Analysis of the Risk to Physical Growth after the Great East Japan Earthquake

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ABSTRACT* – Many findings have been reported on changes in the living environment and states of health after earthquake disasters, but almost none from examining the effects of these changes in the living environment on physical growth during puberty. In this study we analyzed the shift in the age at maximum peak velocity (MPV) in weight from the difficult, stressful environment following the Great East Japan Earthquake, from the relationship between the ages at MPV of weight and height, which is thought to be a mechanism of natural growth, and examined the risks to physical growth that occur with earthquake disasters. The results showed a significant difference (P<0.05) in the discrepancy between ages at MPV of height and weight in a comparison of a control group and disaster group, and suggested a tendency for obesity from stress weight gain. However, although the age at MPV of weight was shown to be shifted in the disaster group on average, the age at MPV was not shifted in all girls in the disaster group. We then determined the individual shift in the age at MPV of weight in the disaster group from a regression polynomial analysis of the age at MPV of weight against the age at MPV of height, and examined the distribution state of the determined shifts. As a result, we derived evidence that the age at MPV of weight was shifted relative to the MPV age of height in girls in Miyagi Prefecture in the disaster group. In particular, we found that the frequency distribution showed a greater shift in the age at MPV of weight in the data for Fukushima Prefecture. This demonstrated that the effects from the Fukushima Prefecture nuclear power plant disaster were large, and also that there was a tendency for unnatural weight gain in junior high school girls in the coastal region of Miyagi Prefecture. Thus, it was confirmed that the effects of the Great East Japan Earthquake still pose a high risk for the growth of school-age children

Keywords— Risk analysis, Physical growth, Earthquake disaster, Secular trend

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1.INTRODUCTION

The effects on physical growth brought by the miserable living environment during World War II had immeasurable risks. Similarly, earthquake disasters are also conjectured to have huge effects that bring risks for the body. Although not to the extent seen during wartime, Ueda and Fujii et al. [1] and Watanabe and Fujii et al. [2] have reported risks to the physical growth of school-age children. Fujii [3] applied the wavelet interpolation method to growth in height from around 1900 to 1990, and examined the secular trends in physical growth from before to after the war. From those findings he reported that the pubertal peak declined temporarily during the war, and afterward showed a gradual trend for early maturity. It is conjectured that the difficult environment of war drastically inhibited physical growth, while the later developments in infrastructure and improvement and enhancement of diet with the high postwar economic growth promoted physical growth. The poor environment from war overlaps somewhat with the situation during earthquake disasters. Thus, it may also be that inhibition of physical growth occurs as a result of earthquake disasters.

Okazaki et al. [4] compared elementary school students in such a disaster area 1 and 4 years after an earthquake disaster, and showed that while physical activity decreased in the year after the disaster, there was no decrease after four years. Ohira et al. [5] investigated the trends in lifestyle diseases in 278,276 Japanese men and women living near the Fukushima Daiichi Nuclear Power Plant before and after the earthquake disaster. The results showed increases in hypertension, diabetes, dyslipidemia, liver dysfunction, atrial fibrillation, and a prevalence of polycythemia in people living in the evacuation zone after the earthquake. In addition, from a comparison of health check-up data 1–2 years and 3–4 years after the disaster, they reported that further increases were seen in diabetes and dyslipidemia. From this as well, although the changes in living environment caused by the earthquake disaster were not long-term, they are thought to have led to abnormalities in the body in the short term and inhibited physical growth. However, there are almost no findings on the effects of changes in the living environment from earthquake disasters such as the Great East Japan Earthquake on physical growth during puberty.

Ueda and Fujii et al. [1] applied the wavelet interpolation model proposed by Fujii [6] to the longitudinal growth data for groups that had and had not been affected by the nuclear accident, based on the two categories of areas that had received an evacuation advisory and other areas in the same year. Then, by examining the changes before and after the nuclear accident in age at maximum peak velocity (MPV) in growth during puberty, they analyzed the risks to physical growth from changes in the living environment after the earthquake disaster. According to these findings, the age at MPV for weight was shown to be delayed in people in areas that received an evacuation advisory. In other words, increased body weight from lack of exercise may be conjectured to have acted in the appearance of MPV for weight.

