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Proposal for a Motor Ability Development Model Based on Fujimmon's Growth Curves

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Abstract: Scammon's growth curves are often cited in discussions of motor ability development and training theory. However, Scammon's theory of growth curves was proposed more than 90 years ago, and its scientific value is weak. Therefore the growth curves of Scammon was reexamined, and Fujimmon growth curves was newly proposed. If based on Fujimmon's growth curves, a motor ability development model can be hypothesized as a mixed type model combining the general and neural types. To verify that hypothesis, author applied the wavelet interpolation model to the motor ability development process, analyzed the behavior of the velocity curves, and investigated whether the motor ability development pattern showed a curve pattern closer to the general type or neural type. As a result, it was shown that development patterns for things such as agility and running ability show curves that depend on the neural pattern, while development patterns for abilities requiring muscle strength and explosiveness show curves that depend on the general type. In girls, the pattern of motor ability development tended more strongly to depend on the neural type compared with boys. Consequently, from this study author was able to newly propose three types of curves: a pattern with a high level of dependence on the general type, a pattern with a high level of dependence on the neural type, and a standard development pattern of those two types. With the proposal of these three types of model curves, author may gain new perspectives on the utilization of sports training and the discovery of sports talent.

Keywords: Fujimmon's Growth Curves, Motor Ability Development Model, General Type, Neural Type

1. Introduction

Scammon's growth curves [1] have long been used to advantage as an effective indicator to conveniently outline the growth of humans after birth. Scammon divided the growth of the physical attributes of humans after birth into four patterns describing those growth processes. Growth classifications into the four patterns of neural, lymphoid, genital, and general are very well known. The place where Scammon's growth curves have been useful is in their convenience in explaining the outlines of human growth. The pubertal spurt phenomenon that is characteristic to human growth can be conveniently explained with the general growth pattern. The growth of the skull that covers the brain is explained by the neural growth pattern, the growth of the human immune system can be explained by the lymphoid pattern, and the male and female reproductive organs can be conveniently explained with the genital pattern. Scammon's growth curves have been particularly useful in explaining why the body proportions of humans change as they grow. With current science it is not possible to decipher human proportion changes as a result of evolution. However, it is possible to explain the phenomenon of changes in proportion. That is, it can be explained that while head size becomes close to that of an adult in the first half of growth in four-legged and other animals, human body size continues to grow even after that and so relative changes in proportion occur.

Scammon's growth curves have been advocated in explaining these proportion changes in humans, and so few papers examining proportion changes are seen. However, Scammon's growth curves were proposed more than 90 years ago, and Scammon's growth curves themselves have not been verified. That is, it cannot be determined whether the growth curves, drawn freehand in four patterns, are all independent. Obviously, each classified pattern needs to be independent. Therefore, Fujii [2, 3] tried to reexamine the legitimacy of

Scammon's [1] growth curves, and examined the independence of the four growth patterns. Fujii [4] then advocated the Fujimmon growth curves. A feature of the Fujimmon growth curves is that there are three major growth patterns. Whereas Scammon's growth curves have separate general and genital patterns, in the Fujimmon growth curves these two patterns are not independent, and the genital pattern is included in the general pattern. The proportion changes in humans could then be explained on this basis (Fujii et al. [3]). While it is not possible to elucidate the evolution of the proportion changes in humans, with the above explanation there is a major causal relationship with upright bipedalism in humans, which is thought to be the result of evolution. The growth of the brain is important for humans, and the period referred to as puberty is necessary to protect the brain and facilitate active growth. It can be assumed that there is a need to enrich the brain in this period. Hence, today's proportion changes in humans became established.

Be reexamining Scammon's growth curves and advocating the Fujimmon growth curves as mentioned above, an outline of human growth can be grasped, proportion changes can be explained, and human physical growth patterns can be understood to advantage. However, Scammon's growth curves [1] were never intended show growth patterns of human function and ability. Therefore, it is a mistake to seek physical function and ability in the growth patterns of Scammon and Fujimmon. In fact, Kimura [5] stated that a general development pattern for motor abilities that seems to combine the properties of the neural and general patterns can be shown in human growth in those works judging from the growth curves of Scammon [1], and drew a diagram of a motor ability development pattern. Figure 1 shows a diagram of the human physical and mental function advocated by Kimura [5]. If motor function in this diagram in particular is judged from the Fujimmon growth curves, it does seem that a mixed pattern that combines the general and neural growth patterns can be assumed. Kimura [5] proposes a pattern diagram of motor function from the growth curves of Scammon, but this proposal may be considered a simple supposition rather than a hypothesis. That is, while verification is possible with a hypothesis, this pattern diagram has not as yet been verified even today. Like the growth curves of Scammon, it is an unverified proposed theory.

