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The Contribution of Food and Nutrition Intake to the Height Increase of Postwar Japanese People Revealed by Multiple Regression Analysis

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ABSTRACT

【OBJECTIVES】In our previous report[1], it was estimated that the food groups that were significantly related to the increase in height of Japanese people after World War II were milk and dairy products (abbreviated as *milk*) and meats, and that such nutrients were animal protein, fat, and vitamin B_2. This report aims to clarify which food groups and nutrients contributed to their height increase by multiple regression analysis. We also compare the findings of this analysis with those obtained so far to verify these contributions to height growth in postwar Japanese.

【METHODS】A 17-year-old adolescent height and intake of food groups and nutrients are based on the data published by the Ministry of Education, Culture, Sports, Science and Technology and the Ministry of Health, Labor and Welfare, respectively. Multiple regression analysis was performed with each male and female height, and average height between both sexes as dependent variables and each set of food groups or nutrients as independent variables.

【RESULTS】As a result, it is estimated that *milk* and meats in the food group contributed most to the height increase of Japanese adolescents after the war, and *milk* was more effective than meats. Such nutrients were presumed to be fat and vitamin B_2. On the other hand, vegetable protein, carbohydrate and rice are estimated to have negatively affected their height growth.

【CONCLUSION】It is estimated that *milk* and meats contributed most to the increase in height of Japanese people after the war. In the future, to increase the height of Japanese people, it is important to promote the intake of *milk* and meats through their growth period.

Key words; height increase, postwar Japanese, *milk*, meats, fat, vitamin B_2, carbohydrate, vegetable protein

Introduction

The findings made so far by Japanese and foreign researchers regarding the relationship between height growth and food / nutrition intake were discussed in our previous reports[1, 2]. Their main contents are the followings. 1. Influences of *milk*, various other foods, calcium, other inorganic substances, proteins, fats, carbohydrate, and vitamins, etc. on height growth, 2. The foods and nutrients, etc. that affected height gain in postwar Japanese people, 3. The foods and nutrients that influenced more on height gain than weight one.

As indicated in our previous report[1], the food groups that may be significantly related to the

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increase in height of postwar Japanese people are *milk* and meats, and such nutrients were animal protein, fats, and vitamin B_2. However, rice, carbohydrate, and vegetable protein may be related to the decrease in height. In this report, multiple regression analysis is used to reveal which food groups and nutrients contribute to height gain and reduction and to what extent each contributes.

Furthermore, we would like to compare the results of this multiple regression analysis with the results obtained so far and clarify the food groups and nutrients that will be important for increasing the height of Japanese people in the future.

Targets and methods

The study subject was the average height between 17-year-old males and females in the third year of high school in Japan. We also targeted male and female height. As detailed in our previous report[1], the reason for targeting third-year high school students is that they are the age closest to adults in the School Statistics Basic Survey and do not grow much until adulthood. And their height can probably be an indicator of adult height. These height data are published based on the collected results of the Annual School Statistics Basic Survey[3]. This survey is judged to be more accurate because the number of people surveyed is larger than other surveys targeting adults and the height is actually measured.

National Health and Nutrition Survey by the Ministry of Health, Labor and Welfare did not report sex-separated intake of each food group and nutrient until 1995, most of this survey period from 1949 to 2017. So, the average intake for all ages of both sexes / person/ day[4] was used in the present paper. Therefore, in interpreting the results of this study, the average results between males and females appear to be more important than the results for each sex.

In the multiple regression analysis, only items (food groups and nutrients, etc.) with the same survey period are included in the analysis. Therefore, the items for which the National Health Nutrition Survey data[4] were published for a long period from 1949 to 2017 were targeted for independent variables. To compare with the result of the previous report[1], the same items as the previous report were targeted. That is, the set of food groups consists of 12 items: rice, wheat, potatoes, beans, green and yellow vegetables, other vegetables, fruits, fish & shellfish, meats, eggs, *milk*, and fats & oils. A combination of *milk* and meats (*milk* + meats) was also used for multiple regression analysis. The set of nutrients, etc. consists of nine items: energy, animal protein, vegetable protein, fat, carbohydrate, calcium, and vitamins B_1, B_2, and C. However, the handling of intake of rice and fats and oils is as described in our previous report[1].