MPV of weight is a term used to mean that body weight shows the highest rate of increase in puberty. It is a phenomenon detected by Fujii [6] by applying the wavelet interpolation model to body weight growth. The MPV for height is considered to be more of an indicator of physical maturity as a biological parameter, for which genetic factors are stronger, while MPV of weight is affected more strongly by environmental factors. Therefore, there are cases in which increases in body weight from stress-induced lack of exercise during growth periods, such as the school years, as a result of restrictions on activity from earthquake disasters cause shifts in the growth velocity peak. Thus, age at MPV of weight is delayed and gives rise to a discrepancy with the age at MPV of height.

Accordingly, if activity restrictions due to an earthquake disaster present the obesity tendency of stress-induced weight gain, the effects on health are also serious. Thus, earthquake disasters are highly likely to produce risks. Fujii et al. [7] devised a BMI aging span evaluation chart for obesity that occurs with lack of exercise in the school years due to earthquake disasters. They proposed risk management to care for health based on obesity trends in earthquake disaster with this evaluation chart. However, the point of whether this is obesity due to the difficult, stressful environment of an earthquake disaster or a simple increase in body weight from lack of exercise could not be clarified. The MPV of weight taken up in this study refers to the pubertal peak in weight growth. It is the peak in weight gain associated with increasing height, a phenomenon that is thought of as a mechanism of natural growth. Therefore, a shift in MPV of weight suggests factors other than natural growth. Given this background, in this study we analyzed the shift in the age at MPV of weight due to the difficult, stressful environment following the Great East Japan Earthquake from the relationship with age at MPV for height, and examined the risk to physical growth that occurs from earthquake disasters

2. METHODS

2.1. Subjects and Materials

The control group was 4,659 girls from western Japan for whom full longitudinal height and weight growth data from the first grade of elementary school to the third year of junior high school (age 6– 14) was collected. The group was limited to girls because it was thought that the MPV of height and weight could be detected in nearly all cases in junior high school, since the age at MPV in height and weight is earlier than in boys. The subject group consisted of 48 girls from the first grade of elementary school to the third year of junior high school who went to a certain junior high school in a coastal region of Miyagi Prefecture that was affected by the tsunami (2011–2019), and 35 girls from the first grade of elementary school to the third year of junior high school (6–14 years old) in a certain junior high school in Fukushima Prefecture after the nuclear power accident in Fukushima Prefecture (2008– 2016). After the aim of the study was fully explained, their height and weight recorded in growth measurements were used.

2.2. Definition of People Affected by the Nuclear Accident

In this study, the definition of being affected by the nuclear accident is when the maximum growth velocity in height and weight during puberty, which is considered to appear around the age of 9–14 in both boys and girls, appears after the age of 14. Thus, for the possibility of effects in puberty, the period in which height and weight distance values are increasing needs to be narrowed to puberty. Therefore, the people taken to be affected by the nuclear accident in this study are those for whom the earthquake disaster occurred at around age 9, the earliest age at which the pubertal MPV appears. The earthquake occurred at around the time they start elementary school, after which they are affected by the evacuation situation. Consequently, the longitudinal data for height and weight in the disaster group in this study are thought to be affected at least to some extent by the earthquake disaster.

2.3. Analysis Procedures

1) First, to identify the MPV of height and weight in the control group, the wavelet interpolation modelwas applied to the longitudinal growth data from the first year of elementary school to the third year of junior high school, and the age at MPV of height and weight was identified.

2) The wavelet interpolation model was applied to longitudinal growth data for height and weight of the junior high school students after the nuclear disaster in Fukushima Prefecture and junior high school students in the coastal region of Miyagi Prefecture, which were affected by earthquake disasters, from 6 to 14 years old. The age at MPV of height and weight was identified for the disastergroup.

3) The statistics for the identified MPV were calculated, and the discrepancy in the ages at MPV in height and weight was calculated. A comparison was then made of the control and disaster groups with respect to the discrepancy.

