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Risk Analysis of Secular Trends for a Later Age at MPV of Weight in an Earthquake Disaster Environment

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1. Abstract

The Great East Japan Earthquake occurred in 2011, bringing unprecedented damage to the Tohoku region of Japan. Today, after 11 years, the scars from that tremendous damage remain. The health damage to young school children has been particularly great. One may imagine a slowing trend in physical growth from the effects of that disaster, but no clear findings have been reported. Certain trends for obesity and decreased physical strength due to a lack of physical exercise have been reported, but there are no clear reports for the entire disaster area. In this study, we analyzed the delay in the age at MPV of weight due to the poor and stressful environment following the Great East Japan Earthquake from the relationship between the ages at maximum peak velocity (MPV) for height and weight, which are thought to be natural growth mechanisms, and examined the risk to physical growth that emerges as a result of earthquake disasters. We first conducted an analysis using data on national averages for height and weight since before World War 2, and height and weight growth data from age 6 to 17 from 1955 to 2011 for Miyagi and Iwate prefectures, which were both affected by the earthquake, which were published in the School Health Statistics Research Reports. We then identified the age at MPV of height and weight and, by analyzing the secular trends in age at MPV of weight, investigated the slowing trend in the MPV age for weight that emerged in the earthquake disaster environment. The results showed that in the national average the age at MPV gradually become younger overall for both boys and girls, while in Miyagi and Iwate prefectures the age at MPV of weight tended to be somewhat delayed starting in the 2000s for both boys and girls. This trend was particularly noticeable in boys. From this, one of the effects of the earthquake is conjectured to have been an unnatural weight gain caused by the stress and lack of activity resulting from the disaster.

2. Introduction

In Japan, cross-sectional data on physical growth (height, weight) from age 6 (first grade of elementary school) to 17 (final year of high school) have been published in School Health Statistics Research from 1900 to 2022. While the results are averages, they are derived from 700,000 pieces of data gathered from across the nation, and are recognized to have sufficient meaning for analyses of cross-sectional data. In the past, Kawahata [1] and Matsuura [2] analyzed these data and examined the age at the maximum growth velocity in height (age at the pubertal peak) and the postwar growth acceleration phenomenon. Kudo et al [3] arranged these average data into cohorts and examined the trends over time in the age at the pubertal peak for height based on cohort data. Similarly, in recent years Fujii [4] applied the wavelet interpolation method and identified the age at the maximum growth velocity during puberty (maximum peak velocity; MPV) from the described height growth velocity curve, and examined the secular trends from before World War 2 until around 1990. He reported that during the war the age at MPV was considerably later and that after the war a trend was seen for earlier maturity together with high economic growth, which then slowed from around 1990. From these trends one may conjecture that in Japan the poor wartime environment had the effect of significantly inhibiting physical growth, and that there was acceleration in physical growth from a postwar catch-up phenomenon with the development of infrastructure associated with high economic growth.

A poor environment due to war has some overlap with the situation caused by earthquake disasters. Inhibition of physical growth from an earthquake disaster may be readily imagined, and in the Great East Japan Earthquake the damage caused by the tsunami and Fukushima nuclear power plant accident in particular had a huge effect on the healthy physical growth of children. It is conjectured that a dulling or stagnating trend in growth would have occurred. Okazaki [5] compared elementary school children in the affected area 1 and 4 years after the earthquake and showed that whereas physical activity decreased after 1 year no decrease was seen after 4 years. There have been few reports on that earthquake disaster. Ueda et al [6] and Watanabe et al [7] reported risks to physical growth of schoolchildren after the Great East Japan Earthquake. However, these few reports presented findings derived from small amounts of data from affected areas, and not findings derived from the entire area. Thus, data obtained from the entire affected area is necessary. One potential data source is the School Health Statistics Research results obtained from the affected areas. It should be possible to examine the effects of earthquake disasters by arranging these data into cohorts and analyzing the age at MPV of height over time based on the cohorts.