Statistical software SPSS Ver.11.5J (basic system for Windows) was used for statistical processing. The multiple regression analysis using the stepwise method was performed with each set of food groups or nutrients, etc. as independent variables, and the average height between both sexes and male or female height as dependent variables. Plotting the regression data of the standardized residue with the vertical axis as the expected cumulative probability and the horizontal axis as the observed cumulative probability, it is judged that when the residual distribution is straight, it follows a normal distribution. A nearly linear relationship was established between the two for all analyzes in the present study. So, it shows that the average height between both sexes and male or female height can be explained by these food groups or nutrients, etc. When the variance expansion coefficient (VIF) is 10 or less between independent variables in each model, there is almost no problem with collinearity.

But if it exceeds 10 between them in the model, it is suspected to be collinear, and that model is basically not listed in the table. If necessary, eigenvalues, condition indexes, dispersion properties, etc. are also performed as further diagnosis of collinearity. From these, it is judged which independent variables had collinearity.

Results

Table 1 shows the basic statistics that were used for this study, calculating based on the published data from 1949 to 2017. They are each average intake of 12 food groups and 9 items of nutrients, etc., the average height between both sexes, male or female height, their standard deviations, minimum values, maximum values, and median values.

To know the food groups and nutrients, etc. that contributed to the increase/decrease in height of Japanese people during 69 years after the war and the degree of their contribution, multiple regression analysis was performed by the stepwise method. The results are shown in Tables 2-1, 2-2, and 3. All of the models listed here have a coefficient of determination (R^2) of 0.937 or higher and the adjusted coefficient of determination (adj-R^2) of 0.936 or higher which have extremely high explanatory power. As a result of analysis of variance for each model, the significance probability of the F value was 0.008 or less. In other words, it is shown that at least 93% ($R^2>0.937$) of increase/decrease in height can be explained by the independent variables of each model in the tables shown here. Therefore, it can be said that the estimation by the regression equation of each model shown in Tables 2-1, 2-2, and 3 is extremely useful.

For the food groups (Table 2-1), models 1 to 7 were submitted by multiple regression analysis with the average height between both sexes as the dependent variable. The larger the value of $|\beta|$, the more it contributes to the increase/decrease in height. In model 1, *milk* has positive and large β value. In Model 2, the β value of *milk* is positively larger than that of meats. However, since their VIFs are 11.985, which is slightly over 10, there is a slight suspicion of collinearity between *milk* and meats. As other models have large VIFs and are suspected to be collinearity among independent variables, they are not shown in this table. This has also been treated similarly in the other tables as well.

As a result of multiple regression analysis with the height by sex as the dependent variable (Table 2-1), in model 2 of male height, the β value of *milk* is positive and large, and that of potatoes is negative and small. In Model 3, *milk* is a positive and larger β value than meats. However, since these VIFs are slightly larger than 10, there remains a slight suspicion of collinearity between these two. The β value of potatoes is negative and small. Other models 4 to 6 have suspicion of collinearity among independent variables. Similarly, in model 2 of female height, the β value of *milk* is positive and large. Rice has negative and somewhat large β value. Other models 3-5 have suspicion of collinearity among independent variables.

From the above, it is estimated that *milk* may contribute most to the increase in the average height between both sexes and male or female height.

As stated above (Table 2-1), the collinearity of *milk* and meats is slightly suspected in the case of male height and average height between both sexes. Therefore, we combined *milk* and meats (*milk* + meats) and performed multiple regression analysis again. The results are shown in Table 2-2. Looking at optimal model 3 of average height between both sexes, *milk* + meats had the positive largest β value in the model. The β values of rice and potatoes were negative, but the absolute value of the former was larger than