4) Next, a regression polynomial analysis was performed for the age at MPV of height, after which theorder of the polynomial was determined. Judging from the coefficient of determination (R2) in this study, and a second order polynomial was adopted.

2.4. Analysis methods (Wavelet interpolation model)

The wavelet interpolation method (WIM) interpolates data point and data point with a wavelet function to approximately describe true growth curves from given data, and draws a growth distance curve. In this method, the drawn distance curve is then differentiated, the obtained growth velocity curve is derived, and the growth distance value at the pubertal peak or time of menarche is investigated. The effectiveness of the wavelet interpolation model is that it sensitively reads local phenomena and has a very high approximation accuracy. The theoretical background and effectiveness of the wavelet interpolation method is described in previous studies by Fujii [16, 17, 18].

When the wavelet interpolation model is applied to longitudinal data for height, a growth distance curve is drawn. A growth velocity curve is then drawn by differentiating that growth distance curve. In this study, the wavelet interpolation model was applied not to height but to weight. As shown in Figure 1, the interval between age at MPV of height and weight was derived from wavelet interpolation model.

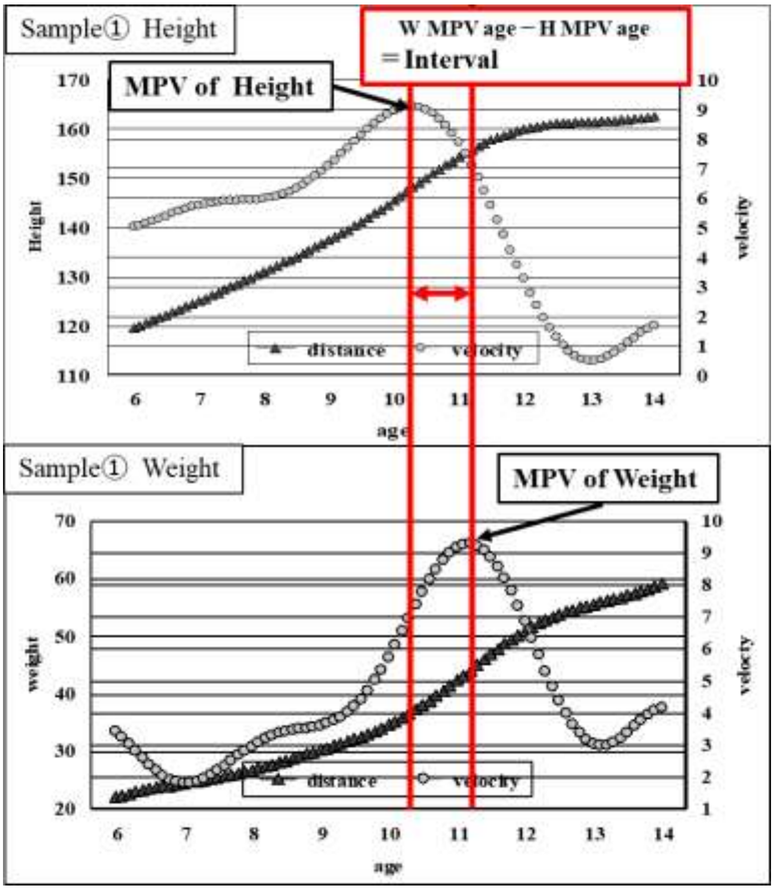

Figure 1. *The interval between age at MPV of height and weight by wavelet interpolation model.*

3. RESULTS

3.1. *Comparison of the control and disaster groups judged from the averagediscrepancy in the ages at MPV of height and weight*

In the control group, the age at MPV of height was 10.78±1.19 and the age at MPV of weight was 11.66±1.55. The discrepancy between the ages at MPV for height and weight was 0.88±1.62 years. Figure 1 shows the frequency distribution in the discrepancy in ages at MPV of height and weight in the control group, but normality is assured. Meanwhile, the age at MPV for height in the disaster group was 10.74±1.10 and that for weight was 11.81±1.54. The discrepancy in age at MPV for height and weight was 1.07±0.93. Similar to the control group, Figure 2 shows the frequency distribution of the discrepancy in ages at MPV of height and weight in the disaster group. Of course, normality is also assured in the disaster group. When the discrepancy in the ages at MPV of height and weight was compared in the control and disaster groups, a significant difference was seen ($P<0.05$). This result shows that the age at MPV of weight is shifted in the victim group on average, but this does not mean that the age at MPV was shifted in all girls in the disaster group. In other words, the effects of disasters differ among individuals, and an analysis needs to be done with consideration of this point.