Ueda et al [8] analyzed cohort data for height growth obtained in the School Health Statistics Research in Iwate and Miyagi prefectures, where the damage from the Great East Japan Earthquake was immeasurable, and showed a slowing trend in the age at MPV of height. Thus, while not as bad as during wartime, a local slowing of height growth would seem to have been shown in the affected areas. However, despite being called cohort data, these were average group data, and so it is unclear whether the reason for the delay in the age at MPV of height for individuals was stress from the disaster environment or the effects of nutritional status. Fujii et al [9] analyzed the growth in height and weight of individual schoolchildren in Miyagi prefecture after the Great East Japan Earthquake. By analyzing the age at MPV of weight against height, they showed that the difference in the two ages was an artificial lag that differed from the natural lag. However, it is exceedingly difficult to ensure individual longitudinal growth data. Ensuring longitudinal growth data in disaster-affected areas is particularly difficult.

In this study, we applied the wavelet interpolation model to the growth distance values for weight from age 6 to 17 shown in the School Health Statistics Research Report, and identified the age at the maximum growth velocity in puberty (maximum peak velocity; MPV) in Miyagi and Iwate prefectures, which are areas affected by the Great East Japan Earthquake disaster, and analyzed the annual trends in the age at MPV of weight. If local slowing trends in the age at MPV of weight can then be supposed, one can conjecture that the slowing of the age at MPV of height is an effect not of nutritional intake but of stress in an earthquake disaster environment. Thus, the gap in the age at MPV of weight indicated by Fujii et al [9] may be conjectured to be an unnatural weight gain from lack of activity in a disaster environment, and true mental and physical stress can be hypothesized. The risk of stress on the mind and body in an earthquake disaster environment would then be verified from the secular trends in age at MPV of weight obtained from the School Health Statistics Research in disaster-affected areas.

3. Methods

3.1. Data set composition

Weight growth data from the 2015 School Health Statistics Survey Report were used for physical elements. Data extracted in a cohort manner from age 6 to 17 so that age 17 was reached in the 2015 school year were used as cohort data sets. Data published since 1955 were used for the weight growth data in Miyagi and Iwate prefectures.

3.2. Analysis methods (Wavelet interpolation model)

The wavelet interpolation model (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 [10-13]. 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.

3.3. Analysis procedure

1) The wavelet interpolation method was applied to height from age 6 to 17 for the cohort data sets, the growth distance and velocity curves for height were derived, and the age at MPV was identified.

2) A least squares approximation polynomial was applied to the age at MPV of height calculated for each year to estimate the trends in those changes, and annual trends in the national average age at MPV was investigated.

3) The wavelet interpolation method was applied to the height growth data in Miyagi and Iwate prefectures, for which similar data sets were made, the growth distance and velocity curves for height were derived, and the age at MPV was identified.

4) A least squares approximation polynomial was applied to the age at MPV of height calculated for each year to estimate the trends in those changes, the annual trends in the age at MPV in Miyagi and Iwate prefectures was derived, and the effect on physical growth at times near the year in which the earthquake disaster occurred was examined.

3.4. Cohort data

A cohort is an observed population that has a common factor. In this study, a cohort is taken to be a group with a series of data that has the same birthdates (see chart below). In this study, 1 data set is based on data continuing from the age of 6 until the age of 17, rising by one year of age for each year as shown in Table 1.

Table 1: Case of male height in cohort data.