Table 1 Basic statistics on this study

	frequency	average value	standard deviation	minimum value	maximum value	median
height (cm)						
average height between both sexes	69	162.4	2.4	156.8	164.5	163.8
male height	69	168.5	2.9	161.2	170.9	170.2
female height	69	156.4	1.9	152.3	158.1	157.4
daily intake						
food group (g)						
rice	69	243	76	152	364	218
wheat	69	85.2	14.1	59.9	105.3	90.2
potatoes	69	64.0	19.2	32.8	169.9	62.5
beans	69	65.8	6.1	49.8	75.6	67.6
green yellow vegetable	69	70.1	18.7	38.6	98.9	73.1
the other vegetable	69	184.0	14.5	152.5	219.8	184.4
fruits	69	113.0	38.9	27.5	193.5	115.1
fish & shellfish	69	84.0	10.3	55.8	98.2	86.3
meats	69	58.8	27.4	5.4	98.5	71.2
eggs	69	33.4	11.1	3.2	43.6	37.6
milk	69	94.9	45.3	4.1	170.0	116.4
oils & fats	69	13.1	4.9	1.8	18.7	14.0
nutrients, etc.						
energy (kcal)	69	2056	120	1840	2287	2080
animal protein (g)	69	35.0	7.6	14.0	44.4	37.9
vegetable protein (g)	69	39.4	5.6	30.6	51.0	38.9
fat (g)	69	46.9	14.1	16.0	59.9	54.0
carbohydrate (g)	69	324	58	253	424	306
calcium (mg)	69	496	83	200	585	532
vitamin B_1 (mg)	69	1.11	0.19	0.80	1.60	1.13
vitamin B_2 (mg)	69	1.06	0.24	0.65	1.47	1.12
vitamin C (mg)	69	105	18	72	135	106

This study period is from 1949 to 2017.
This table has been calculated based on the data published by the Ministry of Health, Labor and Welfare and the Ministry of Education, Culture, Sports, Science and Technology.

that of the latter. The results for male height were about the same as those for the average height between both sexes. However, model 2 of female height had *milk* + meats and rice but not potatoes. For all dependent variables, the β value of *milk* + meats was always larger than those of the other independent variables (Table 2-2).

Similarly, as a result of multiple regression analysis of nutrients, etc. (Table 3), optimal model 3 of the average height between both sexes shows

Table 2－1　The influence of food groups on height increase/decrease revealed by multiple regression analysis

Dependent variables; average height between both sexes (average), male height (male), female height (female).

Independent variables set added one by one with the step-wise method; rice, wheat, potatoes, beans, green-yellow vegetable, other vegetable, fruits, algae, fish & shellfish, meats, eggs, *milk*

		coefficient					model summary	
dependent variable / models	independent variable in each model	Unstandardized coefficient: B	Unstandardized coefficient: Standard deviation error	standardization coefficient: β	t-test: significance probability	Collinear statistic: VIF	multiple determination factor (R^2)	adjusted multiple determination factor (adj-R^2)
(average)	constant	157.6	0.1		<0.001		0.953	0.952
1	*milk*	0.051	0.001	0.976	<0.001	1.00		
(average)	constant	157.4	0.1		<0.001		0.967	0.966
2	*milk*	0.031	0.004	0.586	<0.001	11.99		
	meats	0.035	0.007	0.408	<0.001	11.99		
(male)	constant	162.7	0.2		<0.001		0.948	0.947
1	*milk*	0.062	0.002	0.974	<0.001	1.00		
(male)	constant	164.3	0.4		<0.001		0.963	0.962
2	*milk*	0.058	0.002	0.915	<0.001	1.23		
	potatoes	−0.020	0.004	−0.134	<0.001	1.23		
(male)	constant	164.0	0.3		<0.001		0.974	0.973
3	*milk*	0.036	0.004	0.572	<0.001	12.04		
	pootatoes	−0.019	0.003	−0.126	<0.001	1.24		
	meats	0.038	0.007	0.362	<0.001	12.05		
(female)	costant	152.5	0.1		<0.001		0.951	0.950
1	*milk*	0.041	0.001	0.975	<0.001	1.00		
(female)	costant	155.9	0.6		<0.001		0.966	0.965
2	*milk*	0.027	0.003	0.654	<0.001	7.64		
	rice	−0.009	0.002	−0.344	<0.001	7.64		

