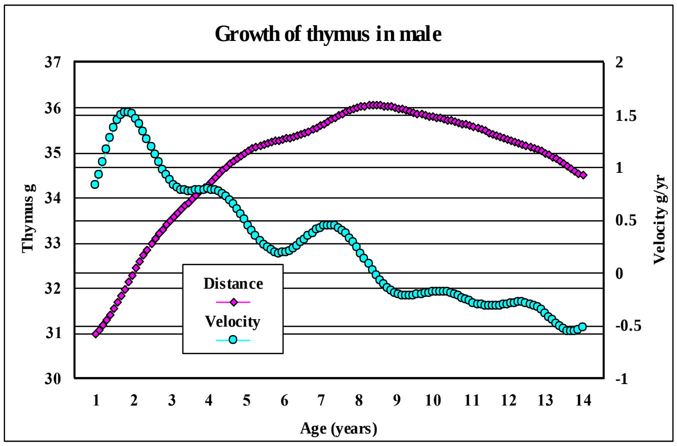

Fig. 6: Growth curve of thymus by wavelet model.

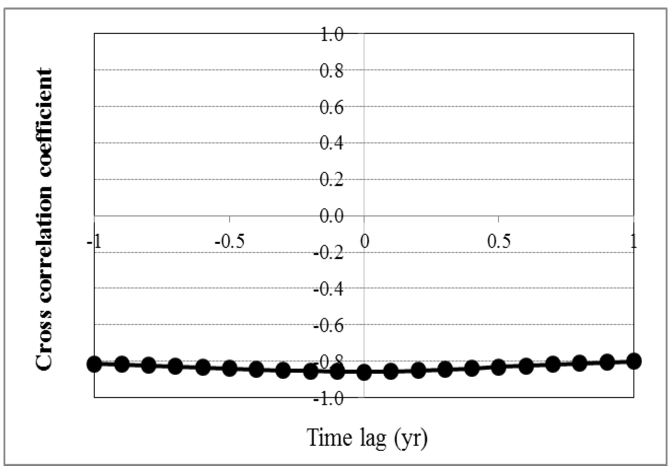

Fig. 7: Cross correlation between liver and thymus.

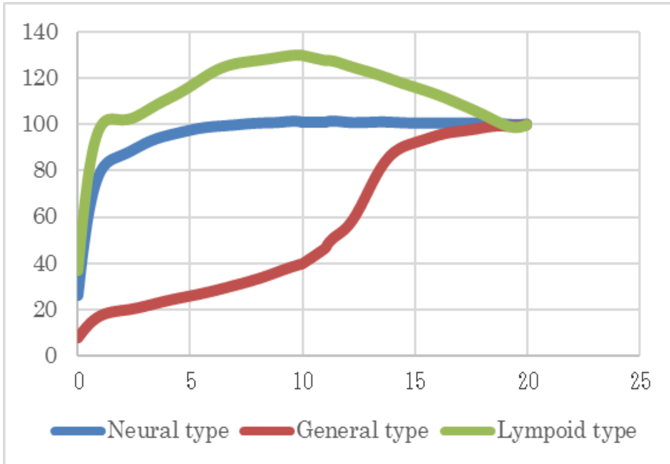

Fig. 8: Newly proposed Fujimmon's growth curve.

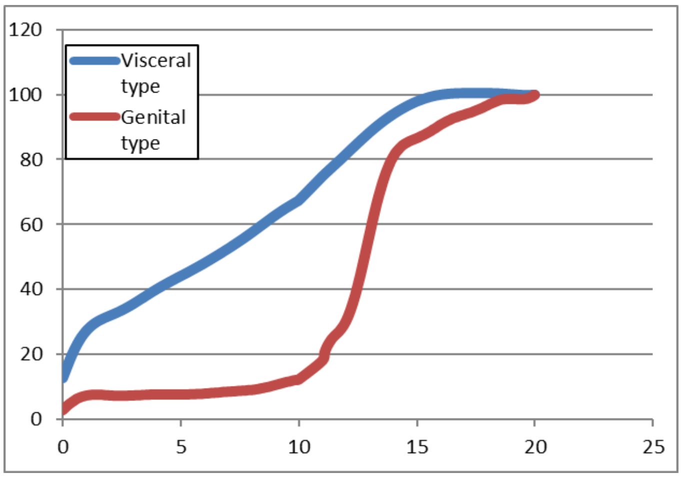

Fig. 9: Visceral and genital types by Fujimmon's growth curve.