3.2. Construction of A Regression Evaluation Chart of Age At MPV of Weight AgainstAge At MPV of Height

Figure 3 shows the results of a regression polynomial analysis attempted for the age at MPV of height, but while first to third order polynomials fit, the third order was more effective according to the coefficient of determination and AIC. However, the difference with second order was not that large, and so the second order was applied in this study. A lower order is judged to be valid if there is little change in the accuracy, and so in this study second order regression polynomials are thought to be valid. Figure 4 shows the frequency distribution when the control group data are fit on the regressionpolynomial evaluation chart derived from the control group, but normality is assured. Accordingly, thedata for both Miyagi Prefecture and Fukushima Prefecture were fit to this regression polynomial evaluation. As seen in both graphs, evidence is shown that the age at MPV of weight is shifted relative to the age at MPV of height. In particular, it is seen that much of the distribution is in the somewhat delayed evaluation band. This demonstrates that both disaster groups include many people with a shift in the age at MPV of weight. In particular, it is seen that the age at MPV is shifted more in the Fukushima Prefecture data distribution frequency.

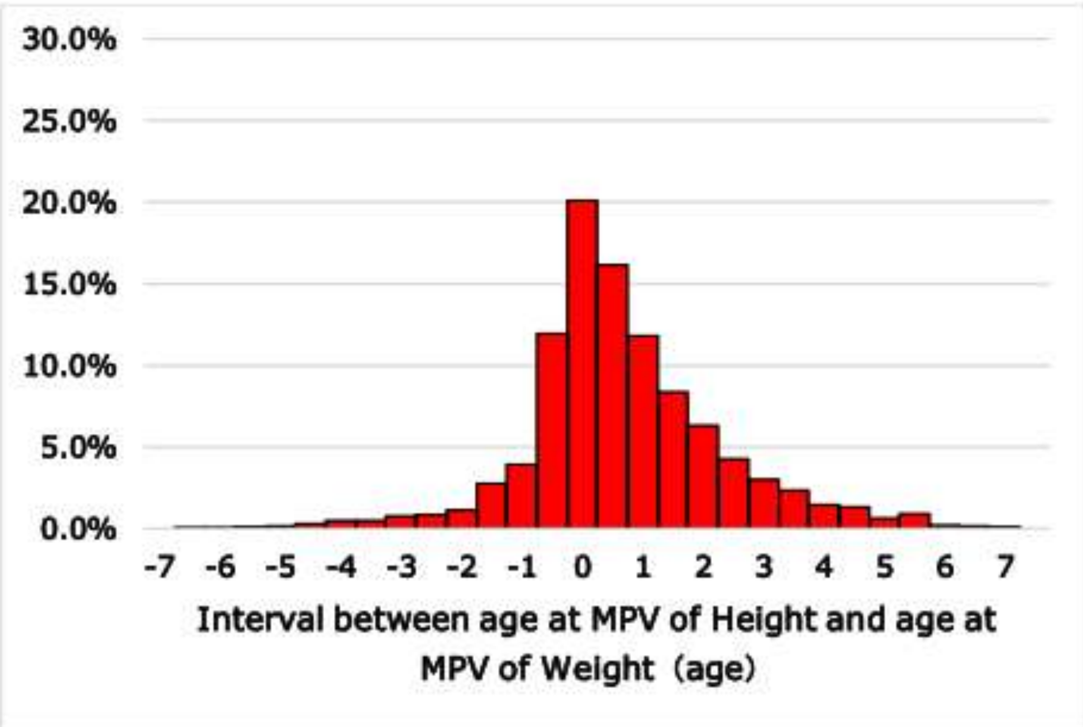

Figure 2. *Frequency distribution of interval between age at MPV of height and age at MPV of weight in the control group.*

