

Foods and Nutrients Remarkably Affected Height Growth of Japanese Adolescents after the War, WWII

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ABSTRACT

【OBJECTIVES】 After the war, the height growth of Japanese people increased rapidly with economic growth. It is presumed that this is due to changes in dietary habits, especially food intake. Therefore, we are interested in finding out foods that are most relevant to the increase in height of Japanese people after the war.

【METHODS】 The present study period from the postwar period to the present has been divided into a postwar economic recovery period, an economic growth period, and an economic stagnation period for the sake of convenience. Based on data published by Japanese government agencies, we mainly examined the differences in adolescent height and intakes of food groups and nutrients between nearest two periods, and the Spearman's, Pearson's, and Partial correlations between adolescent height and their intakes in each period. And the results were combined and overall evaluated. It was examined what food groups and nutrients had the great effect on the height gain of the Japanese adolescents after the war.

【RESULTS】 The food groups and nutrients

that were most likely associated with increased adolescent height in Japan were *milk* (milk & dairy products), meats, animal protein, fat, and vitamin B2. However, the correlations of the height with fat and vitamin B2 were almost pseudo-correlations that appeared by the influence of *milk* and meats. It is suggested that milk components other than these three nutrients are also involved in the height gain by *milk*. There was a strong positive correlation between GDP (Gross Domestic Product) per capita and height gain from 1960 to 1991, but not from 1992 to 2017.

【CONCLUSION】 The food groups and nutrients that remarkably affected postwar Japanese height gain are *milk*, meats, animal protein, fat, and vitamin B2, but fat and vitamin B2 can be almost replaced by *milk* and meats. To increase the height of Japanese adults in the future, it is important to promote the intakes of *milk*, meats, and animal protein before becoming adults.

Key words:

height gain, Japanese, milk, meats, animal protein, animal / vegetable protein ratio, fat, vitamin B2, nutrition, food group, post-war

I Introduction

After World War II (WWII), Japanese stature grew rapidly with economic growth, slightly behind Europe and the United States¹⁻⁶⁾. Naturally, this is presumed to be due to changes in eating

Accepted 11/11/2020

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habits, especially food intakes, accompanying with postwar economic growth.

It was suggested that the nutrients that may have affected post war Japanese height gain were animal proteins and vitamin B2 from our previous report⁵⁾. And also, the relationship between height increase and the intakes of food groups and nutrients during the period of economic growth in Japan from the 1960s to the 1990s was investigated⁶⁾. As a result, it was suggested that the intake of *milk* had the greater impact on the increase in height compared to other food groups and nutrients.

However, as introduced in our previous report⁶⁾, many positive⁷⁻¹⁷⁾ or negative results¹⁸⁻²⁴⁾ have been reported on the relationship between height gain and intakes of milk and dairy products. Therefore, further research is needed for many researchers to accept the positive effects of milk and dairy products on height increase.

Therefore, in the present study, referring to the previous report⁵⁾, the period from post-war to the present (1948-2017) is conveniently divided by three distinct periods in economic growth, such as the post-war economic recovery period (1948-1966), the economic growth period (1967-1996), and the economic stagnation period (1997-2017). Each period was examined, and all the results were ultimately combined to know what food groups had the most impact on height gain. Similarly, the effects of nutrient intake were re-examined for comparison with the food groups. We also examined the interrelationship between food groups and nutrients that affected height.

The main purpose of this study is to estimate food groups and nutrients associated remarkably with height gain and to obtain hints for improving the physique of Japanese people.

II Objects and methods

Each average height (cm) and weight (kg)

from third year junior high (14 years old) to third year high school students (17 years old) are based on chronological tables compiled from annual school health statistics surveys²⁵⁾. The reasons for choosing these ages are, as detailed in the previous report⁶⁾ that 14-year-olds had the greatest height reduction in response to war hunger among adolescent males and females, especially in males and that the subsequent growth rate of them during the postwar economic recovery period was the largest in the ages surveyed. It suggested that the height growth of the age 14 is the most sensitive to nutrition environment in the adolescent ages. The heights of 17-year-old males and females are the closest to those of adults according to the school health statistics survey and have only slightly grown until adulthood⁶⁾. Therefore, the heights of 17-year-old males and females may be an indicator of the heights of Japanese adults.

The World Bank's per capita GNI (Gross National Income) is estimated to reflect more personal income than its per capita GDP (Gross Domestic Product). Both can be compared internationally but GNI data have only been published by the Bank for a short period of time. GNI is the sum of GDP plus trade profit but GDP is not much different from GNI. So, the World Bank's GDP per capita (current US \$)²⁶⁾ was adopted as an indicator of Japanese economic situation during the periods from post-war recovery to the economic stagnation in this study. The GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products.

For the division of the postwar period, the changes in GDP per capita, adolescent height, and intakes of food groups and nutrients, and the length of each period (about 20 years or more), etc. were comprehensively judged,

referring the results in the previous report ^{5,6)}. The entire research period (Whole) (1948–2017) was conveniently divided into three economically characteristic periods; the postwar economic recovery period (PR) (1948–1966), Economic growth period (EG) (1967–1996), and Economic stagnation period (ES) (1997–2017). The characteristics of each period will be described in the discussion.

Time series data on the total age-average intakes (per person per day) of food groups and nutrients obtained from the results of the National Health and Nutrition Survey from 1948 to 2017 were mainly used in this study. The method of calculating the intakes of each food group and nutrient and the composition of the food group have changed during this period. However, the continuity of these calculation methods is important for long-term comparisons, especially as in this study. For rice that had a drastic change in the intake due to the new calculation method, the following calculation method was used (2001–2017). The rice intake after 2001 was calculated from the amount of carbohydrate of rice, using the average intake ratio (1.33) of rice to the carbohydrate of rice in the five years from 1996 to 2000 as a conversion factor. Since 2001, mayonnaise has been excluded from the 'oils & fats' food group in official data, but as before 2001, it remains in this group in this study. Since the calculation method of vitamin A content differs largely after the war and values could not be adjusted, only the period during which the calculation method was the same, that is, a part of the postwar economic recovery period (1955–1966) and the economic growth period, were used as the object of the study. Carbohydrate intake was used here from 1949 to 2017 when the data was published.

The types of food groups and nutrients that were covered by this study were basically limited to the items surveyed throughout the study

period. That is, *milk*, fish & shellfish, eggs, meats, beans, oils & fats, cereals (wheat, rice), potatoes, fruits, vegetables (green-yellow vegetables, other vegetables), energy, protein (total protein, animal protein, vegetable protein, animal protein/vegetable protein ratio), fat, carbohydrate, calcium, and vitamins A, B1, B2, and C. *Milk* includes milk and dairy products other than butter.

Statistical calculation was done by SPSS Ver. 11.5 J (basic system for Windows) statistical software. Skewness is an indicator of distribution asymmetry. The skewness ratio to standard error can be used as a test of normality. If this ratio is less than -2 or greater than +2, it is considered that the variable deviates from the normal distribution. As the follows, variables of some food groups, nutrients, and height in each period had deviated from the normal distribution: In the post-war economic recovery period; rice, potatoes, beans, green-yellow vegetable, fish & shellfish, and vitamins B1 and C. In economic growth period, wheat, potatoes, oils & fats, meats, total protein, animal protein, fat, and female height aged 14. In economic stagnation period; beans, *milk*, meats, oil & fat, total protein, animal protein, vegetable protein, and vitamins B1, B2, and C.

Therefore, these correlations were all determined by Spearman's rank correlation coefficients (ρ) to mutually compare the correlations between adolescent height and all the above food groups or nutrients, and between their intakes.

For variables showing the normal distribution, Pearson's correlation coefficient (r) and partial correlation coefficients (r) were also examined. The strength of the absolute value of the correlation coefficient (ρ) or (r) is as follows: Less than 0.2 is hardly correlated, 0.2 to less than 0.4 is weak, 0.4 to less than 0.7 is slightly strong, 0.7 or more is strong, and 0.9 or more is very strongly correlated. In these cases, the precondition for correlation is that the significance probability (P) of the two-sided test is always 0.05

or less.

When comparing averages in this study, an independent sample t-test was always performed. An equal variance test (Levene's test) was done before the t-test.

In this study, to know the food groups and nutrients that contributed to postwar height increase, height, weight, and their intakes were statistically compared between the nearest two periods (called one comparison period unit). These results and the results of the correlations between height and intakes in each period were combined and comprehensively evaluated according to the following criteria. In the three post-war periods mentioned above, as long as there is no contradiction with the result of the correlation, food groups / nutrients whose intake increased with increasing height in one or two comparison period units may contribute to height increase, and the reverse is also true for the decrease in intake. Regardless of the correlation, it was determined that those whose intake increased in one comparison period unit and decreased in another one may not contribute to the increase or decrease in height. If consistent with the results of the correlation, it was determined that those with the consecutive increased or decreased intakes in both two comparison period units were likely to contribute to height increase or decrease.