year	elementary school						junior high school			high school		
	6	7	8	9	10	11	12	13	14	15	16	17
1927	108	113	118	122	127	131	136.8	143	150	156	158	161
1928	108.1	113	118	123	127	131	136.7	143	150	156	159	161
1929	108.1	113	118	123	127	131	136.9	143	151	157	160	160
1930	108.1	113	118	123	127	131	137.1	143	151	156	160	161
1931	108.3	113	118	123	127	132	137.3	144	151	157	160	161
1932	108.5	114	118	123	127	132	137.5	144	151	157	160	162
1933	108.7	114	119	123	128	132	137.8	144	152	156	160	162
1934	108.8	114	119	123	128	132	138.2	145	152	158	161	162
1935	108.9	114	119	124	128	132	138.2	145	152	158	161	162
1936	109	114	119	124	128	133	138.2	145	153	158	161	162
1937	108.8	114	119	124	128	133	137.7	144	152	157	160	161
1938	108.3	114	119	124	128	133	137.4	145	152	158	160	162
1939	109.1	115	119	125	128	133	137.8	144	152	158	161	163
1940	109.7	115	120	125	130	135	142	150	156	160	162	162
1941	109.9	115	120	121	130	134	143.1	149	155	161	163	163
1942	109.3	115	120	125	129	133	141.9	149	155	160	162	163
1943	108	113	119	124	129	133	141	148	155	160	163	164
1944	109	114	119	124	128	133	140.5	147	154	159	163	163
1945	108.2	113	118	125	127	131	137.4	144	151	157	161	162

4. Results

4.1. Annual trends in age at MPV of weight for boys and girls based on national averages

Cross-sectional growth data for weight were extracted in a cohort manner for cross-sectional data on physique for national averages from 1927 to 2011 published in the School Health Statistics Research. The wavelet interpolation model was applied to these cohort growth data starting with first-grade elementary school students in 1927 and ending with first-grade elementary school students in 2011. A least squares approximation polynomial was applied to the derived annual trends, and the results are shown in Figures 1 and 2. The age at MPV for boys suddenly became later in the 1940s, and then in the late 1950s quickly became earlier. Since that time the age at MPV has shown a gradual tendency to become earlier. Looking overall, the age at MPV was 13.6 years old in 1927, and 11.7 years old in 2011, a difference of 1.9 years. Girls, like boys, showed a somewhat later age at MPV in the 1940s, but from the 1950s showed a trend for age at MPV to become gradually earlier. Overall, the age at MPV was 11.7 years old in 1927 and 10.8 years old in 2011, a difference of 1.1 years.

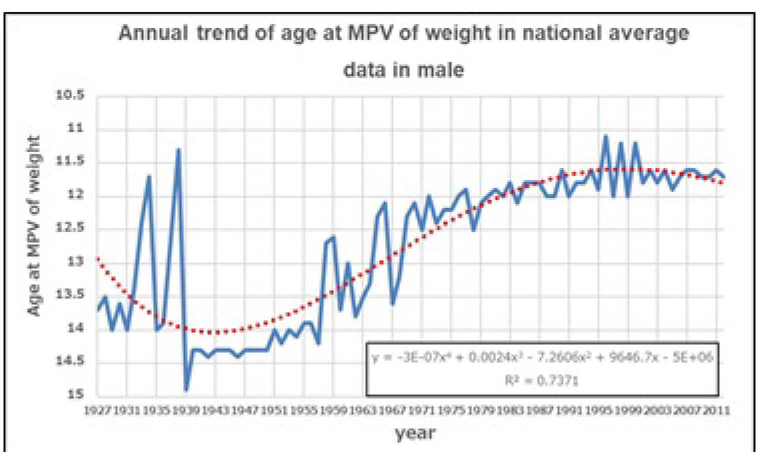

Figure 1: National average male secular trend of age at MPV of weight in cohort data.

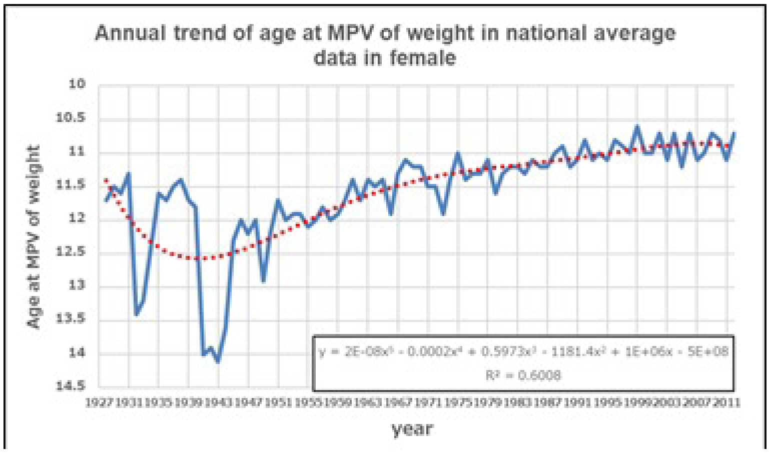

Figure 2: National average female secular trend of age at MPV of weight in cohort data.