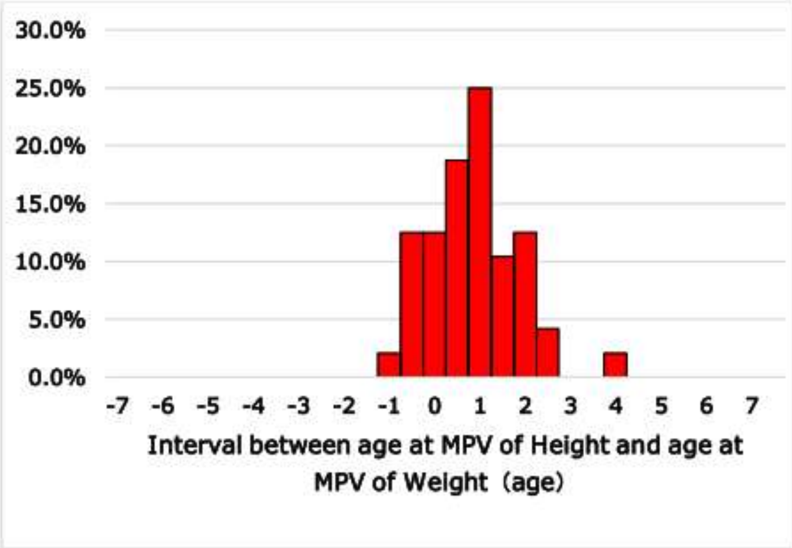

Figure 3.*Frequency distribution of interval between age at MPV of height and age at MPV of weightin the earthquake area group*

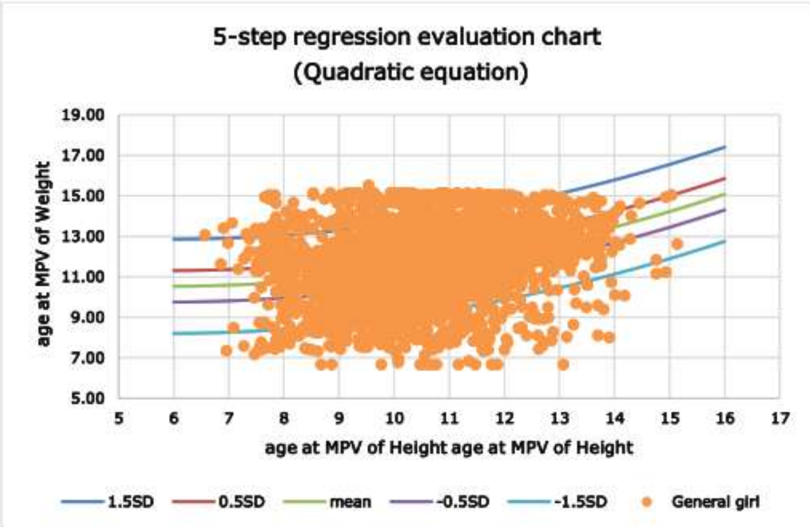

Figure 4. *Regression analysis of MPV age of weight against MPV age of height in control group.*

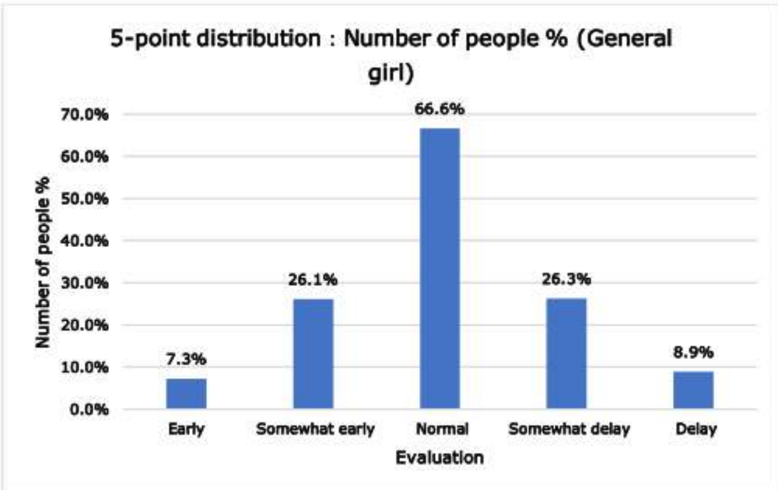

Figure 5. *Frequency distribution in the regression analysis of MPV age of weight against MPV age of height in the control group.*