Therefore, Fujii [4], as in advocating the Fujimmon growth curves, constructed a new hypothesis with a mixed pattern of the general and neural types proposed by Kimura [5] for motor ability and function, and attempted to verify that hypothesis based on the Fujimmon growth curves. As mentioned above, Scammon's growth curves are a classical theory, and the curves were drawn freehand. Kimura [5] proposed a diagram with a mixed pattern combining the general and neural patterns, but ultimately this too is a freehand diagram. The Fujimmon growth curves advocated by Fujii [4] are described based on the wavelet interpolation model, and even if one hypothesizes a mixed type of the general and neural patterns, it is possible to look for this mixed pattern based on the Fujimmon growth curves. Hence, a motor ability development pattern model is put forward by seeking and constructing a mixed pattern of the general and neural patterns.

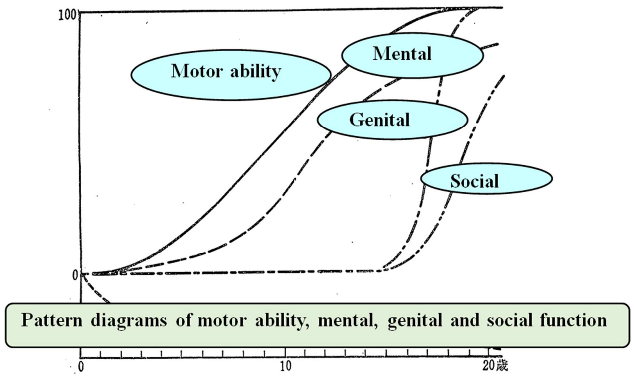


Figure 1. *Developing imitative chart of human function and ability (Kimura, 1966).*

2. Methods

2.1. Data Sets

Data on height and motor ability items (grip strength, sit-ups, side steps, 50-m dash, standing long jump for boys and girls were taken from the Annual Report on the Survey of Physical Fitness and Athletic Ability published by the Ministry of Education, Culture, Sports, Science and Technology in 2005. From these data, cross-sectional growth and development data from the first grade of elementary school (6 years old) to the third year of high school (17 years old) were used.

Neural, lymphoid, and general types are taken as the three attributes classified from the Fujimmon growth curves, from which the neural and general types are used. Figure 2 is the Fujimmon growth curves advocated by Fujii [4], but the neural and general patterns from the three growth curves shown here are combined and a combination of three patterns, a standard intermediate type, neural dependent type, and general dependent type are established.

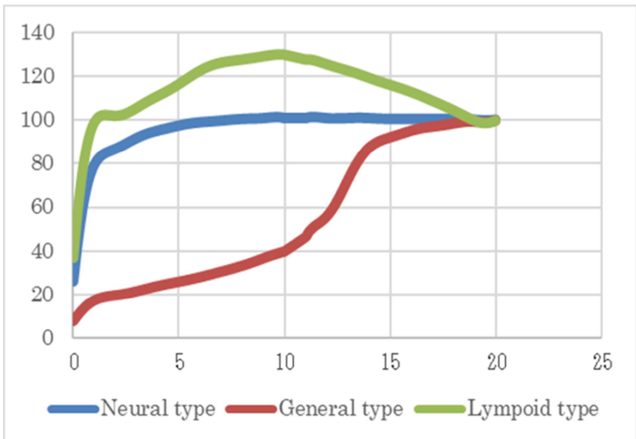


Figure 2. *Fujimmon's growth curve described by wavelet interpolation model (WIM).*

2.2. Analytical Techniques

Wavelet interpolation model

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, the drawn growth distance value curves are differentiated, growth velocity value curves are derived. Growth distance values at times such as the pubertal peak or the age at menarche and 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 [6–10].

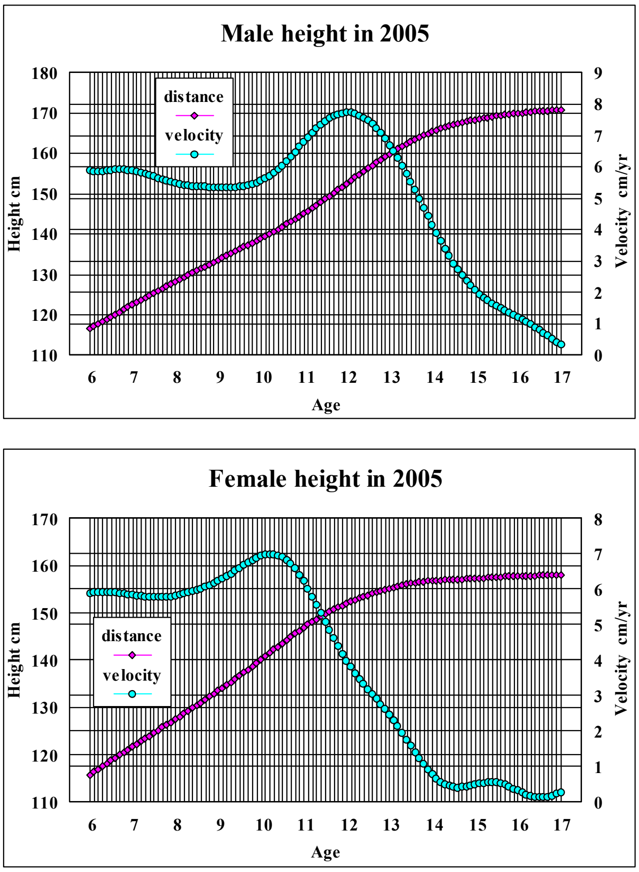


Figure 3. *Growth distance and velocity curve from 6 to 17 years of boy's and girl's height described by wavelet interpolation model (WIM).*