4.2. Annual trends in age at MPV of weight for boys and girls in Miyagi prefecture

Cross-sectional growth data for weight were extracted in a cohort manner from cross-sectional data on physique in Miyagi prefecture from 1955 to 2011, published in the School Health Statistics Research. The wavelet interpolation model was applied to these cohort growth data starting with first-grade elementary school students in 1955 and ending with first-grade elementary school students in 2011, and the age at MPV of weight was derived. Least squares approximation polynomials were applied to the annual trends in the age at MPV of weight, and the results are shown in Figures 3 and 4. For boys the age at MPV rapidly became earlier from 1955 to 2000, but the trend for earlier MPV age then slowed. However, a first-grade elementary school student in 2005 would reach the age at MPV of weight at the time of the earthquake disaster, and from around this time the age at MPV showed a slightly later trend. This phenomenon is a finding that can be assumed to be from the effects of the Great East Japan Earthquake. Girls, like boys, had earlier ages at MPV from 1955 to 2000, but the change was not as sudden as in boys. It was a gradual earlier trend. Then, the age at MPV of weight tended to become later from around 2005 as in boys, a finding that can be assumed to be an effect of the earthquake disaster.

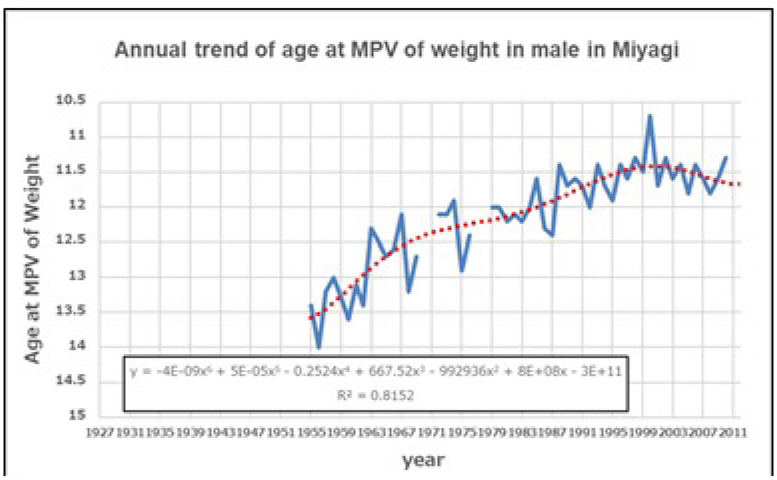

Figure 3: Miyagi male secular trend of age at MPV of height in cohort data.

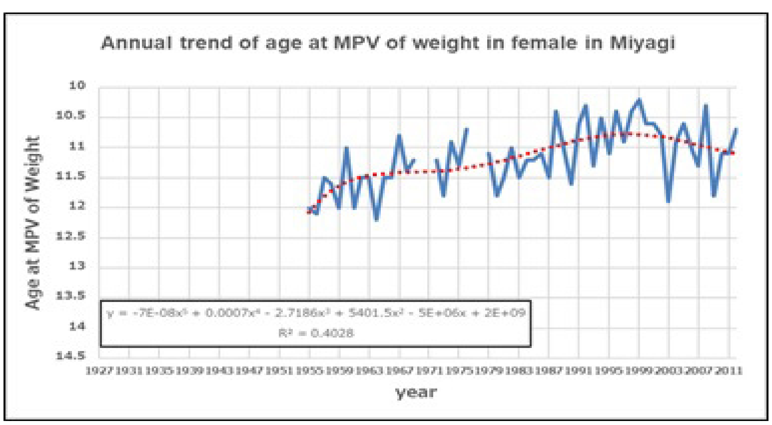

Figure 4: Miyagi female secular trend of age at MPV of height in cohort data.