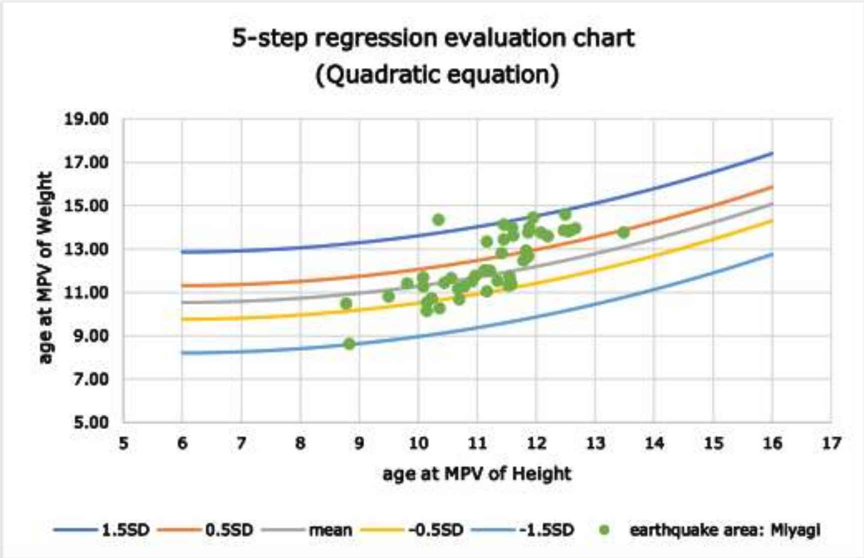

Figure 6. *Regression analysis of MPV age of weight against MPV age of height in earthquakearea group (Miyagi)*

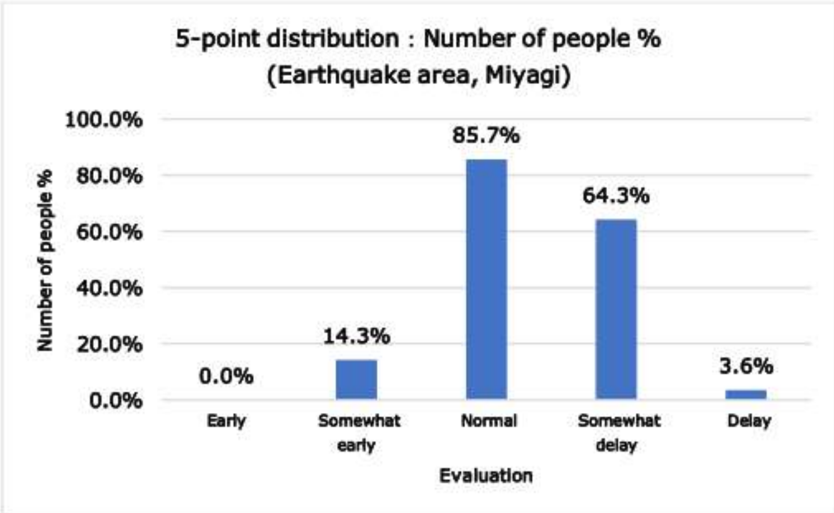

Figure 7. *Frequency distribution in the regression analysis of MPV age of weight against MPV age ofheight in the earthquake area group (Miyagi)*