3. Results

3.1. Analysis of Motor Ability Development Curves Based on the Wavelet Interpolation Model

Figure 3 is a graph of the wavelet interpolation model applied to height growth data for boys and girls. The age at the pubertal peak, that is, the age at the maximum peak velocity (MPV), is clearly shown. It was 12.0 years old for boys and 10.2 years old for girls. The age at MPV of height needs to be clarified because of the need for a comparative investigation with the age at MPV of motor ability development.

First, Figure 4 is a graph of the wavelet interpolation model applied to the development distance values from age 6 to age 17 for grip strength in boys and girls. For grip strength in boys, the development distance value curve shows a sigmoid-like increasing trend, but for grip strength in girls it shows an increasing trend that is more linear than sigmoid. Looking at the development velocity values, in boys an MPV that shows a peak in puberty appears, similar to height growth. An MPV also appears in girls. Looking at the MPV ages specified in boys and girls, the age was 12.7 years old in boys (MPV is 6.78 kg/yr) and 10.4 years old in girls (MPV is 3.28 kg/yr). When this age was compared with the MPV age for height, the MPV for grip strength appeared 0.7 years after the MPV age for height in boys, while in girls the MPV age for grip strength appeared at about the same age as the MPV age for height.

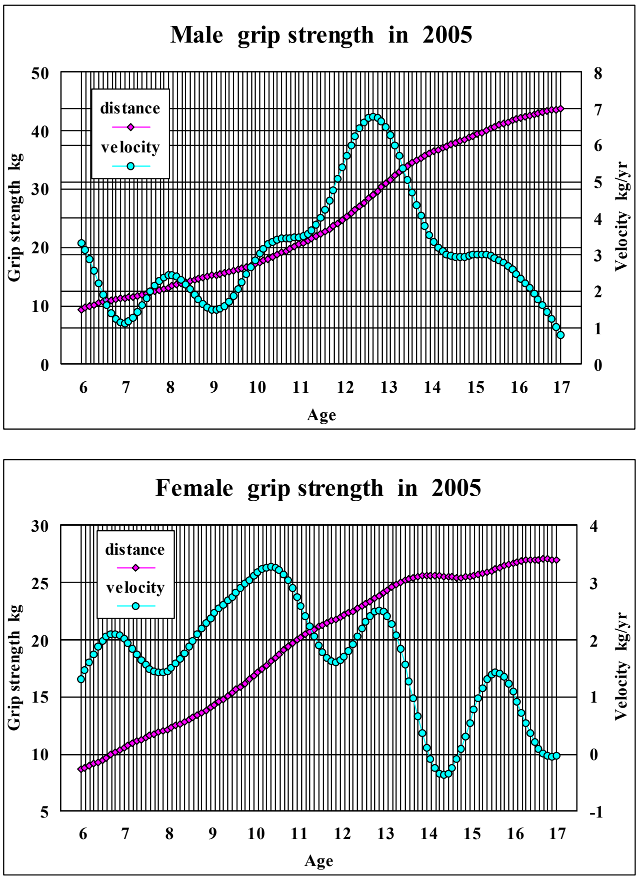


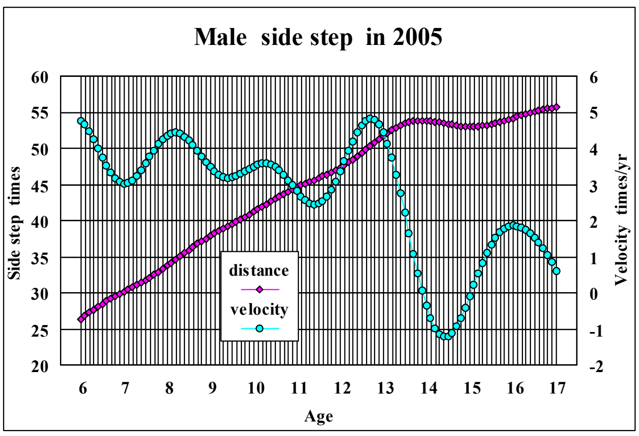
Figure 4. *Developmental distance and velocity curve from 6 to 17 years of boy's and girl's grip strength described by WIM.*

Figure 5 is a graph of the development curve for the sidestep in boys and girls. Looking at the development distance values in boys and girls, a linear increasing trend is seen in both. Looking at the development velocity curves, in both boys and girls a phenomenon of local velocity increases (local peak velocity; LPV) is seen several times from the early elementary school years through puberty. For boys, an MPV is seen as in height, and the age of 12.7 years old was specified as the age at MPV. In girls, however, while an increasing velocity was seen in the early elementary school years, no age at MPV was specified. Unlike grip strength, ability in sidesteps, which represents agility, does not have a clear appearance of MPV. In girls especially, it was found that the phenomenon of a pubertal peak is not seen.