4.3. Annual trends in age at MPV of weight in Iwate prefecture

As for Miyagi prefecture, cross-sectional growth data for weight were extracted in a cohort manner from cross-sectional data on physique in Iwate prefecture from 1955 to 2011, published in the School Health Statistics Research. The wavelet interpolation model was applied to these cohort growth data starting with first-grade elementary school students in 1955 and ending with first-grade elementary school students in 2011, and the age at MPV of weight was derived. Least squares approximation polynomials were applied to the annual trends in the age at MPV of weight, and the results are shown in Figures 5 and 6. The age at MPV of weight rapidly become earlier from 1955 to around 1995 in boys, but from around 2000 the trend for earlier MPV age then slowed. However, from 2000 to 2007, the age at MPV suddenly became later and then tended to become earlier again in 2011. This trend was more pronounced than in Miyagi prefecture, and may be evidence of the strong effect of the Great East Japan Earthquake. In girls, while the trend in age at MPV of weight was much more gradual than in boys, a trend was shown for earlier age from 1955 to 2005. Some change in the age at MPV was shown around the time of the earthquake, but no change big enough to be considered an effect of the earthquake was seen.

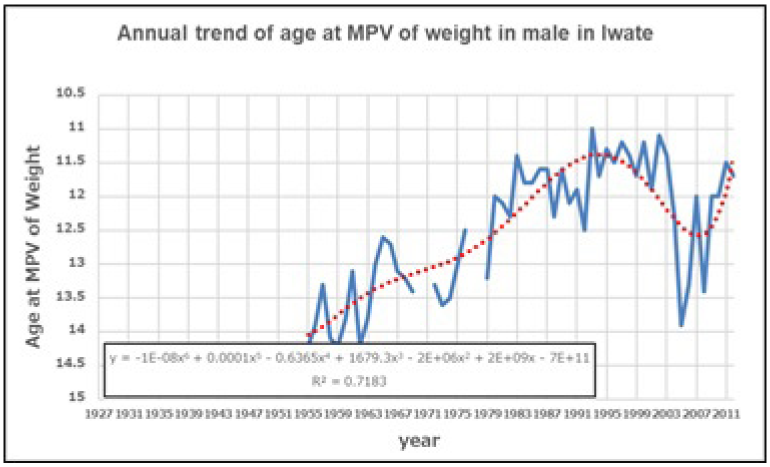

Figure 5: Iwate male secular trend of age at MPV of height in cohort data.

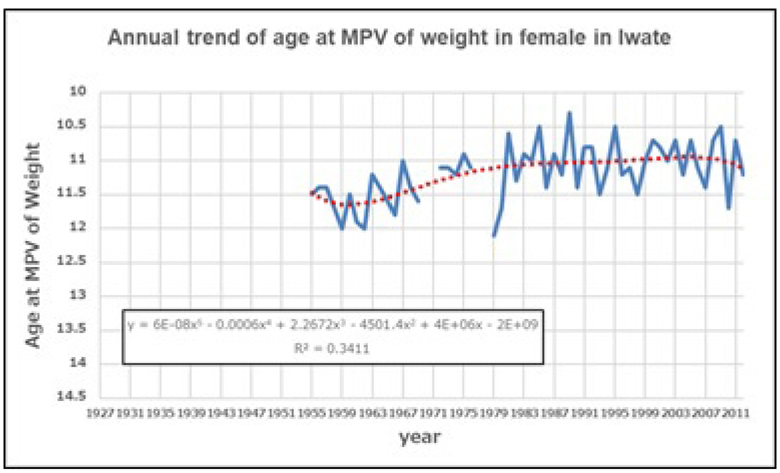

Figure 6: Iwate female secular trend of age at MPV of height in cohort data.