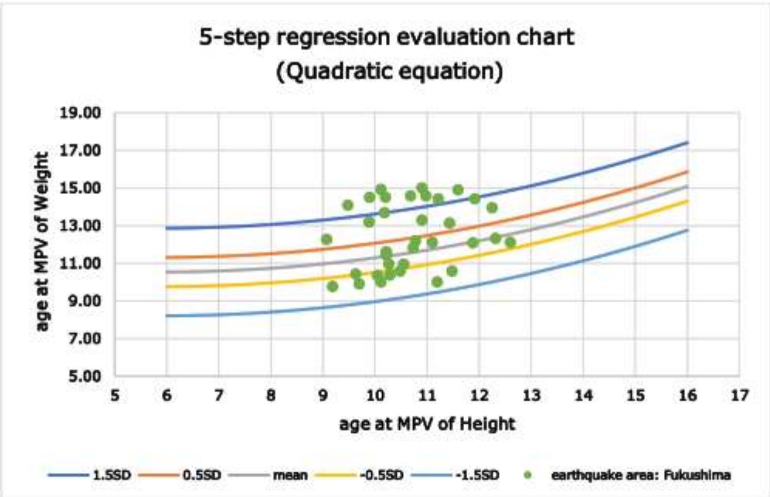

Figure 8. *Regression analysis of MPV age of weight against MPV age of height in earthquake area group (Fukushima).*

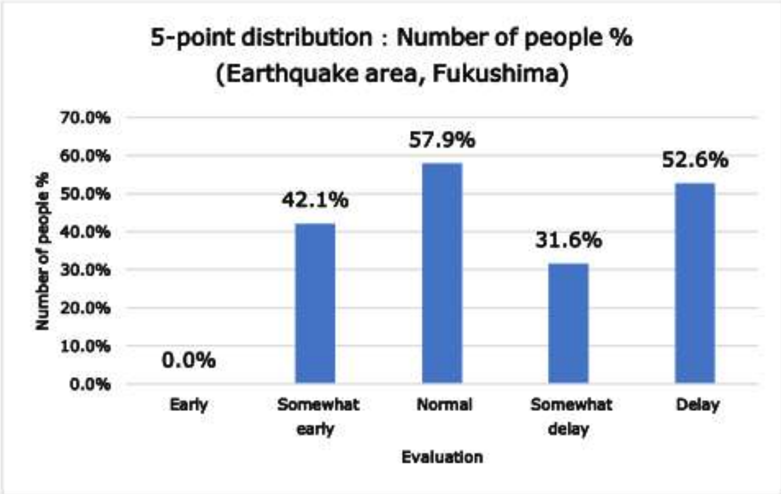

Figure 9. *Frequency distribution in the regression analysis of MPV age of weight against MPV age of height in the earthquake area group (Fukushima).*

4. DISCUSSION

In this study, a shift in the age at MPV of weight was shown in the disaster group on average. This, first of all, suggests a trend for obesity with stress weight gain in the disaster group. Among the disaster group, junior high school students in the coastal region of Miyagi Prefecture experienced the Great East Japan Earthquake during their first year in junior high school. From the fact that the MPV age in weight was still shifted after nearly 10 years, it is conjectured to be unnatural weight gain fromstress and lack of exercise due to the earthquake disaster. However, unnatural weight gain was not seen in the entire disaster group as an effect of the earthquake disaster. The details of this need to beinvestigated. The determination of the age at MPV of weight in individuals from the regression polynomial analysis of the age at MPV of weight with respect to the age at MPV of height suggested an unnatural weight gain from the earthquake disaster. The suggestion of unnatural weight gain in female junior school students in the coastal region of Miyagi Prefecture from these findings implies that the effects of the Great East Japan Earthquake still impose a large risk on the growth of school age children.

Kurokawa et al. [8], from the results of an analysis of the average height and weight values for sixth grade elementary school students in the city of Sendai, reported that the appearance rate of childrenwho tended to be obese, which had been decreasing until 2011, increased in 2012 and 2013. No effect was seen on height. One reason that effects were seen in weight only is that obesity was made morelikely from the decrease in the amount of physical activity due to the living environment within the restricted regions following the huge earthquake disaster. However, it is conjectured that they were not enough to affect height, which is less susceptible to environmental factors. The delay in the age at MPV of weight with respect to the age at MPV of height is a phenomenon in which the pubertal peak in previous natural weight gain is delayed from unnatural weight gain or obesity. For the delay in the age at MPV of weight, it is inferred that the period of the obesity tendency becomes longer andthe period until a return to a standard body weight by adulthood becomes shorter, increasing the riskof an increase in obese adults.