Figure 6 shows a graph of the development curve for sit-ups. Looking at the development distance value curves for boys and girls, a similar increase is seen in both boys and girls, and a small rapid increase is seen in puberty. Therefore, judging from the development velocity curves, a local peak velocity is seen before puberty in both boys and girls, but the age at MPV for boys was identified as 12.6 years (3.83 times/yr) and that for girls at 12.8 years old (2.55 times/yr). However, the appearance of a MPV is more distinct in boys than it is in girls.

Figure 7 is a graph of the development curve for the 50-m dash. Looking at the development distance value curves, in boys a nearly linear increase is seen from the early years of elementary school through puberty, which then tends to slow slightly until age 17. In girls, an increasing trend with a slightly upward convex shape is seen until around the age of 13, after which there is a slowing trend until age 17. Looking at the development velocity curve, in boys the phenomenon of a local velocity increase is seen in the early years of elementary school, and the age at MPV was not seen in puberty. In girls, a clearer decrease in velocity continued from the early years of elementary school than in boys, and ultimately an age at MPV was not seen, similar to boys. Thus, for both boys and girls, a peak (MPV) did not appear in puberty for the 50-m dash.

Figure 8 is a graph of the development curves for the standing long jump. Looking at the development distance value curves, in boys a rapid increasing phenomenon similar to height is seen from age 11 to 14 in puberty. However, in girls a nearly linear trend is shown and the phenomenon of a rapid increase in puberty is not seen. Rather, a slightly decreasing or stagnating trend was seen from age 14 to 17. This trend, looking from the velocity curve, is obvious. That is, in boys a MPV was shown at 12.8 years old (18.6 cm/yr), and in girls a local peak velocity (LPV) was seen. A LPV was shown at age 7 (15.1 cm/yr) and then another slight LPV was shown at age 9.2 (12.6 cm/yr) in the decreasing course of the velocity curve. Hence, it was judged that in girls the age at MPV could not be identified.



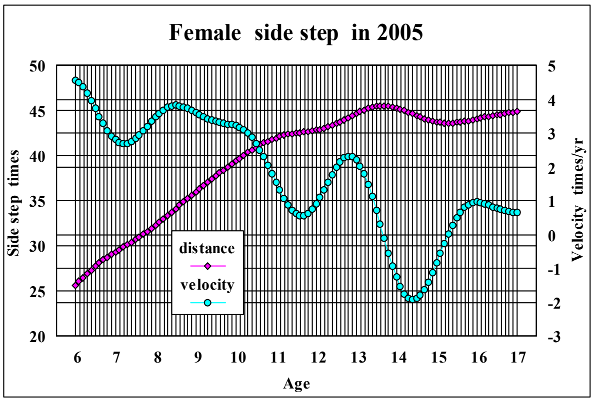
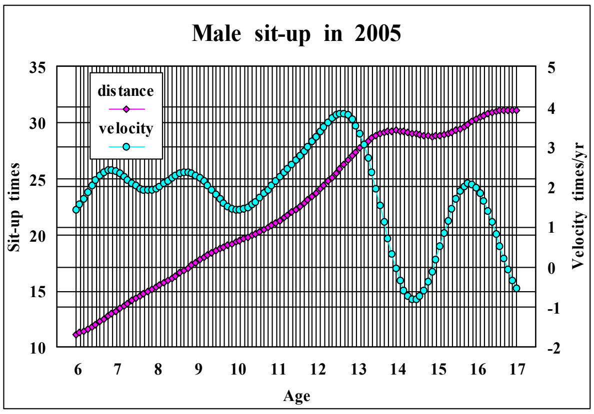


Figure 5. *Developmental distance and velocity curve from 6 to 17 years of boy's and girl's side step described by WIM.*



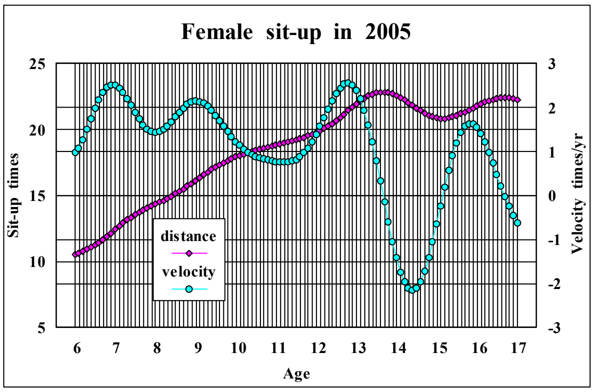
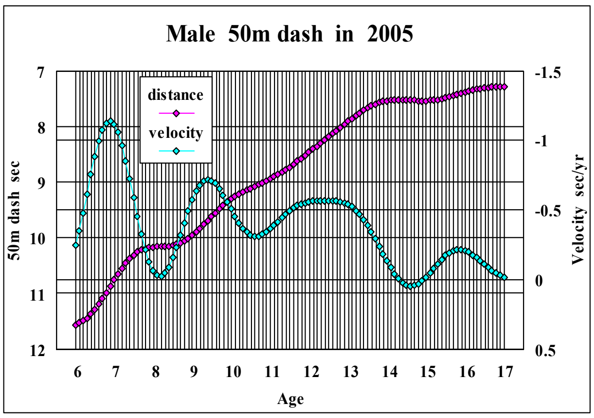