5. Discussion

In this study, using cohort data for weight in boys and girls from 1927 to 2001 from the School Health Statistics Research, which is published every year by the Ministry of Education, Culture, Sports, Science and Technology, the age at the maximum growth velocity during puberty (maximum peak velocity; MPV) and the MPV were obtained by applying the wavelet interpolation model, and the annual trends in the age at MPV of weight were analyzed for the national average and Miyagi and Iwate prefectures. From this we tested whether the catch-up phenomenon that emerged in the period of high economic growth compared with before the war showed slowing and accelerating trends in a short period under an earthquake disaster environment. The results showed an overall trend for younger age at MPV of weight in boys and girls in the national average. The age at MPV of height showed a trend to become later in the 1940s. However, this is thought to be because with the start of World War 2 in 1939 the poor wartime environment led to a rapid increase in deaths and injuries and lack of food. For the age at MPV of height, an overall gradual trend for earlier maturity was seen after 1955. This is thought to be because the age at MPV of height became younger with the restoration of infrastructure associated with high economic growth in Japan. Similar to the age at MPV of height, it is thought that the age at MPV of weight would also show a trend to become younger from the postwar years until today.

From the above, while there was an overall trend for earlier maturity in the age at MPV of weight in boys and girls in Miyagi and Iwate prefectures, a gradual trend for younger ages was seen particularly in the years from 1955 to around 1995. Later, the age at MPV of weight showed a trend of becoming later from 2005. This is related to the cohort weight growth data extracted for children who became first-grade elementary school students in 2005. The year 2011 when the Great East Japan Earthquake struck, it is when the MPV of weight would appear for these students. Thus, if poor environmental conditions were prevalent during the period of this emergence, they could have interfered with physical growth and delayed the age at MPV for the years of around 2000–2005. In a comparison of boys and girls in both Miyagi and Iwate prefectures that focused on cohorts around 2005, which would reach the age at MPV in the period when the Great East Japan Earthquake occurred, boys showed a pronounced slowing trend while girls had a slight slowing and then shifted to a trend for younger age at a relatively early time. If one cites Tanner's [14] theory of a canalization effect, it is presumed that girls are less affected by the environment than boys, but a determination is difficult with the findings of this study only and we must leave this for future study.

Incidentally, Kurokawa [15] analyzed the mean values for height and weight of sixth-grade elementary school students in the city of Sendai, and did not see rapid changes in height or weight after 2011. However, they did confirm an increase in the rate of children who tended to be obese. Thus, after earthquake disasters one could conjecture not only a slowing of physical growth, but also an obesity trend that continues for several years and concern about the development of lifestyle-related diseases due to decreased physical activity and stress from changes in the environment caused by the damage. The slowing trend in the age at MPV of weight in this study is thought to be an unnatural weight gain from stress and lack of activity from the earthquake, according to a report by Fujii et al [9]. Thus, in the relationship judged from the gap in the age at MPV of weight with respect to the age at MPV of height, changes in the age at MPV of height due to the earthquake are difficult to see. However, it is thought that the effects of the disaster are shown from the delay in the age at MPV of weight. The secular trends from about 2005 in the age at MPV of weight in this study may be conjectured to show the effects of the earthquake disaster.

6. Conclusion

In this study, using cohort data for weight in boys and girls from 1927 to 2001 from the School Health Statistics Research, which is published every year by the Ministry of Education, Culture, Sports, Science and Technology, the age at the maximum growth velocity during puberty (maximum peak velocity; MPV) and the MPV were obtained by applying the wavelet interpolation model, and the annual trends in the age at MPV of weight in the national average and in Miyagi and Iwate prefectures were analyzed. The results showed a trend for earlier maturity in the national average since World War 2, but in both Miyagi and Iwate prefectures a trend was shown in girls and boys for slightly later ages at MPV of weight in those born in the early 2000s. This may be assumed to be a local slowing trend in physical growth that emerged in the earthquake disaster environment. This trend was more pronounced in boys than in girls. The slowing trend in the age at MPV of weight is a trend showing a delay in the age at MPV of weight with respect to the gap with the age at MPV of height, and so is conjectured to be caused by unnatural weight gain from stress and a lack of activity from the effects of the earthquake.

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