This study period is from 1949 to 2017. This table has been calculated based on the data published by the Ministry of Health, Labor and Welfare and by the Ministry of Education, Culture, Sports, Science and Technology. Since the significance probability of all models in this table was less than 0.001 as a result of the variance analysis, the dependent variable of these models can be sufficiently explained by independent variables. The following models are not shown in the above table due to suspected collinearity between the variables. Average height between both sexes; Models 3 to 7, Male height; Models 4 to 6, and Female height; Models 3 to 5.

that β values of fat and vitamin B_2 are positively large and small, respectively. Vegetable protein has a negative and somewhat large β value. Model 4 has suspicion of collinearity among independent variables.

When height by sex is used as the dependent variable, model 2 of male height shows that the β value of fat is positively large and that of vegetable protein is negatively small. These β values are the same as model 2 of the average height between both sexes. Models 3 to 5 of male height have suspicions of collinearity among

Table 2-2 The influence of food groups with combination of milk and meats on height increase/decrease revealed by multiple regression analysis

Dependent variables; average height between both sexes (average), male height (male), female height (female).

Independent variables set added one by one with the step-wise method; rice, wheat, potatoes, beans, green-yellow vegetable, other vegetable, fruits, algae, fish & shellfish, *milk*+meats, eggs

dependent variable / models	independent variable in each model	coefficient: Unstandardized coefficient B	Unstandardized coefficient: Standard deviation error	Standardization coefficient β	t-test: significance probability	Collinear statistic: VIF	model summary: multiple determination factor (R^2)	adjusted multiple determination factor (adj-R^2)
(average) 1	constant	157.0	0.2		<0.001		0.958	0.958
	milk+meats	0.042	0.001	0.979	<0.001	1.00		
(average) 2	constant	160.5	0.6		<0.001		0.972	0.971
	milk+meats	0.032	0.002	0.732	<0.001	5.44		
	rice	−0.009	0.002	−0.273	<0.001	5.44		
(average) 3	constant	163.3	0.7		<0.001		0.981	0.980
	milk+meats	0.024	0.002	0.562	<0.001	8.62		
	rice	−0.012	0.001	−0.395	<0.001	7.06		
	potatoes	−0.015	0.003	−0.124	<0.001	1.70		
(male) 1	constant	162.0	0.2		<0.001		0.961	0.960
	milk+meats	0.051	0.001	0.980	<0.001	1.00		
(male) 2	constant	164.7	0.8		<0.001		0.967	0.966
	milk+meats	0.043	0.003	0.818	<0.001	5.44		
	rice	−0.007	0.002	−0.180	0.001	5.44		
(male) 3	constant	168.9	0.9		<0.001		0.980	0.980
	milk+meats	0.032	0.003	0.610	<0.001	8.62		
	rice	−0.012	0.002	−0.328	<0.001	7.06		
	potatoes	−0.023	0.003	−0.152	<0.001	1.70		
(female) 1	constant	152.1	0.1		<0.001		0.945	0.944
	milk+meats	0.034	0.001	0.972	<0.001	1.00		
(female) 2	constant	156.2	0.5		<0.001		0.976	0.975
	milk+meats	0.021	0.002	0.599	<0.001	5.44		
	rice	−0.010	0.001	−0.413	<0.001	5.44		

Except for the following notes, the footnotes in this table are the same as in Table 2-1.
The following models are not shown in the above table due to the suspected collinearity between the variables.
Average height between both sexes; Models 4 and 5, Male height; Model 4, and Female height; Models 3 to 5.

Table 3　The influence of nutrients on height increase/decrease revealed by multiple regression analysis

Dependent variables; average height between both sexes (average), male height (male), female height (female).