Figure 6. *Developmental distance and velocity curve from 6 to 17 years of boy's and girl's sit up described by WIM.*



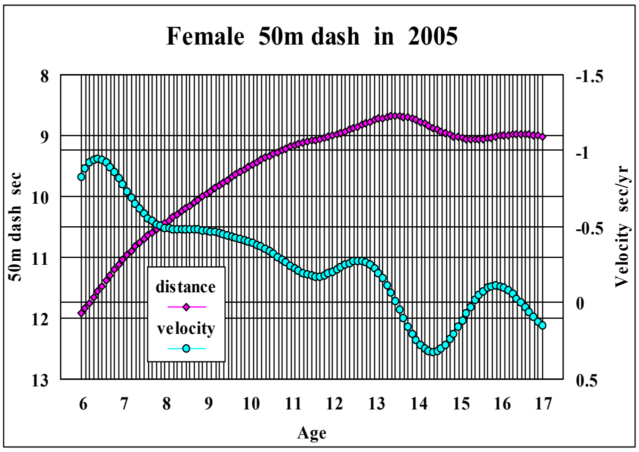


Figure 7. *Developmental distance and velocity curve from 6 to 17 years of boy's and girl's 50m dash described by WIM.*

3.2. Analysis of Development Curves of the Back Hip Circle Achievement Rate with the Wavelet Interpolation Model

Figure 9 is a graph of the wavelet interpolation model applied to the achievement rate for the back hip circle in young boys and girls. The triangles are the achievement rate development distance value curve, and the circles are the velocity curve. In young boys, a velocity peak is shown in two places, with the first peak being the largest. The peak for achieving the back hip circle was around the second year of kindergarten for boys, near 4.5 years old, and is conjectured to be a critical phase for development. In girls, the achievement peak was already detected and the first to second years of kindergarten are considered to be a critical period for development.

3.3. Proposal of a Motor Ability Development Model Based on the Fujimmon Growth Curves

Up to this time, the wavelet interpolation model has been applied to development distance values for the motor ability items of grip strength, sit-ups, side-steps, 50-m dash, and standing long jump, as well as for the back hip circle achievement rate. Development trends were analyzed from the behaviors of those velocity curves. From the results it was found, judging from the Fujimmon growth curves, that the development curves for the three items of the side steps, 50-m dash, and back hip circle achievement rate depend on the neural pattern. Conversely, it was found that the development curves for grip strength, sit-ups, and the standing long jump depend on the general pattern. That is, motor abilities with greater nervous system involvement like agility, running ability, and back hip circle achievement show development close to the neural pattern when viewed from the Fujimmon growth curves. In addition, motor abilities with muscle involvement like muscular system and explosiveness system abilities show development close to the general pattern. Considering these things, we constructed a motor ability development model pattern.

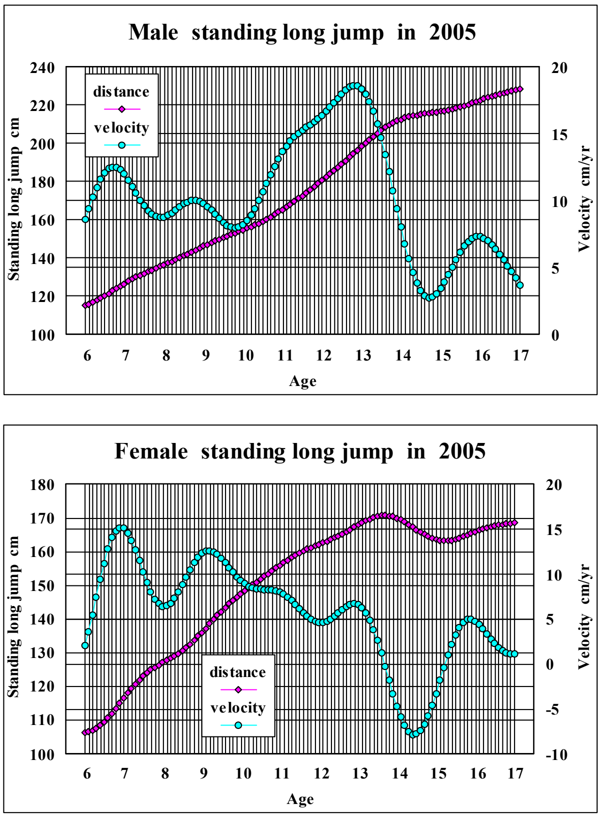


Figure 8. *Developmental distance and velocity curve from 6 to 17 years of boy's and girl's standing long jump described by WIM.*