The correlation between height and food groups / nutrients, etc. often varies remarkably with each period as described later, so the overall evaluation was basically made as follows. As long as it does not conflict with the result of intake, food groups and nutrients that have a positive correlation of 0.7 or more with adolescent height in 3 or more of the 4 periods including the three divided periods and whole period may affect strongly height gain. It was judged that regardless of the result of intake, there is little possibility of height increase due to these food groups/ nutrients if these intakes and height correlated negatively and strongly in

one or more periods or considerably in two or more ones. In addition, the reverse is also true for height decrease. When a positive or negative sign of significant correlation less than 0.7 in only one period like males of meats, males of energy, males and females of vegetable protein, and males of carbohydrates in Tables 5 and 6, was different from that of many significant correlations in the other many periods, this correlation was ignored for total judgment and in the calculation for the probability of increase or decrease. If there was a contradiction between the evaluations of the increase or decrease of the intake and of the correlation between height and a food group or nutrient, the corresponding food group or nutrient was considered to have no contribution to the increase or decrease in height.

As shown in the results of Tables 5 and 6, when the intakes of food groups and nutrients, etc. show the possibility of increase or decrease in height from the overall judgment, the probability of the accidental occurrence of those possibilities was calculated as follows. The probability that an intake will increase with stature or decrease contrarily, will be $1/2$ per comparison period unit, but practically there is a possibility of statistically insignificant increase or decrease, so, the probability of increase or decrease is less than $1/2$ per comparison period unit. The probability of consecutive increase or decrease in the intake is less than $(1/2)^2$ in both comparison period units. If the correlation coefficient is $\pm X1$, the probability that a correlation of $+ X1$ or more or $- X1$ or less occurs by chance in one period is $1/2 \times (1 - |X1|)$. If the correlation of the same sign is 2 periods, then $1/2 \times (1 - |X1|) \times 1/2 \times (1 - |X2|)$, if it is 3 periods, $1/2 \times (1 - |X1|) \times 1/2 \times (1 - |X2|) \times 1/2 \times (1 - |X3|)$. No food group or nutrient had the same sign and four strong correlations (Tables 5 and 6). The values of $X1$, $X2$, and $X3$ are all rounded down to the first decimal place. Therefore, the true probability is less than the

calculated value. Calculating *milk* (male) as an example (Tables 3 and 5), the probability that this increase in the intake for two consecutive comparison period units and positive correlation coefficients of above 0.9 for two periods and above 0.8 for one period will occur by chance, is below $(1/2)^2 \times (1/2)^3 \times (1/10)^2 \times (2/10) = \text{below } 6.25 \times 10^{-5}$. Therefore, the probability that this height increase due to *milk* in males may occur by chance is less than 6.25×10^{-5} .

III Results

It was examined, the relationship between the logarithm of GDP per capita and adolescent height. As a result (Fig. 1), it was found that the heights of adolescent males and females aged 14 to 17 tend to increase with the increase of GDP per capita. As shown in footnote-Table 1 in Fig. 1, from 1960 to 1991, Spearman's correlation coefficients between GDP per capita and their heights were over 0.9. However, from 1992 to 2017, a significant positive correlation between

the two was not found. From the footnote-Table 2 in Figure 1, the average GDP per capita is larger during the economic stagnation period than during the economic growth period. It is also clear that each GDP per capita during the last seven years of the post war-economic recovery period, 1960 to 1966, was always smaller than during the economic growth period (Fig. 1).

From Table 1, the relationship between the adolescent height and the intake of each food group was compared between the two periods (one comparison period unit). Comparing the economic growth period to the postwar economic recovery period, on average, the height of 17-year-old increased by 5.5 cm in males and 3.5 cm in females. Foods whose intake was significantly increased were wheat, oils & fats, fish & shellfish, meats, eggs, *milk*, green-yellow vegetable, other vegetable, and fruits. On the other hand, it was rice and potatoes that had a significant reduction in their intake.

Comparing the economic stagnation period to the economic growth period, the heights of males

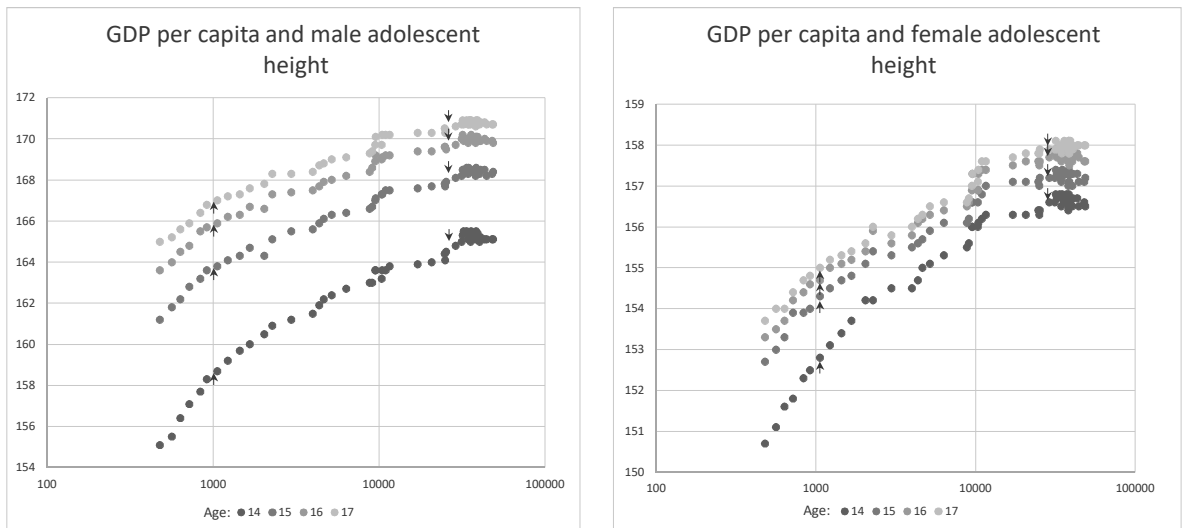


Fig. 1 Relationship between GDP capita and adolescent height
The vertical axis is height (cm). The horizontal axis is Log_{10} (GDP per capita, US\$). Arrows, \uparrow and \downarrow show 1966 and 1991, respectively. Adolescent heights and GDP per capita were obtained from the data published by Japan ministry of Education, Sport, Science, and Technology and by World Bank, respectively.

The footnote-table 1. Spearman's correlation between the height and Log₁₀ (GDP per capita)

| | | male (age) | | | | female (age) | | | |
|---------------------------|-------------------|------------|--------|--------|--------|--------------|--------|--------|--------|
| | | 14 | 15 | 16 | 17 | 14 | 15 | 16 | 17 |
| 1960~ 1991 (N = 32) | Spearman's ρ | 0.996 | 0.998 | 0.996 | 0.996 | 0.997 | 0.994 | 0.995 | 0.997 |
| | P | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| 1992~ 2017 (N = 26) | Spearman's ρ | -0.341 | -0.213 | -0.323 | -0.231 | -0.426 | -0.296 | -0.467 | 0.125 |
| | P | 0.088 | 0.297 | 0.108 | 0.256 | 0.030 | 0.141 | 0.016 | 0.544 |

Avbbreviation is the same as Table 1. P: Significance probability

The footnote-table 2. Average GDP per capita in 3 periods

| | the last 7 years of PR | EG | ES |
|---------|---------------------------|--------|-------|
| Average | 744 | 14896 | 38082 |
| SD | 206 | 13034 | 4538 |
| SP | - | <0.001 | |
| N | 7 | 30 | 21 |

Avbbreviation is the same as Table 1

and females increased by 1.3 cm and 1.0 cm on average, respectively. Food groups whose intakes significantly increased were wheat, meats, *milk*, and green-yellow vegetable. On the other hand, intakes of rice, oils & fats, beans, fish & shellfish, eggs, other vegetable, and fruits significantly decreased.

Like food groups, the relationship between the adolescent height and the intake of each nutrient etc. was compared. As a result (Table 2), comparing the economic growth period to the postwar economic recovery period, the intakes of some nutrients: total protein, animal protein, animal protein / vegetable protein ratio, fat, calcium, vitamins A, B2 and C statistically significantly increased with height. On the other hand, the intakes of vegetable protein and carbohydrate decreased. Energy and vitamin B1 did not increase or decrease significantly.

Comparing the economic growth period to the

economic stagnation one, there was no nutrient whose intake significantly increased with height but the ratio of animal protein to vegetable protein increased statistically significantly. Nutrients etc. whose intakes significantly decreased were energy, total protein, vegetable protein, carbohydrate, calcium, and vitamins B1 and C. Those that were not statistically significant difference between the two periods were animal protein, fat, and vitamin B2.

From the results of Tables 1 and 2, the food groups whose intakes increased significantly with increased height over the two comparison period units were wheat, meats, *milk*, and green-yellow vegetables. However, there were no nutrients that met this condition other than the ratio of animal protein to vegetable one.