Independent variables set added one by one with the step-wise method; energy, animal protein, vegetable protein, fat, carbohydrate, calcium, vitamin B_1, vitamin B_2, vitamin C.

		coefficient					model summary	
dependent variable	independent variable in each model	Unstandardized coefficient		standardization coefficient	t-test	Collinear statistic	multiple determination factor (R^2)	adjusted multiple determination factor (adj-R^2)
models		B	Standard deviation error	β	significance probability	VIF		
average 1	constant	154.7	0.2		<0.001		0.952	0.951
	fat	0.164	0.005	0.976	<0.001	1.00		
average 2	constant	162.2	0.6		<0.001		0.987	0.987
	fat	0.121	0.004	0.717	<0.001	2.88		
	vegetable protein	−0.137	0.010	−0.320	<0.001	2.88		
average 3	constant	161.6	0.5		<0.001		0.991	0.990
	fat	0.101	0.005	0.600	<0.001	7.14		
	vegetable protein	−0.134	0.009	−0.314	<0.001	2.89		
	vitamin B_2	1.34	0.28	0.135	<0.001	5.64		
male 1	constant	159.2	0.3		<0.001		0.955	0.954
	fat	0.199	0.005	0.977	<0.001	1.00		
male 2	constant	167.5	0.7		<0.001		0.985	0.984
	fat	0.150	0.005	0.739	<0.001	2.88		
	vegetable protein	−0.152	0.013	−0.295	<0.001	2.88		
female 1	constant	150.3	0.2		<0.001		0.937	0.936
	fat	0.130	0.004	0.968	<0.001	1.00		
female 2	constant	158.5	0.5		<0.001		0.989	0.989
	fat	0.070	0.004	0.520	<0.001	4.87		
	carbohydrate	−0.017	0.001	−0.503	<0.001	4.87		
female 3	constant	157.8	0.5		<0.001		0.991	0.990
	fat	0.063	0.004	0.470	<0.001	7.17		
	carbohydrate	−0.016	0.001	−0.474	<0.001	5.68		
	vitamin B_2	0.668	0.245	0.084	0.008	6.55		
female 5	constant	156.0	0.4		<0.001		0.992	0.992
	fat	0.063	0.004	0.467	<0.001	7.14		
	vitamin B_2	1.95	0.21	0.245	<0.001	5.64		
	vegetable protein	−0.118	0.006	−0.345	<0.001	2.89		

Except for the following notes, the footnotes in this table are the same as in Table 2-1.
The following models are not shown in the above table due to suspected collinearity between the variables.
Average height beween both sexes; Model 4, Male height; Models 3 to 5, and Female height; Model 4

independent variables. In model 3 of female height, the β values of fat and vitamin B_2 are positively large and small, respectively, but that of carbohydrate is negatively large. Its model 4 has suspicion of collinearity among independent variables. In optimal model 5 of female height, β values of fat and vitamin B_2 are positively large and small, respectively, and that of vegetable protein is negative and somewhat large.

Discussion

From the above multiple regression analysis, it is estimated that the food groups that contributed most to increase in the height of Japanese people after the war were *milk* and meats (Table 2-2), and that *milk* may have contributed more than meats (Table 2-1). These facts support the result of our previous report[1]. It has also been reported that *milk* and meats intake during the postwar economic recovery period is more strongly associated with height gain than weight gain in 17-year-old adolescents[1]. As introduced in the previous our reports[1, 2], it has already been pointed out by Japanese and foreign researchers that *milk* and meats affects positively height growth.

Similarly, the nutrient that contributed most to increase in the height of postwar Japanese males and females and the average height between both sexes, was fat (Table 3). From our previous report[1], it is known that there is a relationship between fat and the height increase of postwar Japanese. Other researchers have investigated about the relationship with *milk* fat, animal fat, and vegetable fat, suggesting that only *milk* fat is associated with height gain[5]. Since the fat in the present study contains these three types of fats, it cannot be denied that only the milk fat contained in the fats may have contributed to the increase in height. However, from the results of the partial correlation in the previous report[1], when *milk* containing milk fat or meats containing animal fat was used as a control variable, the correlation between height and fat has reduced to almost the same level. Therefore, it is suggested that there is no clear difference in the effects of these two types of fats on the height growth. In addition, from the results of the partial correlation in the previous report[1], the correlation between height and fat was often a pseudo-correlation due to the influence of *milk* or meats. Therefore, it is presumed that fat can be replaced by these food groups for height gain.