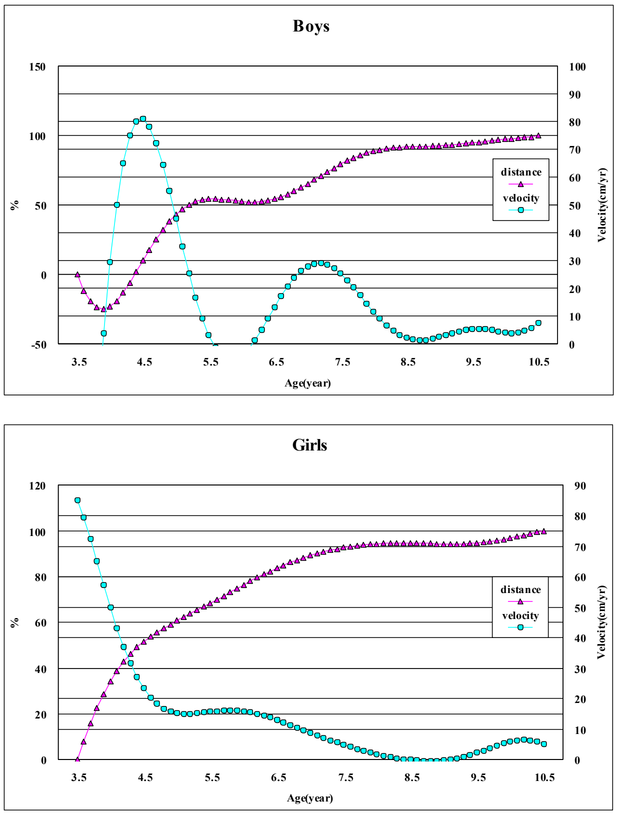


Figure 9. *Back-hip circle fulfillment rate development and velocity curve in boys and girls described by WIM.*

In Figure 10, the achievement rate was calculated for the general and neural types in the Fujimmon growth curves, and the mean achievement rate from 0 to 20 years old and the achievement rates near the general and neural patterns were calculated. The wavelet interpolation model was applied to those calculated achievement rates, and the development distance value curves of the achievement rates were described. However, looking at the development distance value curves for the achievement rates, it is difficult to discern the differences in the three patterns. The velocity curves of the three types of development distance value curves were then calculated. Graphs are shown in Figures 11–13. An average type model, a type model close to the general pattern, and a type model close to the neural pattern are described. Judging from these velocity curves, pubertal peaks are clearly shown in the models for the standard intermediate type and general-dependent type. Thus, even with motor ability there are thought to be types that show pubertal peaks. However, in the neural-dependent type model, a pubertal peak is not detected and it is thought to be a type in which pubertal peaks like those in agility and running ability are not shown. Therefore, we may say that three new types of motor ability development model are proposed here.

4. Discussion

Kimura [5] proposed pattern diagrams of motor function from Scammon's growth curves [1]. These pattern diagrams are simple proposals, not hypotheses. That is, Scammon's growth curves themselves are described in freehand, and since the pattern diagrams are based on those descriptions they cannot be hypotheses as model curves for motor ability development. In this study, then, model curves for motor ability development based on the Fujimmon growth curves are hypothesized. The Fujimmon growth curves are a new theory advocated by Fujii [4, 11, 12] from a re-examination of Scammon's growth curves. The Fujimmon growth curves are described scientifically, based on the wavelet interpolation model, and so can hypothesize a motor ability development model. The pattern diagrams of motor function by Kimura [5] were described based on conjecture and so were not described objectively. By basing Kimura's [5] pattern diagrams on the Fujimmon growth curves it becomes possible to describe them scientifically.

In this study, among motor ability items we first separated grip strength, sit-ups, and standing long jump as abilities of the muscle and explosive ability systems that have a high level of dependence on the general type, and side steps and the 50-m dash as agility ability, which has a high level of dependence on the neural type. We then analyzed the development distance values and velocity curves of those abilities. Looking at the development velocity curves for the muscle and explosive ability systems (muscle strength, sit-ups, standing long jump), pubertal peaks clearly appear in boys. In girls, pubertal peaks similar to those in boys are shown except for the standing long jump, for which a pubertal peak is not obvious. That is, if based on the Fujimmon growth curves, they are thought to have strong dependence on the general type. Then, in the development velocity curves for agility and running ability (side steps, 50-m dash), a pubertal peak appeared for the side steps in boys, but was not seen in girls. In the 50-m dash, pubertal peaks did not appear for either boys or girls. This is because in girls a strong dependence on the neural type is thought to clearly exist. In boys, however, while there is thought to be dependence on the neural type, the contribution of muscle development also cannot be overlooked.