From the footnote in Table 2, among the major energy sources in Japanese people, energy intake from carbohydrate changed from about 76% during the postwar economic recovery period to about 56% during the economic stagnation period. Similarly, energy intake changed about 13% to 15% from protein and about 10% to 26% from fat.

As shown in Table 3, food groups having a positive correlation coefficient of 0.4 or more with adolescent heights of males and females over 3 periods are oils and fats, fish & shellfish, meats, eggs, and *milk*. Those of 0.7 or more were meats and *milk*. Food groups with a positive correlation of 0.7 or more in one period or 0.4 or more in two

Table 1 Comparison of food intake between the nearest two periods among the periods of the postwar recovery, the economic growth, and the economic stagnation

| Food group (g) | PR: N=19 | | SP | EG: N=30 | | SP | ES: N=21 | |
|------------------------|----------|------|--------|----------|------|--------|----------|------|
| | Average | SD | | Average | SD | | Average | SD |
| rice | 348 | 16 | <0.001 | 233 | 43 | <0.001 | 165.9 | 7.1 |
| wheat | 67.2 | 4.6 | <0.001 | 86.8 | 10.1 | <0.001 | 98.6 | 4.2 |
| potatoes | 85.4 | 43.0 | 0.0160 | 59.0 | 9.0 | 0.896 | 58.7 | 6.0 |
| oils & fats | 5.5 | 2.6 | <0.001 | 16.9 | 1.6 | <0.001 | 14.1 | 1.3 |
| beans | 66.7 | 8.4 | 0.433 | 68.3 | 2.8 | <0.001 | 60.5 | 5.8 |
| fish & shellfish | 73.6 | 9.1 | <0.001 | 92.1 | 3.9 | <0.001 | 80.3 | 10.6 |
| meats | 17.3 | 9.1 | <0.001 | 66.4 | 12.6 | <0.001 | 83.1 | 6.5 |
| eggs | 16.6 | 10.2 | <0.001 | 41.1 | 1.6 | <0.001 | 36.2 | 2.3 |
| <i>milk</i> | 25.0 | 17.4 | <0.001 | 110.7 | 18.7 | <0.001 | 131.3 | 14.9 |
| green yellow vegetable | 55.4 | 15.6 | 0.021 | 66.3 | 15.3 | <0.001 | 90.2 | 4.3 |
| the other vegetable | 172.5 | 12.8 | <0.001 | 191.0 | 15.2 | 0.029 | 184.1 | 5.9 |
| fruits | 66.1 | 28.8 | <0.001 | 139.3 | 32.3 | <0.001 | 113.9 | 9.2 |
| Height, male aged 17 | 164.0 | 1.9 | <0.001 | 169.5 | 1.1 | <0.001 | 170.8 | 0.1 |
| female aged 17 | 153.5 | 0.8 | <0.001 | 157.0 | 0.9 | <0.001 | 158.0 | 0.1 |

Abbreviation : SD, standard deviation, SP, significance probability in difference between the two.

N: number of years for calculation, PR: the post-war economic recovery period, EG: economic growth period, ES: economic stagnation period.

Table 2 Comparison of nutritional intake between the nearest two periods among the periods of the post-war recovery, the economic growth, and the economic stagnation

| Nutrient | PR: N=19 | | SP | EG: N=30 | | SP | ES: N=21 | |
|-----------------------------|----------|------|--------|----------|------|--------|----------|------|
| | Average | SD | | Average | SD | | Average | SD |
| energy (kcal) | 2109 | 48 | 0.306 | 2128 | 84 | <0.001 | 1904 | 45.5 |
| total pr otein (g) | 69.5 | 2.7 | <0.001 | 79.4 | 1.6 | <0.001 | 71.3 | 4.2 |
| animal protein (g) | 23.0 | 4.7 | <0.001 | 39.5 | 3.2 | 0.190 | 38.4 | 2.4 |
| vegetable protein (g) | 46.5 | 2.5 | <0.001 | 39.8 | 2.4 | <0.001 | 32.8 | 1.9 |
| animal / vegetable | 0.50 | 0.12 | <0.001 | 1.00 | 0.13 | <0.001 | 1.17 | 0.02 |
| fat (g) | 24.1 | 6.8 | <0.001 | 54.2 | 4.8 | 0.206 | 55.5 | 2.0 |
| carbohydrate (g) | 402 | 13 | <0.001 | 318 | 34 | <0.001 | 264 | 6 |
| calcium (mg) | 369 | 76 | <0.001 | 547 | 15 | 0.005 | 528 | 26 |
| vitamin A (I.U.) | 1300 | 149 | <0.001 | 2068 | 471 | - | - | - |
| Vitamin B ₁ (mg) | 1.18 | 0.21 | 0.405 | 1.22 | 0.09 | <0.001 | 0.91 | 0.13 |
| Vitamin B ₂ (mg) | 0.73 | 0.06 | <0.001 | 1.15 | 0.18 | 0.161 | 1.21 | 0.11 |
| Vitamin C (mg) | 89 | 20 | <0.001 | 118 | 11 | <0.001 | 103 | 14 |
| Height, male aged 17 | 164.0 | 1.9 | <0.001 | 169.5 | 1.1 | <0.001 | 170.8 | 0.1 |
| female aged 17 | 153.5 | 0.8 | <0.001 | 157.0 | 0.9 | <0.001 | 158.0 | 0.1 |

Abbreviation is the same as Table 1.

N: number of years for calculation except for vitamin A (N=12) and carbohydrate (N=18) in the PR period.

Energy intake ratio (%) of major energy sources: Total protein 13.2 (PR), 14.9 (EG), 15.0 (ES), Fat: 10.3 (PR), 22.9 (EG), 26.3 (ES), Carbohydrate: 76.2 (PR), 59.8 (EG), 55.5 (ES).

These energy intake ratios were calculated using the Atwater's caloric factor as the energy conversion factor.

Table 3 Spearman's correlation between height of 17-year-old adolescence and food intake, in different periods

| Food group | height | | | | | | | | |
|------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| | sex | male | | | | female | | | |
| | period | PR | EG | ES | Whole | PR | EG | ES | Whole |
| rice | | 0.326 | -0.992 | 0.373 | -0.909 | 0.303 | -0.990 | 0.013 | -0.910 |
| | | 0.174 | <0.001 | 0.096 | <0.001 | 0.208 | <0.001 | 0.955 | <0.001 |
| wheat | | -0.565 | 0.284 | -0.704 | 0.738 | -0.579 | 0.269 | -0.446 | 0.719 |
| | | 0.012 | 0.129 | <0.001 | <0.001 | 0.009 | 0.151 | 0.043 | <0.001 |
| potatoes | | -0.857 | 0.794 | 0.790 | -0.259 | -0.848 | 0.784 | 0.516 | -0.254 |
| | | <0.001 | <0.001 | <0.001 | 0.030 | <0.001 | <0.001 | 0.017 | 0.034 |
| oils & fats | | 0.993 | 0.544 | 0.431 | 0.531 | 0.988 | 0.545 | 0.105 | 0.541 |
| | | <0.001 | 0.002 | 0.051 | <0.001 | <0.001 | 0.002 | 0.650 | <0.001 |
| beans | | 0.759 | -0.225 | 0.247 | -0.265 | 0.749 | -0.219 | 0.157 | -0.247 |
| | | <0.001 | 0.232 | 0.281 | 0.026 | <0.001 | 0.246 | 0.497 | 0.039 |
| fish & shellfish | | 0.519 | 0.801 | 0.778 | 0.422 | 0.528 | 0.783 | 0.551 | 0.429 |
| | | 0.023 | <0.001 | <0.001 | <0.001 | 0.020 | <0.001 | 0.010 | <0.001 |
| meats | | 0.991 | 0.834 | -0.515 | 0.917 | 0.989 | 0.818 | -0.338 | 0.907 |
| | | <0.001 | <0.001 | 0.017 | <0.001 | <0.001 | <0.001 | 0.135 | <0.001 |
| eggs | | 0.996 | 0.526 | 0.438 | 0.496 | 0.992 | 0.521 | 0.174 | 0.511 |
| | | <0.001 | 0.003 | 0.047 | <0.001 | <0.001 | 0.003 | 0.450 | <0.001 |
| <i>milk</i> | | 0.995 | 0.899 | 0.250 | 0.907 | 0.989 | 0.897 | -0.038 | 0.886 |
| | | <0.001 | <0.001 | 0.275 | <0.001 | <0.001 | <0.001 | 0.869 | <0.001 |
| green yellow vegetable | | -0.826 | 0.756 | 0.467 | 0.732 | -0.817 | 0.746 | 0.287 | 0.713 |
| | | <0.001 | <0.001 | 0.033 | <0.001 | <0.001 | <0.001 | 0.208 | <0.001 |
| the other vegetable | | 0.527 | -0.741 | -0.251 | 0.123 | 0.527 | -0.746 | -0.234 | 0.104 |
| | | 0.020 | <0.001 | 0.273 | 0.312 | 0.020 | <0.001 | 0.307 | 0.390 |
| fruits | | 0.861 | -0.120 | 0.619 | 0.453 | 0.853 | -0.137 | 0.359 | 0.443 |
| | | <0.001 | 0.529 | 0.003 | <0.001 | <0.001 | 0.470 | 0.110 | <0.001 |
| *male | | | | | | 0.996 | 0.996 | 0.594 | 0.980 |
| | | | | | | <0.001 | <0.001 | 0.005 | <0.001 |
| N | | 19 | 30 | 21 | 70 | 19 | 30 | 21 | 70 |

upper rows: Spearman's correlation coefficient, under rows: significance probability