So far the discussion has developed on the mean shift in ages at MPV of height and weight, but this is just the mean shift. There are also individual cases in which no shift is seen. If the individual shifts inthe ages at MPV of height and weight could be assessed, it would be possible to grasp unnatural weight gains from stress or lack of exercise in individuals. Therefore, we conducted a regression polynomial analysis of age at MPV of weight versus height. This idea is something Fujii [6, 9, 10] focused on from a regression analysis of age at menarche versus age at MPV of height in cases when there was a delay in menarche. In other words, when judging the delay in menarche from the discrepancy between age at MPV of height and age at menarche, a composition occurred in which the size of that discrepancy was no longer constant as the age at MPV of height increased. Accordingly, considering a composition in which this discrepancy is not constant, a regression polynomial analysis was adopted for age at menarche versus the age at MPV of height. In this way, it was possible to clearly identify delayed menarche in individuals.

In attempting to make individual judgments for the age at MPV of weight in this study, it is noted thatthe size of the discrepancy in the ages at MPV of height and weight would no longer be constant as the age at MPV of height increased, similar to when judging delayed menarche. Hence, a regression polynomial analysis of height at MPV of weight versus height was judged to be valid. When the data for the disaster group are applied to this regression polynomial evaluation chart, the delays in age at MPV of weight in individuals can be determined. In the Miyagi Prefecture disaster group, shown in Figure 4, the delay in age at MPV of weight is shown in the distribution frequency of Figure 5. When compared with the control group, a delay in the age at MPV of weight is certainly seen. However, in the case of Fukushima Prefecture in Figure 6, a more pronounced delay in the age at MPV of weight is shown, and a larger delay in the age at MPV of weight than in Miyagi Prefecture was clear.

By constructing a regression polynomial evaluation chart for age at MPV of weight versus height, individual delays in the age at MPV of weight can be identified. In fact, Watanabe and Fujii [2] previously applied a BMI aging span evaluation chart and analyzed the obesity trends due to lack of exercise from the tracking status of BMI in children affected by the Fukushima nuclear accident. In that study, they analyzed the tracking of data in individuals. If the delay in age at MPV of weight in thisstudy could be identified, there would be the advantage of being able to simultaneously identify the age at MPV of weight in that tracking data. With regard to future prospects, we would like to determine the age at MPV of weight individually, apply that determined data to the BMI aging span evaluation chart, and examine unnatural weight gains with certainty.

5. CONCLUSION

The MPV of weight taken up in this study indicates the pubertal peak in weight growth. It is the phenomenon of a weight gain peak associated with increase in height, which is thought of as a natural growth mechanism. Therefore, a shift in the MPV of weight suggests a factor other than natural growth. Given this background, this study analyzed the shift in age at MPV of weight due to the difficult, stressful environment of the Great East Japan Earthquake from the relationship with the ageat MPV of height, and examined the risk to physical growth from the occurrence of an earthquake disaster. The result showed a significant difference ($P<0.05$) in the discrepancy in ages at MPV of height and weight from a comparison of the control and disaster groups. The results showed a shift inthe age at MPV of weight in the disaster group on average, but that does not mean there was a shift in the age at MPV in all girls in the disaster group.

A regression polynomial evaluation chart based on the control group was then constructed. First, the control group data were applied and the frequency distribution was shown, as a result of which normality was guaranteed. Then the Miyagi Prefecture data were applied to this regression polynomial evaluation as the disaster group. As shown in the graph, this gives proof that the age at MPV of weight was shifted in relation to the age at MPV of height. In particular, it was found that much of the distribution was in the somewhat delayed evaluation band. Thus, it was demonstrated that the age at MPV of weight was shifted in many people in the disaster group. The data from Fukushima Prefecture in particular show a clear shift in the age at MPV of weight in the frequency distribution.

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