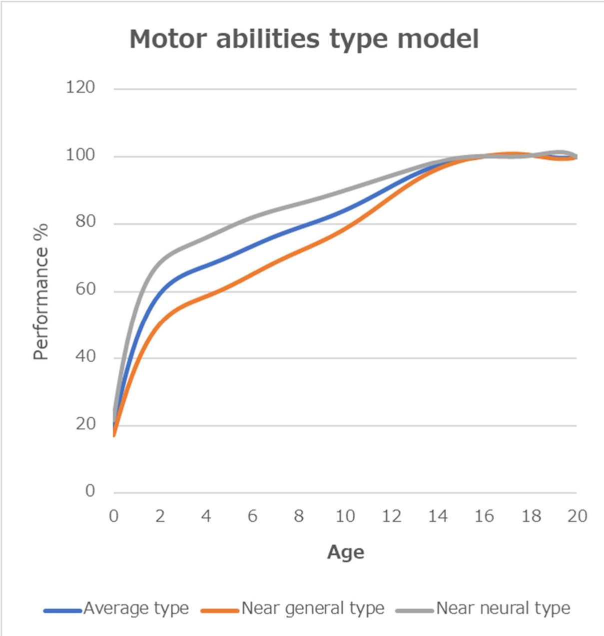


Figure 10. *Newly proposed motor abilities type model by Fujimmon's growth curve.*

While not all velocity curves of motor ability development were analyzed, model patterns of motor ability development can be hypothesized from the differences in level of dependence on the general and neural types. Motor ability development type models were then constructed with consideration of the differences due to the levels of dependence on the neural type and general type based on the Fujimmon growth curves. In addition, the development velocity curves of those type models were described and specific differences due to the level of dependence on the general type and neural type were analyzed. According to that, if the standard intermediate type model is taken as a reference, pubertal peaks are shown in the behavior of the velocity curves; moreover, with types that depend on the general pattern, pubertal peaks conspicuously appear. With types that depend on the neural pattern, however, pubertal peaks no longer appear. Based on the behavior of the velocity curve of each of these models, we may say that new type models for motor ability development have been put forward.

Looking at the achievement rate curve for the back hip circle taken up in this study based on these newly advocated motor ability development type models, it approximates the development curve for the 50-m dash and can be judged to be a model that depends more on the neural type. Tanaka and Fujii et al [13] analyzed the behavior of the velocity curve from the achievement rate curve for the back hip circle on a horizontal bar, and indicated that it approximated the development curve for the 50-m dash and was especially conspicuous in girls. That is, girls fundamentally have an increase in the amount of body fat during puberty (Malina and Bouchard, [14], Takaishi et al, [15], Fujii et al, [16]). Therefore, unlike the case for boys in which muscle mass increases and muscle development velocity shows a peak in puberty, the muscle development in girls is not as pronounced. In motor ability development in girls, pubertal peaks are not detected in the development velocity of explosiveness and agility abilities in particular. In boys, pubertal peaks are detected. From these characteristics of motor ability development in girls, their motor ability development pattern is thought to depend more on the neural type model than in boys.

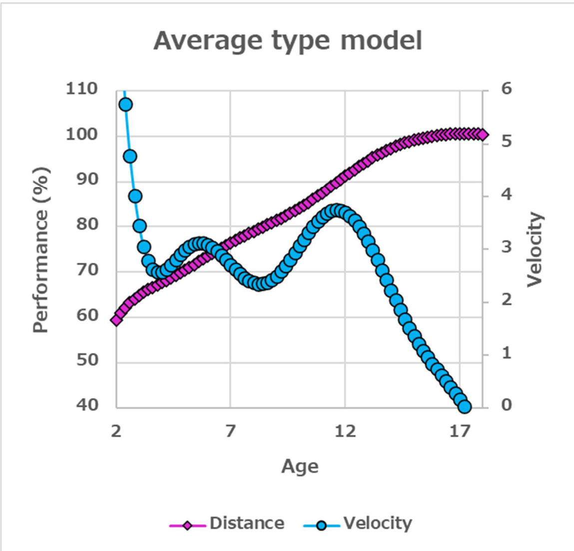


Figure 11. Average type model based on development velocity curve of motor abilities.

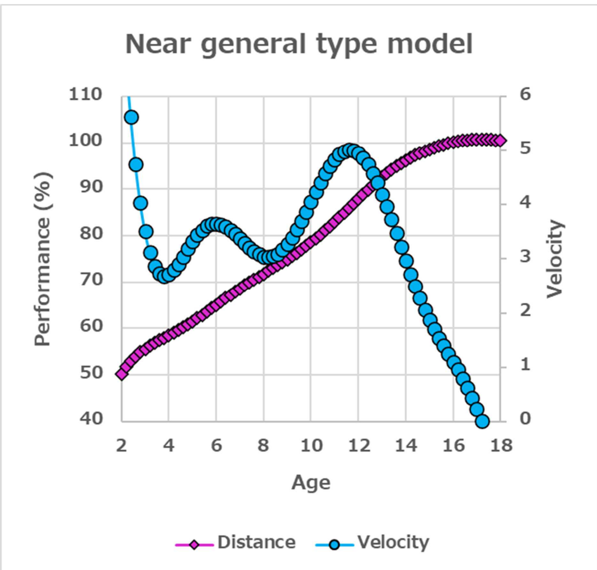


Figure 12. Near general type model based on development velocity curve of motor abilities.