As shown in Table 3, vitamin B_2 may also have contributed to the increase in the average height between both sexes and height of females in post war Japan. The previous report[1] also has pointed out the strong relationship between vitamin B_2 and the increase in male and female height of Japanese. Except for our previous reports[1, 2] and this paper, there are few reports that vitamin B_2 is associated with height gain. In the future, vitamin B_2 intervention studies will be needed to clarify the relationship between height growth and vitamin B_2.

As a result of multiple regression analysis (Table 3), a model that showed the contribution of animal protein was not obtained. However, from the results of the comprehensive evaluation of height increase, nutrition intake and their correlations between the two in our previous report[1], it has been pointed out that animal protein may associate with height increase. Other group has also reported positive effects of animal protein on height growth[5]. From a country comparison, the association between animal protein and height increase has also been previously reported[6]. Therefore, it cannot be denied that animal protein may have contributed to the increase in height of postwar Japanese people.

The relationship between intake of rice, carbohydrate, and vegetable protein and height decrease of post war Japanese males and females was pointed out in the previous report[1]. The results of multiple regression analysis also showed the negative impact of these items on height growth of Japanese people (Tables 2-1, 2-2, 3). Other researchers also have already reported the negative effect of rice intake on height growth from comparative studies by country[7]. The reason for suppressing the height gain by rice, carbohydrate and vegetable protein was discussed in detail in the previous report[1], so it has not been repeated here. The effect of potatoes on height reduction is unknown due to the discrepancy between current (Table 2-2) and previous studies[1].

After the war, the height of Japanese males and females have increased along with economic growth, as in other countries[1, 2]. As pointed out in the previous report[1], along with Japan's economic growth, Japan's post-war diet tended to reduce the intake of cheap rice which has a negative effect on height growth, and to increase the intake of more expensive *milk* and meats, which have the positive effect on it. As a result, the intake of fat, vitamin B_2, and animal protein, etc. which have a positive effect on it, increased. Conversely, the intake of vegetable protein and carbohydrate, which have the negative effect on it, decreased. As a result, it is presumed that the height of Japanese people has increased after the war.

In recent years, it has been reported that an increase in *milk* intake raises the overall mortality rate and heart disease mortality rate of middle-aged and older males and females in Sweden, especially females[8]. However, the daily *milk* intake per Japanese person has 200 g or less (Table 1) with a minimum risk of the death. So, there is almost no need to consider this point for young people in the growth period. Moreover, in Western countries that consume a large amount of meats, the risk of ischemic heart disease and an increase in colon cancer mortality due to the intake of meats, especially red meats, has become a problem[9]. However, meat intake of Japanese people seem not to increase mortality from stroke and ischemic heart disease within the average Japanese meats intake range[10], such as within 100 g / person / day shown in Table 1. In addition, compared to Westerners, average Japanese have consumed less red meat and more chicken which may reduce these risks[11], so it is thought that the risk of death due to intake of meats is not high in Japanese. Therefore, increasing *milk* and meat intake in order to increase height of adolescents may pose little health risk.

The epidemiological method is used in this study. It means that the result of this study may be high in probability, but the coincidence cannot be completely excluded. Therefore, in our previous report[1], we calculated the probability that the relationship of each intake of *milk*, meats, rice, fat, vitamin B_2, animal protein, vegetable protein, and carbohydrate with the increase / decrease in height would occur by chance. These probabilities were less than 1/1000. This time, even if they were recalculated in only three periods, the postwar economic recovery period, the economic growth period, and the economic stagnation period, except whole period to avoid the risk of duplication, they were less than 13/1000. Therefore, it is highly possible that the relationship between height change, and intake of these food groups and nutrients which were considered to have contributed to the increase or decrease in height in this paper is not a coincidence.

Conclusion

The intake of *milk* and meats may have contributed most to the height growth of males and females in postwar Japan. *Milk* intake may have contributed more to it than meats intake. For nutrients, fat intake may have contributed more than vitamin B_2 intake. However, it has been suggested from the previous report[1] that these nutrients intake can be replaced by the intake of *milk* and meats for height growth. Therefore, in order to increase the height of Japanese people, in the future, it is important to promote the intake of *milk* and meats.

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