N: the number of years for calculation

*male: correlation between male and female heights

Whole: all years from 1948 to 2017

Table 4 Spearman's correlation between height of 17-year-old adolescence and nutrient intake, in different periods

| Nutrients | height | | | | | | | | |
|------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| | sex | male | | | | female | | | |
| | period | PR | EG | ES | Whole | PR | EG | ES | Whole |
| energy | | 0.418 | -0.947 | 0.617 | -0.686 | 0.418 | -0.958 | 0.344 | -0.683 |
| | | 0.075 | <0.001 | 0.003 | <0.001 | 0.075 | <0.001 | 0.127 | <0.001 |
| total protein | | 0.894 | 0.512 | 0.650 | 0.279 | 0.900 | 0.473 | 0.337 | 0.280 |
| | | <0.001 | 0.004 | 0.001 | 0.019 | <0.001 | 0.008 | 0.135 | 0.019 |
| animal protein | | 0.982 | 0.869 | 0.622 | 0.737 | 0.981 | 0.854 | 0.313 | 0.743 |
| | | <0.001 | <0.001 | 0.003 | <0.001 | <0.001 | <0.001 | 0.167 | <0.001 |
| vegetable protein | | -0.931 | -0.968 | 0.676 | -0.920 | -0.924 | -0.975 | 0.444 | -0.913 |
| | | <0.001 | <0.001 | 0.001 | <0.001 | <0.001 | <0.001 | 0.044 | <0.001 |
| animal / vegetable | | 0.968 | 0.973 | 0.113 | 0.955 | 0.965 | 0.971 | -0.134 | 0.933 |
| | | <0.001 | <0.001 | 0.626 | <0.001 | <0.001 | <0.001 | 0.563 | <0.001 |
| fat | | 0.997 | 0.924 | 0.238 | 0.822 | 0.909 | 0.868 | 0.164 | 0.824 |
| | | <0.001 | <0.001 | 0.298 | <0.001 | <0.001 | <0.001 | 0.479 | <0.001 |
| carbohydrate | | -0.893 | -0.987 | 0.665 | -0.921 | -0.893 | -0.991 | 0.369 | -0.917 |
| | | <0.001 | <0.001 | 0.001 | <0.001 | <0.001 | <0.001 | 0.100 | <0.001 |
| calcium | | 0.977 | 0.300 | 0.711 | 0.607 | 0.976 | 0.276 | 0.418 | 0.593 |
| | | <0.001 | 0.107 | <0.001 | <0.001 | <0.001 | 0.139 | 0.059 | <0.001 |
| vitamin A | | 0.811 | 0.916 | - | - | 0.801 | 0.903 | - | - |
| | | 0.001 | <0.001 | - | - | 0.002 | <0.001 | - | - |
| vitamin B ₁ | | -0.899 | 0.660 | 0.603 | -0.229 | -0.909 | 0.652 | 0.442 | -0.197 |
| | | <0.001 | <0.001 | 0.004 | 0.056 | <0.001 | <0.001 | 0.045 | 0.102 |
| vitamin B ₂ | | 0.738 | 0.939 | 0.578 | 0.875 | 0.736 | 0.927 | 0.385 | 0.882 |
| | | <0.001 | <0.001 | 0.006 | <0.001 | <0.001 | <0.001 | 0.085 | <0.001 |
| vitamin C | | -0.087 | 0.572 | 0.702 | 0.373 | -0.091 | 0.555 | 0.472 | 0.381 |
| | | 0.722 | 0.001 | <0.001 | 0.001 | 0.712 | 0.001 | 0.031 | 0.001 |
| *male | | | | | | 0.996 | 0.996 | 0.594 | 0.980 |
| | | | | | | <0.001 | <0.001 | 0.005 | <0.001 |
| N | | 19 | 30 | 21 | 70 | 19 | 30 | 21 | 70 |

upper row: Spearman's correlation coefficient, under row: significance probability

N: number of years for calculation except for vitamin A (N=12) and carbohydrate (N=18) in the PR period.

*male: correlation between male and female heights

Abbreviation is the same as Table 3.

Table 5 Relationship between height growth and food intake summarized from a comparison of the nearest two periods and those correlations

| nutrients & height | comparison between the nearest neighbored periods | | evaluation of changes in intake | evaluation from | | total judgement about the effect on height gain |
|------------------------|---|----------|---------------------------------|-----------------|--------------|--|
| | PR: EG | EG: ES | | correlation♂ | correlation♀ | |
| rice | decrease | decrease | DD | 2N | 2N | decrease (6.25×10^{-4}) |
| wheat | increase | increase | II | P, N, n | P, 2n | none |
| potatoes | decrease | neither | D | 2P, N, (n) | P, p, N, (n) | none |
| oils & fats | increase | decrease | ID | P, 2p | P, 2p | none |
| beans | neither | decrease | D | P, (n) | P, (n) | none |
| fish & shellfish | increase | decrease | ID | 2P, 2p | P, 3p | none |
| meats | increase | increase | II | 3P, n | 3P | increase (6.25×10^{-5}) |
| eggs | increase | decrease | ID | P, 3p | P, 2p | none |
| <i>milk</i> | increase | increase | II | 3P | 3P | increase ($M6.25 \times 10^{-5}$, $F1.25 \times 10^{-4}$) |
| green yellow vegetable | increase | increase | II | 2P, p, N | 2P, N | none |
| the other vegetable | increase | decrease | ID | p, N | p, N | none |
| fruits | increase | decrease | ID | P, 2p | P, p | none |
| height | increase | increase | | | | |

These results are summarized from tables 1 and 3.

Increase' or 'decrease' means the increase (I) or decrease (D) in height and food group or nutrient intake, respectively, when going from the previous period to the next period. 'Neither' means neither statistically significant increase or decrease in the stated above. 'No examined' means that the data is not available because calculation methods are different or it has not been examined.

Abbreviation is the same as Table 2. If the correlation coefficient is $|0.7|$ or more, and $|0.4|$ or more below $|0.7|$, it is written with a capital and small letter, respectively. And the positive or negative correlation is shown with p or n, respectively. And it is shown (p) or (n) if the correlation coefficient is below $|0.4|$. Regardless of the correlation evaluation, if the intake was ID, total evaluation is neither the increase nor decrease, indicating 'none'. N or 2n means that the correlation between height and intake of food group or nutrient is clearly negative. Therefore, even if the evaluation of changes in food group or nutrient intake is II, the presence of N or 2n in the correlation gives an total judgment of "none. Similarly, if there is P or 2p in the correlation, a total judgment will be "none", even if the intake evaluation is D. M and F in parentheses of the table mean only male and female, respectively and the case without them means both male and female. The numbers in parentheses indicate the probability that each food group and nutrient, etc. will increase or decrease height by chance.

periods or more were wheat, potatoes, beans, green-yellow vegetable, and fruits. So, there is a high possibility that they will not be involved in height reduction because of the clear positive correlations between height and them. On the other hand, those of -0.7 or less in one or more periods, or -0.4 or less in 2 periods or more were rice, wheat, potatoes, green-yellow vegetable, and the other vegetable. They may not be involved in height increase because of the clear negative correlation. Wheat, potatoes, and green-yellow vegetable which meet both these criteria may not

contribute to the increase and decrease in height.