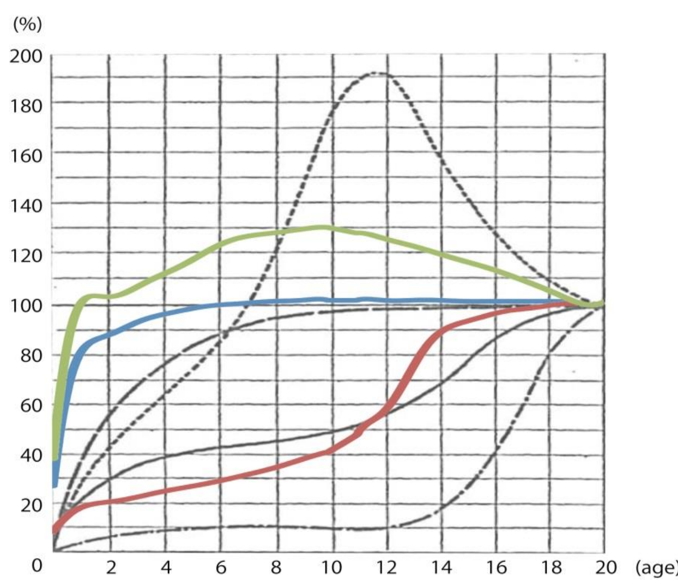

Fig. 10: Fujimmon's and Scammon's comparative growth curve.

2. Proposal for Fujimmon growth curves

Fujii [10] previously re-examined Scammon's growth curves and considered the general type and genital type, which show the same phenomenon of rapid increase during puberty, to be the same pattern. He then proposed the Fujimmon growth curves. Figure 8 shows Fujimmon growth curves classified as neural, lymphoid, and general curves. Compared with the traditional Scammon growth curves, the growth in the neural type growth reaches a value near the adult value in early childhood. In the lymphoid type, it may be more valid to consider a growth peak up to about 130%, not to 200%, in puberty. The general type is not all that different from the general type in Scammon's growth curves, but the sigmoid shape is not formed to the extent that it is in Scammon's general growth type. This may be the difference between curves drawn freehand and by mathematical functions.

Figure 9 shows the morphological/visceral type and genital type curves classified within the general growth type. The genital type remains classified in the general type and is recognized as a growth type that is split off from the general type. At first glance they appear to be quite different, but they have a very high degree of similarity in that a pubertal peak appears. These morphological/visceral and genital type curves also resemble a logistic curve. In other words, these two curves also have changes that resemble a logistic curve, like the changes in the curve depending on the coefficient of the denominator in a logistic equation. In the framework of a logistic curve, therefore, both the morphological/visceral curve and the genital curve are thought to be the same general type curve. Japanese data on organs and other data used in analysis were naturally available in proposing the Fujimmon curve, but there are data for only a few types of organ and it is thought that more precise Fujimmon curves can be proposed when it becomes possible to measure the weight of organs with scans as scientific technology progresses in the future. Today we cannot expect accuracy above the current level in Fujimmon curves.

4. Discussion

In this study, the Fujimmon growth curve is proposed as a standardization of growth systems. For this purpose, it is thought that application of a cross-correlation function can ensure greater scientific evidence to show that the general and genital types shown by Scammon[3] are the same standard type pattern. That is a pattern in which the neural and lymphoid types do not show the phenomenon of a rapid increase during puberty. It is also clear from the growth phenomena that the neural type shows maximum values in adults while the lymphoid type shows maximum values in puberty. However, both the general and genital types show rapid growth phenomena in puberty, and clear evidence is lacking to make judgments based on growth phenomena as a standard pattern and classify the two attributes. According to Scammon, the increasing trend for attributes in the genital type is smaller from birth through early childhood than that for attributes of the general type, and a standard pattern with more rapid growth than the general type was established as a characteristic of the genital type. The evidence for this is weak scientifically. Neither the various attributes belonging to the general type nor the various attributes belonging to the genital type can be determined from the growth change rate; they are nothing more than judgments from the changes in the distance curve. This is simply observing the raw data with the naked eye, and is an interpretation completely lacking in objectivity. In fact, the morphological/visceral and genital type curves resemble logistic curves. There is a context in which logistic equations have been applied to the proliferation trends of microorganisms, and they are mathematical functions that are still used. The coefficient of the denominator in a logistic equation reflects the proliferation trends of microorganisms, and the shape of a curve changes with changes in this coefficient. In both types of curve those changes are similar to the changes in a logistic curve. Therefore, in the mathematical function framework that is a logistic curve, both the morphological/visceral type and the genital type are thought to be the same general type.

Therefore, the study result that the velocity curves in general type visceral growth and genital type testicular growth can be shown to be very similar is something that seems to have been demonstrated for the first time by Fujii [10]. This proposal for the Fujimmon growth curves as a standardization of the human growth system may make it possible to verify the changes in human proportions formed from three patterns, a neural type, lymphoid type, and general type, from the relative changes in the growth of the head, which is representative of the neural type, and the growth in height, which is representative of the general type.

5. Conclusion

The findings in this study obtained in investigating the changes related to human proportions from standardization of the growth system have not been known until now. The Fujimmon growth curves have been proposed as standardization of a new growth system built on Scammon's growth curves. Analysis of the changes in human body proportions with this may be considered significant. It is thought that the proportion details for each age can be presented in the future by examining how various factors in actual human body proportions change.

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