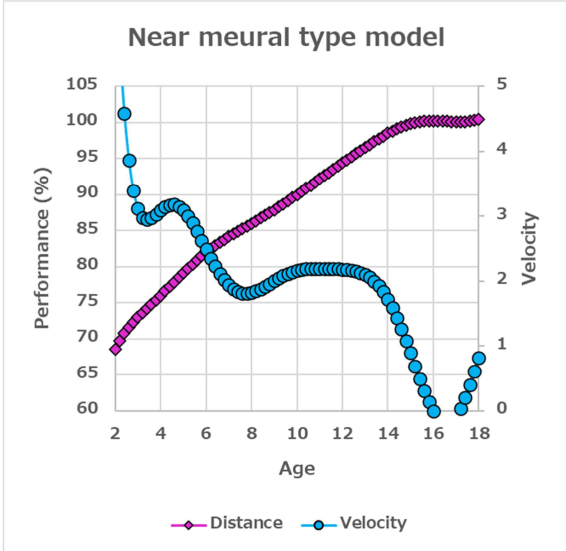


Figure 13. Near neural type model based on development velocity curve of motor abilities.

Motor ability development is closely related to sports training, and is an important issue in the appropriate timing of training. Fujii et al [17] analyzed the timing of training from the age at MPV of height growth with the wavelet interpolation method. That is, they investigated the optimum age for the start of training from the level of physical maturity. However, this was not an analysis based directly on motor ability development, and so the motor ability development attainment level and the age for the start of training could not be verified. In recent years, the term “golden age” has been used in soccer training. There is no evidence at all, but it is taken to be a time when “immediate acquisition” of skills is possible. There are no research papers on this golden age, but Jogo and Takeda [18] used the words “pre-golden age” and advocated the effectiveness of the KIDS ladder in young children. In that, the sole golden age was indicated to be ages 9–12 in late elementary school, and it was stated that if a certain movement is performed, that movement is incorporated in the neural pathways of the brain and learned, and that this is a time very well suited to acquiring sports skills. As mentioned above, there is almost no research on the golden age, and the explanation of Jogo and Takeda [18] lacks a foundation. A theory that is evidence for a golden age is the growth curves of Scammon. Based on the neural pattern in Scammon’s growth curves, the term golden age was probably created presuming a period of “immediate acquisition” from the motor function achievement period. In any event, the scientific evidence for the golden age theory itself, grounded on Scammon’s growth curves after more than 90 years, is weak.

In this study, the Fujimmon growth curves were verified with scientific evidence, and type model curves for motor ability development based on that theory were proposed. Based on these motor ability development model curves, it is possible to determine the age for the start of training based on the level of physical maturity judged from the age at MPV of height for training activities in which there is strong involvement of the general type, like muscle strength. However, for training activities with strong neural type involvement, a pubertal peak does not appear and so it may be important to start training between the age of 3 to about 8. That is, the development velocity reaches a peak in this period and the attainment of motor function and ability ends early, and so the timing may be appropriate for training. If motor function and ability are attained early, the genetic involvement of that ability also appears early. Therefore, even if there is taken to be a golden age, it should be possible to start training while also considering genetic involvement based on the peak development velocity of motor functions and abilities that have strong neural type involvement. Ultimately, the hereditary aspects of motor ability have been shown by Fujii et al [19] and Kasuya and Fujii [20], although in the elementary school years, to track at a consistent level in those with high motor ability, suggesting the hereditability of motor function. Therefore, by judging the behavior of the development velocity of motor functions and abilities that have strong neural type involvement, it can be said that the motor ability development type model proposed in this study can be used for the implementation of training.

5. Conclusion

Author constructed a new hypothesis for motor function and ability of the mixed pattern of the general and neural types proposed by Kimura [5], and attempted to verify that hypothesis based on the Fujimmon growth curves. As a construction for that hypothesis, we devised type models for motor ability development with consideration of differences depending on the level of dependence on the neural and general types based on the Fujimmon growth curves. Development velocity curves of the devised type models were then described and the differences due to the level of dependence on the general type and neural type were analyzed. The results showed that, taking the average type model as a reference, the behavior of the velocity curves showed a pubertal peak, and with types depending on the general type the pubertal peak was conspicuous. However, with types depending on the neural type, the pubertal peak no longer appeared. That is, a new type model of motor ability development based on the behavior of the velocity curves of each of these models may be proposed here. These newly proposed type models for motor ability development may be able to provide new perspectives for the use of sports training and sports talent discovery.

Acknowledgements

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