Similarly, from Table 4, the nutrients that positively correlated at the coefficient of 0.7 or more with adolescent height of both sexes for over 3 periods were animal protein, the ratio of animal protein to vegetable protein, fat, and vitamin B2. Those that negatively correlated with the height at the coefficient of -0.7 or less for over 3 periods were vegetable protein and carbohydrate. Those with a positive correlation coefficient of 0.7 or more in one or more periods or 0.4 or more in two or more periods were total

Table 6 Relationship between height growth and nutrient intake summarized from a comparison of the nearest two periods and those correlations

| nutrients & height | comparison between the nearest neighbored periods | | evaluation of changes in intake | evaluation from | | total judgement about the effect on height gain |
|------------------------|---|-------------|---------------------------------|-----------------|--------------|---|
| | PR: EG | EG: ES | | correlation♂ | correlation♀ | |
| energy | neither | decrease | D | p, N, n | N, n | weak decrease (0.005) |
| total protein | increase | decrease | ID | P, 2p, (p) | P, p, (p) | none |
| animal protein | increase | neither | I | 3P, p | 3P | increase (3.75×10^{-4}) |
| vegetable protein | decrease | decrease | DD | p, 3N | p, 3N | decrease (3.125×10^{-5}) |
| animal / vegetable | increase | increase | II | 3P | 3P | increase (3.125×10^{-5}) |
| fat | increase | neither | I | 3P | 3P | increase ($M1.25 \times 10^{-4}$, $F2.5 \times 10^{-4}$) |
| carbohydrate | decrease | decrease | DD | p, 3N | 3N | decrease (6.25×10^{-5}) |
| calcium | increase | decrease | ID | 2P, p | P, p | none |
| vitamin A | increase | no examined | ? | 2P | 2P | unknown |
| vitamin B ₁ | neither | decrease | D | 2p, N | N, 2p | none |
| vitamin B ₂ | increase | neither | I | 3P, p | 3P | increase ($M9.375 \times 10^{-5}$, $F3.75 \times 10^{-4}$) |
| vitamin C | increase | decrease | ID | P, p, (p) | 2p, (p) | none |
| height | increase | increase | | | | |

These results were summarized from tables 2 and 4. The footnotes in this table are the same as those in Table 5. 'unknown' in the total judgement means that vitamin A content is the published data with different calculation methods during three periods and cannot be compared among the periods.

protein, calcium, and vitamins B1 and C. They may not be involved in height reduction. Those having negative correlation coefficients of -0.7 or less in one or more periods, or -0.4 or less in two or more periods were energy, vegetable protein, carbohydrate, and vitamin B1. Those may not be involved in height increase. As mentioned above, vitamin B1 that meet both criteria is unlikely to be involved in height increase and decrease.

From Table 5 which summarized the results of Tables 1 and 3, total judgment about the effect of each food group was made on the increase / decrease in male and female height. The food groups that may have contributed to increasing the heights of males and females are *milk* and meats, and rice may have contributed to decreasing it. The probability that intakes of these food groups and the height will increase or decrease together or contrarily by chance has ultimately been calculated as less than 6.25×10^{-5} to 6.25×10^{-4} as shown in Table 5. Therefore, these

changes in height would not happen by chance.

Similarly, from Table 6 which summarized the results of Tables 2 and 4, it is estimated that the nutrients that may have contributed to the increase in the heights of males and females are animal protein, animal protein / vegetable protein ratio, fat, and vitamin B2. On the other hand, the nutrients that may have related to height decrease are carbohydrate and vegetable protein. Energy may have contributed only a little to the height decrease. Like food groups stated above, the probability that the intakes of these nutrients and height will accidentally increase or decrease together or contrarily, through overall process with the intake and correlations was calculated as below 0.005 to below 3.125×10^{-5} . Thus, these changes in height would not happen by chance.

Using Pearson's and partial correlations, it was examined, the interrelationship between food groups such as *milk* and meats and nutrients such as animal protein, fat, and vitamin B2, which may

Table 7 Pearson's and partial correlations between adolescent height and intakes of *milk* and nutrients affecting height gain, in the postwar economic recovery period

| food group and nutrient | control variable | male height | | female height | |
|----------------------------|--|-----------------|-----------------|-----------------|-----------------|
| | | age 14 | age 17 | age 14 | age 17 |
| <i>milk</i> | none | 0.968 <0.001 | 0.973 <0.001 | 0.966 <0.001 | 0.979 <0.001 |
| animal protein | none | 0.946 <0.001 | 0.963 <0.001 | 0.960 <0.001 | 0.935 <0.001 |
| fat | none | 0.930 <0.001 | 0.954 <0.001 | 0.934 <0.001 | 0.978 <0.001 |
| vitamin B2 | none | 0.723 <0.001 | 0.740 <0.001 | 0.721 <0.001 | 0.787 <0.001 |
| <i>milk</i> | animal protein | 0.842 <0.001 | 0.931 <0.001 | 0.860 <0.001 | 0.896 <0.001 |
| <i>milk</i> | fat | 0.734 0.001 | 0.669 0.002 | 0.696 0.001 | 0.632 0.005 |
| <i>milk</i> | vitamin B2 | 0.952 <0.001 | 0.955 <0.001 | 0.949 <0.001 | 0.944 <0.001 |
| <i>milk</i> | animal protein, vitamin B2, fat | 0.790 <0.001 | 0.818 <0.001 | 0.802 <0.001 | 0.653 0.006 |
| animal protein | <i>milk</i> | 0.717 <0.001 | 0.905 <0.001 | 0.830 <0.001 | 0.644 0.004 |
| fat | <i>milk</i> | -0.069 0.786 | 0.246 0.326 | 0.016 0.950 | 0.624 0.006 |
| vitamin B2 | <i>milk</i> | -0.533 0.023 | -0.489 0.040 | -0.526 0.025 | -0.175 0.486 |

Decimals in the table; Pearson's or partial correlation coefficient (upper row) and significance probability (lower row)

have contributed to the increase in adolescent height. As all these variables did not deviate from the normal distribution only in the postwar economic recovery period, it was examined in this period.

As a result (Table 7), when animal protein, fat, and vitamin B2 were used as each control variable, the partial correlation coefficient between height and *milk* decreased slightly. Contrarily, the positive correlations between height and these nutrients, vitamin B2, and fat excluding

17-year-old female disappeared when *milk* was used as a control variable. In other words, these correlations were pseudo correlations appeared by the influence of *milk*. Similarly, *milk* of a control variable reduced the positive correlation between height and animal protein more strongly than animal protein of a control variable reduced that between height and *milk*. The correlation coefficients from 0.653 to 0.818 between *milk* and height remained even though these three nutrients together were used as control variables.

Table 8 Pearson's and partial correlations between adolescent height and intakes of meats and nutrients affecting height gain, in the postwar recovery period

| food group and nutrient | control variable | male height | | female height | |
|-------------------------|---------------------------------|-------------|--------|---------------|--------|
| | | age 14 | age 17 | age 14 | age 17 |
| meats | none | 0.962 | 0.967 | 0.963 | 0.979 |
| | | <0.001 | <0.001 | <0.001 | <0.001 |
| meats | <i>milk</i> | 0.237 | 0.243 | 0.281 | 0.448 |
| | | 0.344 | 0.331 | 0.259 | 0.063 |
| <i>milk</i> | meats | 0.448 | 0.493 | 0.403 | 0.443 |
| | | 0.062 | 0.038 | 0.097 | 0.066 |
| meats | animal protein | 0.772 | 0.834 | 0.792 | 0.879 |
| | | <0.001 | <0.001 | <0.001 | <0.001 |
| meats | fat | 0.673 | 0.572 | 0.657 | 0.605 |
| | | 0.002 | 0.013 | 0.003 | 0.008 |
| meats | vitamin B2 | 0.939 | 0.940 | 0.943 | 0.946 |
| | | <0.001 | <0.001 | <0.001 | <0.001 |
| meats | animal protein, vitamin B2, fat | 0.633 | 0.527 | 0.640 | 0.582 |
| | | 0.008 | 0.036 | 0.008 | 0.018 |
| animal protein | meats | 0.654 | 0.816 | 0.772 | 0.564 |
| | | <0.001 | <0.001 | <0.001 | 0.015 |
| fat | meats | -0.029 | 0.282 | 0.019 | 0.593 |
| | | 0.910 | 0.257 | 0.941 | 0.010 |
| vitamin B2 | meats | -0.489 | -0.432 | -0.513 | -0.212 |
| | | 0.039 | 0.074 | 0.029 | 0.398 |

Abbreviation is the same as Table 7.

Similarly, the partial correlation between height and meats was examined using these nutrients as control variables (Table 8). Like the case of *milk* and height, the correlation between height and either fat excluding 17-year-old female or vitamin B2 was a pseudo correlation by meats. Although Pearson's correlation coefficient between height and *milk* or meats is almost equal, the partial correlation between height and animal protein was lower when meats were a control variable than when *milk* was (Tables 7 and 8). Therefore, this suggested that the relationship with animal protein is stronger with meats than with *milk*.

The correlation coefficients from 0.527 to 0.640 between meats and height remained when these three nutrients were used as control variables at the same time. However, those coefficients with meats were lower than with those of *milk* stated above (Tables 7 and 8).

Effects of *milk* and meats were compared on adolescent height increase. Pearson's correlation between the height and *milk* or meats was strong and positive (Tables 7 and 8). Partial correlation between the height and meats disappeared significantly when *milk* was a control variable. On the contrary, when meats was a control variable,

Table 9 Pearson's and partial correlations, between intake of food groups or nutrients affecting height gain and adolescent height or weight, in the postwar economic recovery period

| | correlation | control variable | male height | | female height | | male weight | | female weight | |
|--------------------------------|-------------|------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| | | | age 14 | age 17 | age 14 | age 17 | age 14 | age 17 | age 1 | age 1 |
| <i>milk</i> | Pearson's | none | 0.968 <0.001 | 0.973 <0.001 | 0.966 <0.001 | 0.979 <0.001 | 0.964 <0.001 | 0.953 <0.001 | 0.948 <0.001 | 0.977 <0.001 |
| <i>milk in economic growth</i> | Pearson's | none | 0.943 <0.001 | 0.951 <0.001 | - <0.001 | 0.936 <0.001 | 0.927 <0.001 | 0.905 <0.001 | 0.913 <0.001 | 0.798 <0.001 |
| meats | Pearson's | none | 0.962 <0.001 | 0.967 <0.001 | 0.963 <0.001 | 0.979 <0.001 | 0.962 <0.001 | 0.944 <0.001 | 0.940 <0.001 | 0.973 <0.001 |
| animal protein | Pearson's | none | 0.946 <0.001 | 0.963 <0.001 | 0.960 <0.001 | 0.935 <0.001 | 0.947 <0.001 | 0.957 <0.001 | 0.947 <0.001 | 0.915 <0.001 |
| fat | Pearson's | none | 0.930 <0.001 | 0.954 <0.001 | 0.934 <0.001 | 0.978 <0.001 | 0.928 <0.001 | 0.920 <0.001 | 0.906 <0.001 | 0.940 <0.001 |
| vitamin B2 | Pearson's | none | 0.723 <0.001 | 0.740 <0.001 | 0.721 <0.001 | 0.787 <0.001 | 0.727 <0.001 | 0.701 <0.001 | 0.696 <0.001 | 0.777 <0.001 |
| <i>milk</i> | partial | weight or height | 0.380 0.120 | 0.720 0.001 | 0.675 0.002 | 0.634 0.005 | -0.169 0.502 | -0.398 0.102 | -0.400 0.100 | 0.609 0.007 |
| <i>milk in economic growth</i> | partial | weight or height | 0.478 0.009 | 0.732 <0.001 | - - | 0.823 <0.001 | -0.137 0.477 | -0.340 0.071 | - - | -0.243 0.205 |
| meats | partial | weight or height | 0.111 0.661 | 0.718 0.001 | 0.739 <0.001 | 0.654 0.003 | 0.105 0.679 | -0.435 0.071 | -0.521 0.027 | 0.522 0.026 |
| animal protein | partial | weight or height | 0.034 0.895 | 0.393 0.107 | 0.521 0.027 | 0.485 0.041 | 0.145 0.566 | 0.046 0.857 | -0.199 0.430 | 0.142 0.575 |
| fat | partial | weight or height | 0.177 0.482 | 0.824 <0.001 | 0.688 0.002 | 0.795 <0.001 | -0.026 0.918 | -0.668 0.002 | -0.512 0.030 | -0.083 0.743 |
| vitamin B2 | partial | weight or height | -0.056 0.825 | 0.475 0.046 | 0.357 0.146 | 0.222 0.376 | 0.120 0.636 | -0.362 0.140 | -0.250 0.317 | 0.110 0.664 |

Avbbreviation is the same as Table 7.

Milk in italic is the results in the economic growth period.

Footnote-table 3 The following was examined in the economic growth period by the same methods as the above Table 9. The object food groups are green yellow vegetable and fish & shellfish that correlated strongly with height and did not deviated from the normal distribution in the economic growth period.

| | correlation | control variable | male height | | female height | | male weight | | female weight | |
|------------------------|-------------|------------------|-----------------|-----------------|---------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| | | | age 14 | age 17 | age 14 | age 17 | age 14 | age 17 | age 14 | age 17 |
| green yellow vegetable | Pearson's | none | 0.715 <0.001 | 0.710 <0.001 | - - | 0.715 <0.001 | 0.762 <0.001 | 0.785 <0.001 | 0.775 <0.001 | 0.848 <0.001 |
| fish & shellfish | Pearson's | none | 0.801 <0.001 | 0.762 <0.001 | - - | 0.745 <0.001 | 0.811 <0.001 | 0.775 <0.001 | 0.809 <0.001 | 0.736 <0.001 |
| green yellow vegetable | partial | weight or height | -0.426 0.021 | -0.413 0.026 | - - | -0.183 0.342 | 0.545 0.002 | 0.599 0.001 | - - | 0.667 0.000 |
| fish & shellfish | partial | weight or height | -0.023 0.905 | 0.047 0.809 | - - | 0.289 0.129 | 0.215 0.262 | 0.219 0.255 | - - | 0.232 0.226 |

Avbbreviation is the same as Table 7.

the partial correlation coefficients of 0.403 to 0.493 between height and *milk* remained (Table 8). The correlation between 17-year-old male height and meats may be a pseudo-correlation due to *milk*.

During the postwar economic recovery period, the food groups and nutrients that remarkably affected height growth did not deviate from the normal distribution. Whether they were related to height or weight was examined using Pearson and partial correlations in this period (Table 9).

It was found that these food groups and nutrients had a strong positive correlation with height and weight (Tables 8 and 9). When weight was a control variable, there were strong correlations between height and *milk*, meats, and fat except for a 14-year-old male. But when height was a control variable, the positive and significant correlations between weight and *milk*, meats, and fat disappeared except for a 17-year-old female. Namely, this suggests that *milk*, meats, and fat are more related to height than weight. Except for a 14-year-old male, when height was a control variable, the correlation between weight and animal protein or vitamin B2 was lower than that with height when weight was a control variable. So, it is possible that animal protein and vitamin B2 are also more closely related to height than weight.

During the economic growth period (Table 9 italics), when weight was a control variable, there were still strong or considerable correlations between *milk* and male and female heights including 14-year-old males. Also, when height was a control variable, a positive significant correlation between *milk* and the weight of both sexes disappeared including 17-year-old females. That is, the correlation between *milk* and weight is a pseudo correlation appeared by the influence of height. So, this clearly shows in the economic growth period as well as the post war economic recovery period that the relationship of *milk* with height gain is stronger than with weight gain.

A similar study in the economic growth period (footnote-Table 3 in Table 9) have shown that green-yellow vegetable has a stronger relationship with weight than height, but the fish & shellfish is unclear. Pearson's correlations between these food groups and height or weight were positive and strong in this period.

IV Discussion

From the results of this study (Tables 5 and 6), it was estimated that the food groups that contributed to the increase in height of postwar Japanese were especially *milk* and meats. From a comparison of food consumption by country, it has already been reported that there was a positive correlation between these foods and male height²⁸⁾.

Furthermore, from the results of partial correlations (Table 8), the correlation between meats and height was likely to be a pseudo-correlation due to *milk* in at least a 17-year-old male. Namely, *milk* may be more strongly associated with height growth than meats. It has been indicated that milk proteins are more strongly involved in height growth in 9-year-old girls than normal animal proteins¹⁰⁾. In our previous report⁶⁾, *milk* had the greatest impact on adolescent height growth compared to other foods and nutrients examined during Japan's economic growth period. *Milk* had more effective on height gain than weight gain (Table 9). As described in 'Introduction' of this paper and the previous report⁶⁾, a considerable number of positive and negative reports have been made on the contribution of *milk* intake to height gain. However, recent papers based on meta-analysis^{16, 17)} show the positive effect of *milk* on height gain, as described in our previous paper⁶⁾.

Therefore, it is interested in milk components related to height gain. It has been described that calcium in milk is important in height gain in post war Japanese^{3, 4)}. However, it seems that calcium

in milk is not the candidate because calcium was almost not related to height increase in post war Japanese people (Table 6). This has been also supported by some researchers, as introduced in our previous report⁶⁾. From Table 6, fat and vitamin B2 contributed to height increase but the positive correlation between height and fat or vitamin B2 was almost a pseudo-correlation due to *milk* (Table 7). Therefore, *milk* can replace for fat and especially vitamin B2 in height gain. Incidentally, milk is one of the major sources of vitamin B2 for the Japanese²⁹⁾. Unlike the case of meats, a strong or considerable strong positive correlation between *milk* and height remained when three nutrients, animal proteins, fats, and vitamin B2 were control variables at the same time (Tables 7 and 8). In other words, some component/s other than these nutrients in milk may have a strong effect on height increase. Berkey et al. have already suggested that milk may have a growth-promoting factor specific to milk other than animal protein and fat¹⁰⁾. Therefore, further studies are expected to identify unknown factors in milk that are associated with height growth.

It was found that meats were likely to have contributed to height gain (Table 5). Like *milk*, meats remained a fairly strong positive correlation with height when three nutrients, animal protein, fat, and vitamin B2 were control variables at the same time (Table 8). Although the partial correlation with meats was not as high as that with *milk* (Tables 7 and 8), it cannot be denied that some component other than these nutrients in meats may also be involved in height gain.

Fish & shellfish was mainly composed of animal protein, but it has been not regarded as a food group that may contribute to height increase unlike *milk* and meats (Table 5). The results of multiple regression analysis during the economic growth period in our previous report⁶⁾ also showed that fish & shellfish did not contribute to

height increase in Japan. In European countries only, fish consumption had a positive correlation with height, but there was no correlation between them in all 93 countries surveyed and 49 non-European countries²⁸⁾. In Japanese people, there was a positive correlation between fish & shellfish intake and height, which may be said to be European type, but the coefficients varied greatly from 0.8 to 0.4 depending on the periods examined (Table 3). Although the reason is unknown now, the relationship between fish consumption and the height varies greatly depending on the country, region, and time.

It has been reported that the combination of dairy products, pork, beef, eggs, and potato proteins has the highest correlation with male height²⁸⁾. Since the present study did not examine the combination of food groups, we consider the relationship between these individual food groups and height increase. Our results (Table 5) indicated that *milk* and meats intakes were more likely to be associated with increased adolescent height, whereas eggs and potatoes intakes were not. From the results of multiple regression analysis in the economic growth period in the previous report⁶⁾, eggs and potatoes did not almost contribute to height increase, too. From the above, at least for Japanese people, it may be unlikely that the combination of *milk* and meats with eggs and potatoes will promote height growth more strongly than *milk* and meats.

From the results of this study (Table 6), animal protein are likely to have contributed to height increase. It was reported that there was not significant increase in height when a meat was given to a 6-year-old child with poor growth³⁰⁾, but that girls who consumed a large amount of animal protein showed better growth in height compared to girls with the less amount¹⁰⁾. It also was reported that from comparing food consumption by country, the most important factor explaining current differences in stature among European

countries was the ratio of high quality proteins (mainly animal protein) to low quality protein (wheat protein)²⁾ and that animal protein also was associated with height increase while vegetable protein had the reverse effect²⁸⁾. Similar results on Japanese people were also obtained in this study (Table 6). From the results of this study (Tables 7 and 8), unlike fat and vitamin B2, animal protein cannot be completely replaced by *milk* or meats for height gain. The reasons for this specificity of animal protein are as follows. In addition to *milk* and meats, animal protein sources include fish & shellfish and eggs, which fairly correlated with height (Table 3) and Japanese people consume considerable amounts of those food groups comparable to *milk* and meats intakes (Table 1). So, those food groups may be involved in the correlation between animal protein and height.

As mentioned above, it is highly possible that fat contributed to the height increase (Table 6). However, from the examination of partial correlations (Tables 7 and 8), the correlation between height and fat excluding a 17-year-old female was a pseudo-correlation by the influence of *milk* or meats. On the other hand, a correlation between height and *milk* or meats was not almost lowered when fat was a control variable. Therefore, fat may be replaced with them on height-increasing effects. Other researchers have examined dairy fat, animal fat, and vegetable fat, suggesting that only dairy fat is associated with increased height¹⁰⁾. Since the fat in the present study includes these three types of fat, it is possible that the dairy fat in them contributed to the height increase. However, from Tables 7 and 8, the correlation between height and fat disappeared similarly when *milk* containing dairy fat or meats containing animal fat was a control variable. So, it is suggested that there is no clear difference between the effects of these two kinds of fats.

Except for our previous report⁵⁾, it has been

rarely reported that vitamin B2 is associated with the increase in height (Table 6). The positive correlations between height and vitamin A, B1, and green-yellow vegetable, that was observed in the economic growth period (Tables 3 and 4), were pseudo-correlations that appeared due to vitamin B2 from our previous report⁶⁾. Namely, vitamin B2 may have these alternative effects on height increase. Vitamin B2, as is well known, is involved in energy production from carbohydrate, fat, and protein. Vitamin B2 is a necessary component for animal growth but is not clear in humans³¹⁾.

Thus, it is expected that further studies will be conducted on the role of fat and vitamin B2 in increasing height.

The food groups and nutrients that may have affected height reduction are estimated to be rice, carbohydrate, and vegetable protein (Tables 5 and 6).

From these results (Tables 5 and 6), it was suggested that rice, unlike other food groups, may be involved in height reduction like carbohydrate. From the previous reports, rice may have had the greatest effect on height reduction among all examined food groups⁶⁾ and samples²⁸⁾. And compared to Europe, the negative correlation between height and rice was stronger in the other areas²⁸⁾. During the post-war economic recovery, the Japanese people ingested more carbohydrate from rice than from other food groups under condition with low intakes of food groups that affected height growth (Table 1). Therefore, in postwar Japan during the economic recovery period, and perhaps in Asia, where rice is the staple food, high carbohydrate intake from rice leads to low nutritional density. As a result, high rice intake may suppress height growth.

Carbohydrate intake may be involved in height reduction (Table 6). However, the mechanism by which carbohydrate directly suppress height growth is unknown. From Table 2, energy intake

per capita in Japan remained almost unchanged during all the three divided postwar periods, declining slightly during the economic stagnation period. During the postwar economic recovery period, the energy intake ratio from carbohydrate was higher, the intake ratio of animal protein and fat that contributed to height increase was lower, and the height was considerably lower than after the economic growth period (Table 2). Namely, when the economic level is low, it is impossible to sufficiently obtain *milk* and meats, which are likely to contribute to height gain, containing animal protein, fat, and vitamin B2, and more expensive than carbohydrate sources. So, stature becomes short. This may be the current situation in developing countries in tropical Asia, which consumes a large intake ratio of carbohydrate among energy sources²⁸⁾. As the economy grows, the intakes of food groups which may increase height, increase. So, stature becomes high. This may be the situation in Japan after the economic growth period (Table 2) and in developed countries²⁸⁾.

From the above, a diet with an extremely high carbohydrate energy intake ratio may indirectly lead to height suppression due to insufficient intake of nutrients and food groups that are likely to contribute to height gain. In addition, it cannot be denied that the well-known mechanism of feeding regulation by blood sugar, which can lead to satiety by taking a large amount of carbohydrate without consuming sufficient protein and fat, may lead to short stature.

As already pointed out in other reports^{2, 28)} and our previous report⁶⁾, the present results (Table 6) also suggested that a large intake of vegetable protein or a low ratio of animal protein to vegetable protein might suppress height increase of Japanese adolescents. It is well known that vegetable protein has a lower amino acid score than animal protein and a low amino acid score suppresses animal growth. Therefore, a large

intake of vegetable protein or a low ratio of animal protein to vegetable protein may lower the amino acid score and suppress height increase.

In Japanese males and females, the correlations between height and the three food groups that are carbohydrate sources are quite different (Table 3). Rice may be involved in strongly height reduction, but potatoes and wheat not to height increase / decrease (Table 5). The strength and the sign of these correlations differed greatly in each period from the postwar period to the present (Table 3). In India and China, male height correlated negatively with rice and a positively with wheat²⁸⁾. Potatoes did not correlate with male height in Europe²⁸⁾ but positively in other countries. Thus, the correlations between height and these major carbohydrate sources vary by time, country, and region.

The difference in the effects of rice, wheat, and potatoes on the increase and decrease in height in Japanese people (Table 3) may not be attributed to carbohydrate and vegetable protein that are the main components of them. Because in Japanese people, there was a strong negative correlation between height and carbohydrate or vegetable protein during all periods except the economic stagnation (Table 4), and these nutrients are likely to act for height reduction from the total judgement (Table 6). Wheat protein is vegetable protein that is likely to affect height reduction (Table 6). However, there are contradictory reports that the correlation between male height and wheat protein is negative in Europe and positive outside Europe²⁸⁾.

Therefore, some factor peculiar to each food other than carbohydrate and vegetable protein, may be responsible for the difference in effects of rice, wheat, and potatoes on height.

In the previous report⁶⁾, the correlations between height of Japanese males and females and energy intake during the economic growth period were strong and negative. From the overall

evaluation of this study, energy intake showed a tendency to decrease height slightly (Table 6). However, the correlation largely changed depending on each period (Table 4). There were no correlations between them during the postwar economic recovery period but there were a strong or fairly strong negative correlation between energy and male and female height during the economic growth period and the whole period. And there was a positive correlation between energy and male height having no correlation between energy and female one during the economic stagnation period. Examining the cause of these correlations based on changes in height⁽²⁵⁾ and energy intake⁽²⁷⁾ during each period, during the postwar economic recovery period male and female height increased but energy intake remained almost unchanged. During the economic growth period male and female height increased but energy intake decreased. During the economic stagnation period, energy intake decreased, and male height decreased slightly but female height did not almost change.

In all 93 countries and 49 non-European countries surveyed on the relationship between energy and height, there was a strong positive correlation between energy and male height, but not in 44 European countries⁽²⁸⁾. Except for Europe, in many countries their height tend to grow as their energy intake increases. However, in Europe, energy intake is high and no longer increase⁽²⁸⁾. It may be the reason why there is no correlation between energy and height in Europe. In the case of postwar Japan, energy intake has hardly increased since the postwar economic recovery period, though it is much lower than that of Europe. Energy intake during the economic stagnation period is the same as the lowest intake in 1946 immediately after the war^(5, 27). Japanese people can be characterized by the increase in height, even though their energy intake hardly increases (Table 2).

Therefore, the postwar Japanese people have the specificity of restricting food intake not to increase energy intake, despite the increase in height and intakes of animal protein, fat, *milk*, and meats, as the economy grows.

As shown in Table 9, it was found that *milk*, meats, animal protein, fat, and vitamin B2 all had a stronger relationship with height gain than weight gain except for a male aged 14 in the postwar economic recovery period. However, only for a male aged 14, there was almost no difference in the relationship between these and weight or height. The reason for this is currently unknown. Only in the 17-year-old female, the correlation between weight and *milk* or meats did not disappear even when height was a control variable. However, examined about *milk* in the economic growth period, it was suggested that *milk* was strongly associated with height rather than weight in both males and females aged 14 and 17 (Table 9 italic). Although there may be some differences depending on each period, it is suggested that *milk* has a stronger relationship with the growth of height than weight, as our previous report⁽³²⁾. Incidentally, when the same examination was done during the economic growth period, green-yellow vegetable have a stronger relationship with the growth of weight than height but fish and shellfish not (footnote-table 3 in Table 9). Each food group and nutrient may be closely related to either height or weight gain.

Regarding the peculiarity of 17-year-old females in the postwar economic recovery period, when the correlation between weight and meats or *milk* was examined under a control variable of height (Table 9) or also when the correlation between fat and height was examined under a control variable of meats or *milk* (Tables 7, 8), their partial correlations did not disappear only in the 17-year-old females, unlike the others. As reported in our previous report⁽⁵⁾, females aged 17 showed

less height reduction due to war starvation than males of same age or both sexes of younger ages. It was suggested that unlike the 17-year-old males, the 17-year-old females have almost recovered this height reduction during 10 to below 17 years old⁵⁾. This may be the cause, of the exception in the partial correlations with height or weight of the 17-year-old females mentioned above, of the insensitivity to changes in nutritional status and other factors, and of the peculiarity of 17-year-old females.

As shown in Fig. 1, the changes in Japan's economy after the war show that the economy recovered rapidly, grew, and stagnated. Therefore, the stages of Japan's economic development during the postwar economic recovery period, economic growth period, and economic stagnation period were examined based on the current classification of the World Bank³³⁾. From Fig. 1, data on the GDP per capita of the World Bank during the postwar economic recovery period, 1948 to 1966, have not been published until 1959. According to our calculations from data published by the Japanese government in the previous report⁶⁾, Japan's per capita GDP continued to increase from 1955 to 1966. This period between 1955 and 1966 was around the first half of rapid economic growth period, and from 1948 to 1954 before that, it started from the lowest level of economic conditions due to the devastation of the war, and then was the period to recover the prewar economic level. So, it can be easily inferred that the average economic level from 1948 to 1954 is lower than that from 1955 to 1966. From Fig. 1, the economic level during most of this period excluding 1966 is estimated to have been under a low-income state of less US\$1006, based on the level of the current GNI per capita of the World Bank. During the economic growth period (1967 to 1996), the economy grew rapidly, passing through low middle income (up to \$3955) and then high middle income (up to \$12,235) in the classification

of the World Bank, and then Japan has become a developed country with a high income (>\$12,235). During the economic stagnation period (1997 to 2017), although Japan is a high income and a developed country, economic growth is almost stagnant (Fig. 1). However, from footnote-table 2 in Fig. 1, the average GDP per capita during this period is larger than that during the economic growth period.

From the above, it was found that these three periods in Japanese post war period may clearly be classified by characteristics in each stage of economic development.

Previous studies have already reported that economic conditions and height growth are closely related in many countries^{1,2)}. According to our previous report⁵⁾, during the postwar economic recovery period in Japan, there was a linear recovery from adolescent height that was significantly lower than the height before the war. And during the economic growth period, height continued to grow considerably, reaching its peak for the first time at most adolescent ages^{6,25)}. However, during the economic stagnation period^{5,25)}, adolescent heights of all ages were stagnant or slightly decreased. In this study (footnote-Table 1 in Fig. 1), there are positive strong correlation between adolescent height and the logarithm of GDP per capita during the period from 1960 to 1991, but there are no positive correlations between GDP per capita and heights, for 26 years after 1992 including all the economic stagnation period. In addition, as shown in Table 3, during the postwar economic recovery period and economic growth period, there is a strong positive correlation between the height and the food groups of *milk* and meats that contributes to height increase, but during the economic stagnation period, these positive correlations are not seen. The correlations between height and nutrients such as animal protein, fat, and vitamin B2 tend to be like those of food groups, though

less clear than these food groups (Table 4). Therefore, the correlation between the logarithm of GDP per capita and height may be closely related to the strong positive correlation between height and these food groups. That is, as pointed out in our previous report⁶⁾, economic growth may affect height gain through the increased intakes of foods and nutrients that have a strong positive correlation with height.

From stated above, it can be said that the postwar economic recovery period in Japan was almost under a low income, which is equivalent to that of the current developing countries, and during the economic growth period, Japan rapidly grew economy and became an advanced country before the economic stagnation period. Changes in food group/nutrient intakes and height were larger from the postwar economic recovery period to economic growth one, compared to those changes from the economic growth one to the economic stagnation one (Tables 1 and 2). Namely, the comparison between these two periods with big changes is especially important to understand the relationship between height increase and food group / nutrient intakes. In the transition from the postwar economic recovery period to the economic growth one, intakes of *milk*, meats, wheat, animal protein and fat, vitamin B2, and animal protein / vegetable protein ratio increased. Instead, the intakes of rice, carbohydrate, and vegetable protein decreased. These food groups and nutrients except for wheat may be involved in the increase / decrease in height (Tables 5, 6). As the results, the average height may have increased by 5.5 cm for males and 4.0 cm for females. By the way, the average height from the economic growth period to the economic stagnation one increased by only 1.3 cm for males and 1.0 cm for females. Thus, economic changes from the postwar economic recovery period to the economic growth one may strongly reflect the increase / decrease of food group and

nutrition intakes, which are estimated to be the factors of height increase / decrease (Tables 1, 2, 5 and 6).

Grusgruber et al.²⁸⁾ have proposed three categories based on the relationship between the stature and the intake of major protein sources as follows: 1) In areas (tropical Asia) that depend on rice, total protein and energy intakes are extremely low and height is the shortest. 2) Wheat-dependent areas (in the Muslim countries of North Africa and the Near East) have the highest intakes of vegetable protein and total protein, and energy intake is comparable to that in Europe. This area is moderately tall stature. 3) The stature is the highest in areas (Northern / Central Europe) that depend on animal protein, especially dairy protein. According to this classification, when looking at changes in food and nutrition intakes in Japan after the war, especially from the postwar economic recovery period to the economic growth one, it can be said that the food and nutrition intakes except for energy intake have shifted rapidly from their features in shorter stature areas to those in higher stature ones.

V Conclusion

The food groups and nutrients that remarkably affected the height increase of Japanese people after the war were *milk*, meats, animal protein, fat, and vitamin B2, but with respect to height gain, fat and vitamin B2 can be almost replaced by *milk* and meats. Carbohydrate, vegetable protein, and rice may have affected height reduction. In the future, to improve the physique of Japanese people, it is important to promote the intakes of meats and animal protein together with *milk* until the late adolescents.

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戦後日本人の身長伸びに著しく影響を与えた 食品群及び栄養素

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和文摘要

戦後、日本人の身長は経済成長とともに、急速に伸びてきた。この背景には、食生活とりわけ食品摂取の変化があることが推測される。そこで、この身長伸びに最も関係した食品が何であるかは興味深い。

戦後から現在までを戦後経済回復期、経済成長期、経済停滞期に便宜的に分け、日本の政府機関が公表したデータに基づいて、思春期の身長成長と食品群や栄養素等の摂取量との関係について期間毎に検討した。最近接の2期間の摂取量と身長差の差異並びに身長とそれら摂取量との相関（Pearsonの単相関、Spearmanの順位相関、偏相関）を調べ、それらの結果を総合して、最終的に、どのような食品群が日本人の身長増加に最も影響を与えたか推定した。

その結果、日本人の思春期の身長増加に寄与した可能性が高い食品群は、乳類と肉類であった。同様にその栄養素は動物性たんぱく質、脂肪、ビタミンB2であった。しかし脂肪やビタミンB2はほとんど乳類や肉類の疑似相関であった。乳類の身長増加にはこの3種類の栄養素以外の乳中成分の関与が示唆される。植物性たんぱく質、炭水化物、米類などは身長減少に寄与した可能性がある。動物性たんぱく質/植物性たんぱく質の摂取比率も身長増加に寄与した可能性がある。一人当たりGDPの対数とその身長増加とは、1960年から1991年までの期間、強い正の相関がみられたが、1992年から2017年までの期間では、この関係はみられなかった。

結論として、戦後、日本人の身長増加に顕著に影響を与えた食品群・栄養素は乳類、肉類、動物性たんぱく質、脂肪、ビタミンB2と推定されるが、身長増加に関して脂肪やビタミンB2は乳類や肉類でほとんど代替可能であると判断された。今後、日本人の身長の向上のためには、思春期後期までに乳類をはじめ、肉類や動物性たんぱく質の摂取を推進することが重要である。